Annex 2 Shared autonomous urban vehicles

A-S-I: substitute/improve

Context: passenger road transport/urban public transport

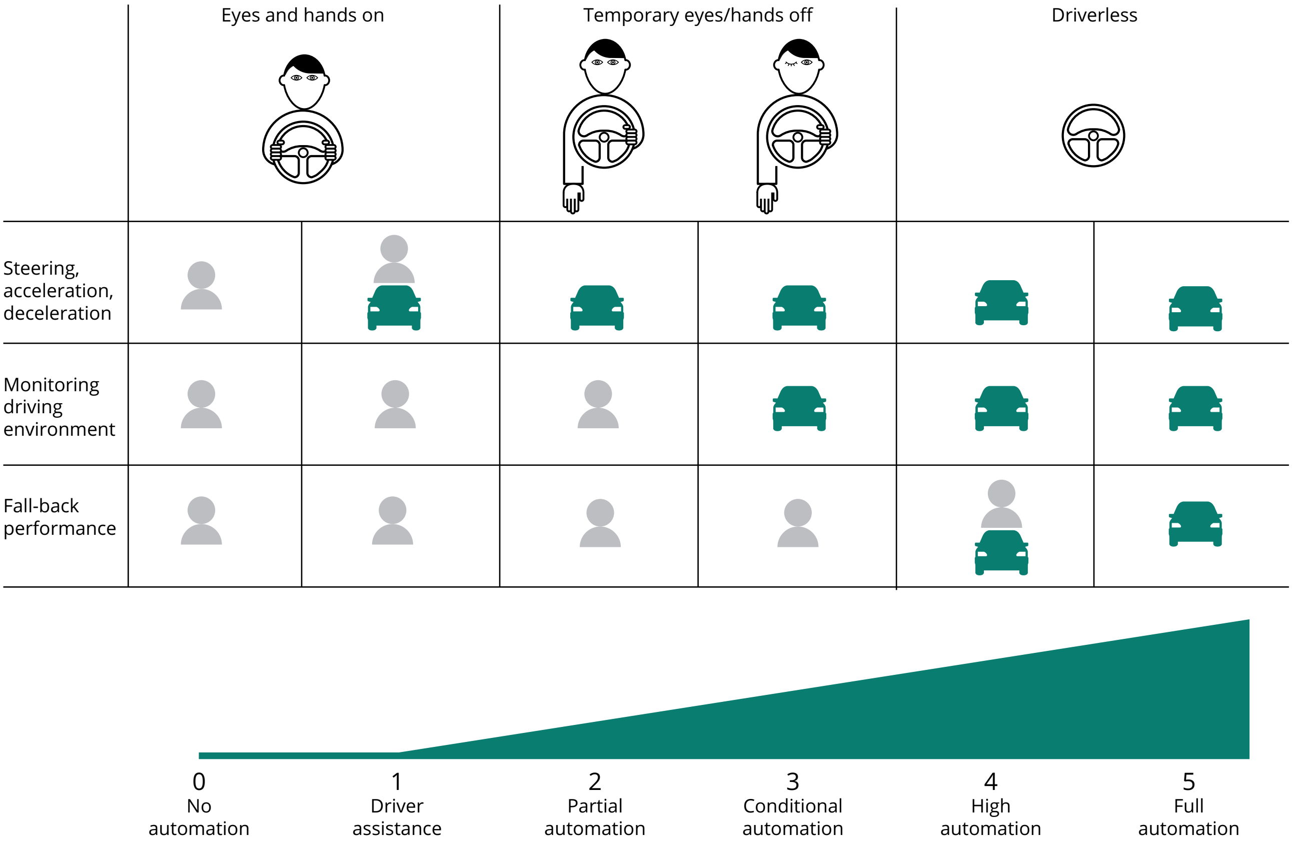
Time frame: mid- to long term

A2.1 Definition

An autonomous vehicle (AV), also known as a self-driving car, is a vehicle that can operate with only limited or no human intervention. AVs use advanced sensors, cameras, big data, machine learning and artificial intelligence to perceive their surroundings to safely travel between different locations. The Society of Automotive Engineers (SAE) has developed a widely used classification system (SAE International, 2021) with six levels based on the degree of human interaction, starting from manual driving (level 0) up to full automation on all roadways and in all environmental conditions (level 5) (Figure A2.1). This is the same framework that is discussed for autonomous trucks in Annex 3.

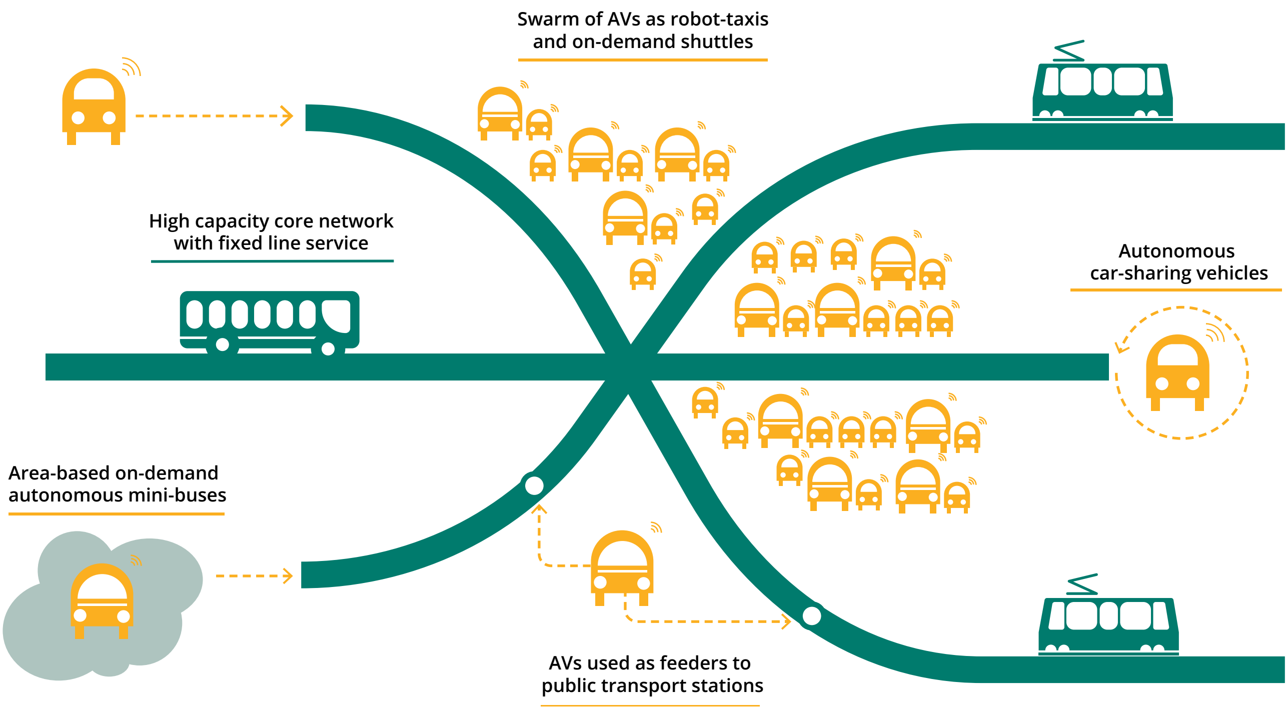
There are three main domains where automated driving can be deployed, each with its own specific features: passenger vehicles, commercial vehicles and urban transport systems (Alonso Raposo et al., 2019). This factsheet focuses on shared autonomous vehicles (SAVs), which refers to AVs that can be shared by several people (Nemoto, et al., 2021) and are used mainly in an urban context. Examples of SAVs are automated shuttles or robot buses. SAVs can be used for on-demand ride services, ride sharing or on fixed routes with fixed stops or on-demand stops (Figure A2.2). One of their main characteristics of interest is that they can be used to improve access to the existing public transport network by providing first/last mile services. They are expected to increase road safety and the efficiency and accessibility of the urban transport system as well as social inclusion.

Figure A2.1 Levels of automation in cars



Source: EEA compilation based on European Parliament (2019).

Figure A2.2 Possible applications of autonomous vehicles as part of a diversified public transport system



Source: UITP (2017).

A2.2 Context

A first important driver for AV development and uptake is the potential envisaged to increase road safety and to drastically reduce fatalities both within and outside urban areas ('Vision Zero' (EC, 2023b) and the impact assessment of the draft General Safety Regulation (EC, 2018c)). Indeed, although the number of road fatalities has decreased considerably since the beginning of the century, with a 61% reduction from 51,400 in 2001 to 19,800 in 2021 (preliminary figure) (EC, 2021e), this trend has been slowing down in recent years (EC ,2018c). It is unlikely that the EU objective of a 50% reduction in road fatalities between 2010 and 2030 will be reached. The social cost associated with these accidents (e.g. rehabilitation, healthcare, death and suffering, material damage) remains high. For 2016 it was estimated to be EUR 237 billion for road passenger transport and EUR 42.8 billion for road freight transport (EC, 2019a). On average, about half of road fatalities are among cyclists and pedestrians. It is estimated that, in approximately 95% of road accidents, human error plays a part (EC, 2018c).

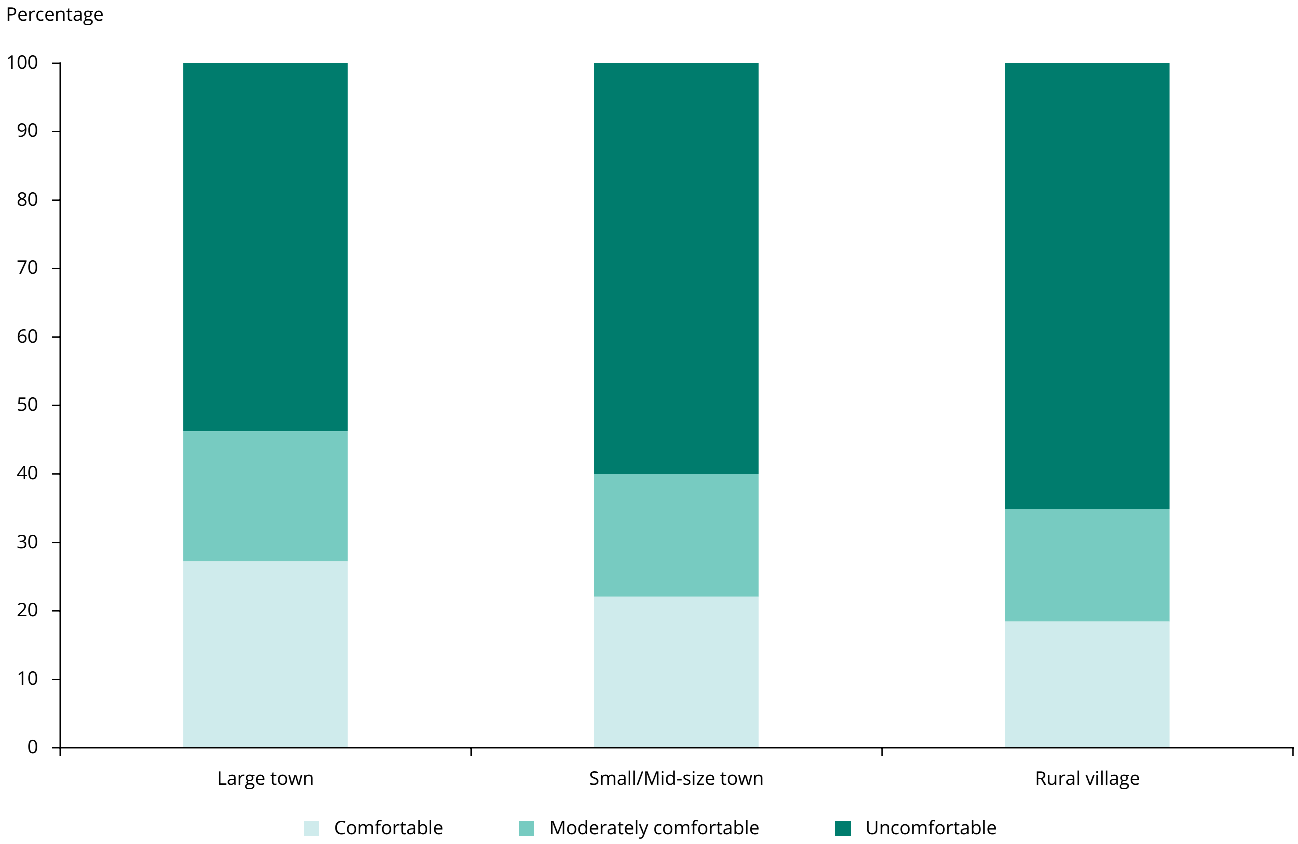
Apart from road safety, increasing the use of public transport in cities and shifting from privately owned cars to more sustainable transport modes are regarded as a high priority in Europe. Here, 75% of the population lives in urban areas, and this is predicted to increase by up to 84% by 2050 (Alonso Raposo et al., 2019). Although car ownership is typically lower in cities and other modes, such as public transport, cycling and walking, are used more than in non-urban areas, it remains a pressing concern because of the high environmental costs of individualised motorised transport modes (see additional details in Factsheets 4 and 7 and related annexes). An increasing modal shift is seen as necessary to achieve the environmental targets set by the EU and summarised in Chapter 4 (e.g. European Green Deal). Urban public transport, however, faces several challenges, such as a lack of flexibility and high operational costs, especially in cities with a low population density. SAVs are seen as a possible solution to these problems. In addition, in Europe the population is progressively ageing: in January 2021, the share of the European population at least 65 years old was 20.8%. This is projected to increase up to 29.5% by 2050 (Eurostat, 2022h). This implies that a growing share of people will be at risk of having limited mobility and an increased difficulty in accessing transport and other public services. Thus, it will become even more important to develop and guarantee an accessible and inclusive public transport system. SAVs have the potential to contribute to this, providing at the same time a less polluting, more efficient and safer transport system (Alonso Raposo, et al., 2017, 2019; Mäkinen et al., 2020).

The development and application of AVs is, however, challenging. The challenge varies greatly with the level of automation. Indeed, while level 2 AVs are more similar to conventional vehicles but with advanced safety features (e.g. lane assistant or adaptive cruise control), vehicles in the level 4 category will be able to operate in an almost completely automated way in environments with well-defined boundaries. Key enablers of this higher automation level are artificial intelligence and machine learning. The technical complexity associated with higher automation levels increases, however, in a non-linear way. Experts in the field often support an evolutionary paradigm, with a stronger diffusion of level 2 vehicles that can operate in less challenging conditions while gathering extensive data sets on users' behaviour and realistic driving scenarios. These will be then used to improve their performance. As anticipated, due to the technical complexity associated with the handling of all possible scenarios arising while driving, there are still significant uncertainties associated with level 5 automation. Indeed, it is still unclear whether it will be technically feasible at all (Schmidt et al., 2021). Even lower levels of automation remain challenging, as level 4 automation requires additional infrastructure to be successfully implemented and, depending on the situation (e.g. urban driving), a detailed mapping of the surrounding environment. The former is the so-called V2X infrastructure and requires high bandwidth and low latency wireless connections, sensors and communication devices (Alonso Raposo et al., 2019; Schmidt et al., 2021).

Equally important for the deployment of AVs is the existence of a legal framework. Policymakers are actively developing the legislation to lower the associated uncertainties and increase acceptability. A recent amendment to UN Regulation No 157 has extended the maximum speed for level 3 AVs up to 130km/h on motorways and allowed other automated systems such as lane changing (UNECE, 2022). In Europe, in July 2022, the EU General Safety Regulation came into force (EC Regulation 2019/2144), which sets a legal framework for the approval of level 4 AVs in Europe. It sets technical rules to ensure that the vehicles are safe and that the technology is mature before entering the market. Based on this new regulation, the EU is planning to align its legislation with the new UN rules mentioned above (EC, 2022m).

Lastly, user acceptance is essential, not only from direct passengers but also from other road users. According to recent surveys, a significant share of people would still feel uncomfortable using a high-level automation vehicle in both urban and rural environments. As noted in the Commission's strategy for the mobility of the future (EC, 2018b), 'in order for automated mobility to gain societal acceptance only the highest safety and security standards will suffice'. A large majority of people are still uncomfortable with driverless vehicles (Figure A2.3). Although acceptance is higher in urban areas, more than half of the participants are still uncomfortable about travelling in a driverless vehicle.

Figure A2.3 Answers to the question 'How comfortable would you feel being driven in a driverless car in traffic?'



Source: Alonso Raposo et al. (2019).

A2.3 Time frame

There are several challenges to be overcome before vehicles with a high level of automation will be widely available and present in daily life. The market share of vehicles with an automation level equal to 3 or higher is currently negligible and, according to the estimates reported, future uptake will also remain very limited, at least until 2030 (Schmidt et al., 2021). There are large uncertainties about the speed of market penetration, especially for higher levels of automation. Litman (2015) projects that AVs will be commercially available by the 2030s but that, due to the cost and the long life cycle of cars, market penetration will remain fairly low at the beginning. The percentage of vehicle-km driven by AVs would be around 40% by 2050, with 30% of the fleet consisting of AVs by 2050, including those with low levels of automation (e.g. level 2). When looking at the projected penetration rate of level 4 and level 5 AVs by 2050 in Germany, they vary between 17% (Trommer, et al., 2016) and 36% (Krail, 2021).

Given the potential of AVs for the automobile sector, the EU is actively supporting a coordinated rollout of AV and SAV initiatives. The European Road Transport Research Advisory Council (ERTRAC) has published a roadmap for connected, cooperative and automated mobility (ERTRAC, 2022). It includes an agenda to 2030 and a vision for 2050, which includes a roadmap for deploying AVs in different domains. Four types of domains are described, in increasing order of complexity: highways and corridors, confined areas, urban mixed traffic and lastly rural roads. In the context of highways and corridors, it is expected that the share of vehicles up to level 2 automation will increase, with higher automation levels possible depending on regulation and the maturity of the technology. Level 3 pilot projects, (see also the example in case study 2.1) are being undertaken, and assisted corridors that can meet the requirements for deploying AVs are currently being identified. Figure A2.4 gives an overview of the outlook for highways.

Figure A2.4 ERTRAC outlook on highway automation

Driving assistance comfort	Driving assistance safety	Hands-off/Eyes on	Hands-off/Eyes on lite	Hands-off/Eyes on PLUS
Slow, e.g. during traffic jams	Safety-relevant assistance during driving	Driving mostly automated, attention still required	Transport of goods and people along highways, mostly right lane	Transport of goods and people on highways
<70 km/h	Up to 70 to 100 km/h	Up to 70 to 100 km/h	Up to 70 to 100 km/h	Up to 70 to 110 km/h
First experience/acceptance	Safety benefits	Experience building for higher levels of automation	Experience building for higher levels of automation	Relax times for truck drivers and business travellers
ACC highly equipped, usage on highways rising	Consumer protection driven	Regulation driven	Affordable, business case for logistics — high penetration	Penetration starts
Routes on highways (separated carriageways), possibly with lane restriction				**Flexible routes on highways**
'Simple' safety concept				**Full highways automated driving safety concept**

Source: ERTRAC (2022).

Confined areas are considered well suited for the early introduction of level 4 vehicles, such as valet parking services or buses and shuttles. From a societal point of view (increased safety, efficiency of transport system, accessibility and social inclusion) urban mixed traffic is a high priority, but the challenges of integrating AVs into the intermodal mobility system are considerable. Therefore, an incremental approach is suggested. It is believed that the introduction of AVs in restricted applications should be possible within a decade, while more complex applications will need more time. The relevant cases are level 4 applications such as bus-like or taxi-like applications. Figure A2.5 presents the deployment outlook for low-speed vehicles in confined and urban mixed traffic domains.

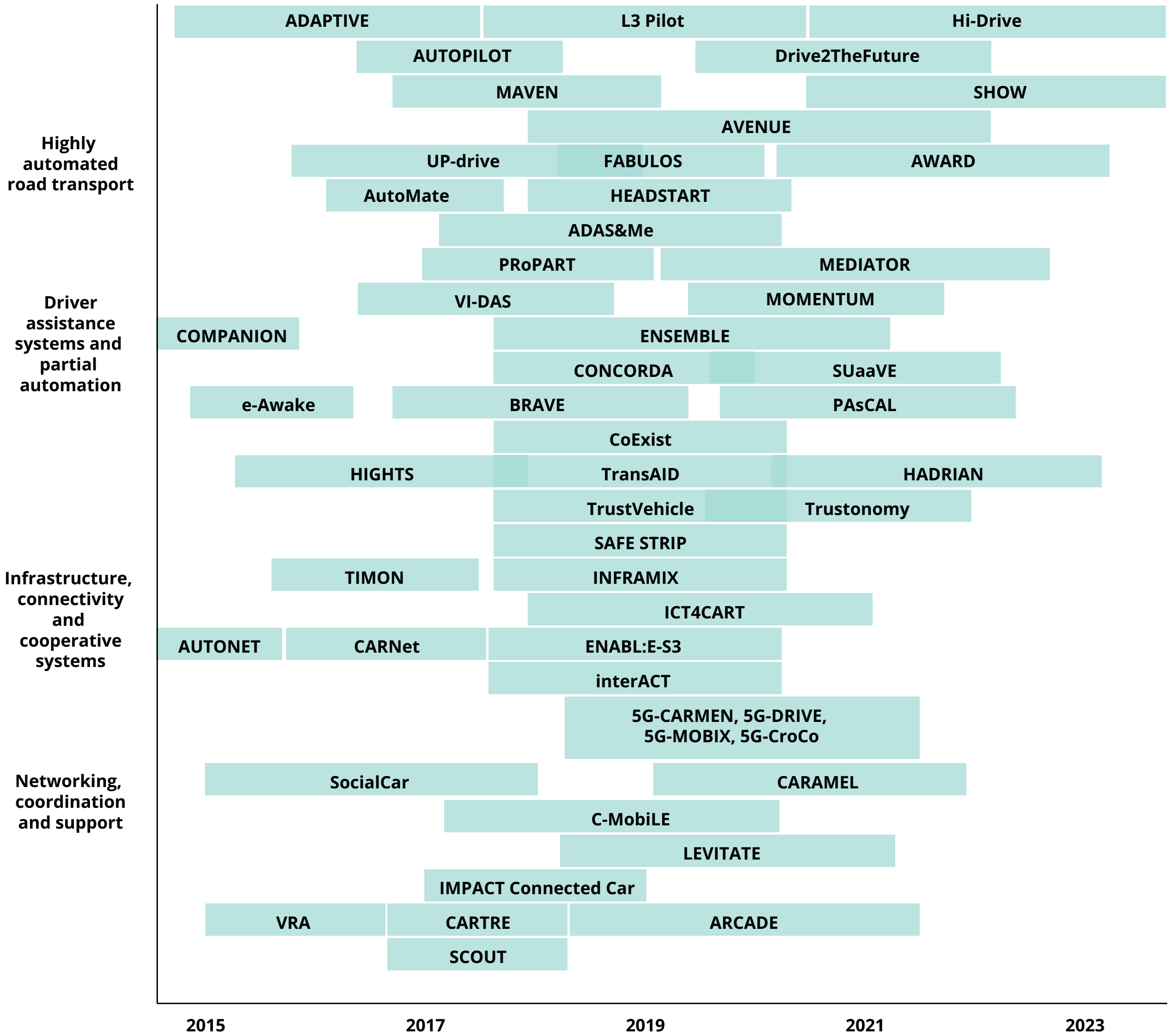
Figure A2.5 ERTRAC outlook on low-speed automation

Restricted	Red carpet	Residential	Bus-like	Taxi-like
Transport of goods, parking	Transport of goods	Last mile transport of goods and people	Transport of goods and people on predefined routes	Transport of goods and people in urban areas
<25 km/h	25 up to 50 km/h	Up to 30 km/h	Up to 50 km/h	Up to 50 km/h
Private, gated area, one-lane road — valet parking (today limited 10 km/h)	Dedicated lane on primary road	Well structured residential lane that guarantees lane driving	Mixed traffic lane on primary and well-structured secondary roads	Complex urban road net
Convenience and productivity	Improved network efficiency	Convenience and productivity	Transport operator driven	Convenience and productivity
In 2040 highly available at terminals/hubs/parking	Partly depending on needs and regulation	User/Market driven	In 2040 in use depending on cost/benefits/needs/ regulation	User/Market demand driven
Predefined routes				**Flexible routes on defined net**
'Simple' safety concept			**Full high-complexity/low speed automated driving safety concept**	

Source: ERTRAC (2022).

The most complex environments are rural roads, as they are used by traffic travelling at higher and widely variable speeds. In addition, the quality of the road and support infrastructures (e.g. 5G coverage, GPS signal) can vary a lot. This significantly increases the difficulty of introducing high-level AVs in rural settings. The EU and its Member States are actively supporting R&D in the domain of AVs and SAVs to address the technical and legislative barriers discussed, as illustrated in Figure A2.6 which gives an overview of projects funded by the EU.

Figure A2.6 **Overview of a subset of EU-funded projects that support the development of connected, collective and automated mobility**



Source: ERTRAC (2022).

Several pilot projects in Europe (Fabulos (2021), Avenue (2021), SHOW (2022), Sohjoa (2020), L3Pilot (2021b); see also case studies 2.1 and 2.2 for more details about the last two projects) and the Mcity Driverless Shuttle in the United States (Kolodge et al., 2020)) have been successfully completed or are still in progress. Since June 2016, two 'smart shuttles' have been operating in Sion, Switzerland (Eden et al., 2017). People can book them via an app or at the railway station. The shuttle does not operate on a fixed route but adapts according to the demand along the 17 virtual stops.

A2.4 Expected environmental impacts

Using the taxonomy set out in Chapter 3 the following higher order environmental impacts of automation can be identified.

A2.4.1 Indirect effects — efficiency effects

It is generally expected that AVs could operate with higher fuel efficiency than traditional vehicles. There is, however, considerable uncertainty about the magnitude. A lot depends on the assumptions made about the level of penetration of AVs, the level of automation and which optimisation systems are being used. Milakis et al. (2017) and Massar et al. (2021) both give an extensive overview of studies reporting the potential fuel savings of various automation systems influencing the driving style and behaviour of the driver. Some of the examples cited include driving simulator experiments done in urban contexts. These are reported in Wu et al. (2011), where a 31% decrease in fuel consumption was estimated, thanks to an automated system that provides the driver with advice on acceleration and deceleration values for optimal fuel efficiency. Khondaker and Kattan (2015) calculate 16% fuel savings for their variable speed limit algorithm if 100% of vehicles were using their system. In conclusion Milakis et al. (2017) note that fuel savings of up to 31-45% can be achieved, depending on which automation system is used. The higher the penetration rate of the system, the greater the potential savings. Taiebat et al. (2018) list other results with efficiency gains from 5% to 20%, depending on the specific automation and operational systems used in the vehicles.

AVs are also believed to be able to reduce emissions in city centres by reducing the time spent searching for parking. Indeed, in city centres this causes between 2% and 11% of the greenhouse gas (GHG) emissions according to Shoup (2006). If driver can be directly and accurately informed about parking space availability, Brown et al. (2014) estimate that a 5-11% of emissions could be saved. Shared AVs could decrease the need for parking even more and reduce the time spent looking for parking to nearly zero (ITF 2015) and Fagnant and Kockelman (2015).

Compared to traditional public transport, SAVs have the benefit that they are more flexible and can better match specific vehicles to specific trips by using the right size of vehicle according to the demand. Therefore, SAVs can achieve better occupation levels per individual vehicle, reducing the number of vehicles needed. Fagnant and Kockelman (2015), estimate that if 3.5% of trips were made with SAVs, this could lead to a decrease of 5.6% in GHG emissions, as each SAV could replace up to 12 conventional vehicles.

Although there is a potential to reduce emissions, AVs will lead to an increase in energy consumption because of the additional requirements of the onboard systems, the mobile communication, the backend systems and the network infrastructure. A detailed study on this additional energy consumption has been performed by Krail (2021). That study uses the estimated energy savings potential for a mid-sized car across all automation levels from Krail et al. (2019) as a starting point. The savings potentials range from 493Wh/100km at level 1 to approximately 2,000Wh/100km at levels 4 and 5 in 2050. To estimate the extra energy consumption, the study considers two scenarios, with various degrees of complexity of the information and communications infrastructure. In the 'minimal networking' scenario, savings potentials remain substantial, albeit lower: 125Wh/100km in 2020 up to 1,617Wh/100km in 2050. Interestingly, in the 'efficient networking' case, however, there is an initial substantial increase of energy consumption up to 2,500Wh/100km. It is only in 2040, with the deployment of level 4 automation that energy savings can be achieved (579Wh/100km for level 4 and 631Wh/100km for level 5). It is also noted that this means that an increase of 2.6% in the vehicle-km travelled would render the overall effect of AVs negative in terms of energy efficiency.

A2.4.2 Indirect effects — substitution effects

SAVs can be a useful tool to address the first/last mile problem, to increase the accessibility of the existing public transport system and to reduce the use of private transport, as suggested in Lau and Susilawati (2021) and Moorthy et al (2017). Lau and Susilawati (2021) simulate the impact of integrating SAVs in the public transport network in Kuala Lumpur and find that public transport use increases by 3% and car-km travelled fall by 6%, suggesting a modal shift from private car to public transport. Moorthy et al (2017) find a 37% reduction in energy consumption when SAVs are used for the first/last mile rather than private cars. On the other hand, Alonso Raposo et al. (2019) and references therein, as well as Mäkinen et al. (2020), state that autonomous buses are more likely to be a substitute for walking or cycling rather than to reduce the number of car trips. The overall effect on emissions therefore remains uncertain. Moreover, autonomous taxi services, especially if not shared among different users, could also directly compete with the existing public transport systems, reducing their use. The impacts of this remain largely unknown.

A2.4.3 Structural and behavioural effects — direct rebound effects

AVs are expected to reduce travel costs through higher fuel efficiency. This reduction in the marginal cost of driving is expected to induce more travel. Moreover, travel is likely to become much more comfortable and thus more attractive. Taiebat et al. (2019) analyse the possible rebound effects and conclude that, assuming a 15% improvement in fuel efficiency and a 100% market penetration, AVs could potentially induce a 17.2% increase in fuel consumption. Other studies the authors reference also suggest considerable rebound effects on vehicle-km travelled but with considerable uncertainty, ranging between +2% and +341%, with a median of +43%, based on our own calculations. This underlines the importance of complementing such technological advances with measures aiming to internalise transport externalities, similar to those described in Factsheet 7. This is to avoid as much as possible the increase in vehicle-km travelled that could offset some of the environmental benefits mentioned above.

Other studies conclude that the use of SAVs will lead to fewer vehicles being needed to deliver the same number of trips but that the number of vehicle-km travelled is likely to increase. Dia and Javanshour (2017) use an agent-based model to examine the impact of SAVs from a pilot study on a small road in Melbourne, Australia. They model two scenarios, varying the passenger waiting time for the SAV. The results show a significant reduction in the number of vehicles needed (between 43% and 88%). However, the number of vehicle-km travelled would increase (+29% and +10%) and the overall effect on emissions would depend on the load factor of the SAVs. In a case study for Lisbon (ITF, 2015), it is estimated that SAVs (whether shared by several passengers at the same time or sequentially) could reduce the number of cars needed to deliver the same trips by 80-90%. The number of vehicle-km travelled would, however, increase by 6% if self-driving cars are shared by several passengers and high-capacity public transport is still available.

Apart from the rebound effect caused by a reduction in travel costs, SAVs create a mobility opportunity for people with disabilities, elderly people or other people with limited access to public transport. This creates new demand for mobility, increasing overall demand. Harper et al. (2016) estimated the potential increase in vehicle-km travelled at 14% due to an increase in mobility among the elderly and people with medical conditions.

A2.4.4 Structural and behavioural effects — economy-wide impacts

The cost structure for public transport can be expected to evolve, with lower operating costs (no drivers, more fuel efficient) but a higher capital cost. Currently, the final unit costs for SAVs are still uncertain, but it is likely that, especially in the short term, the purchase price of SAVs will remain higher than that of traditional vehicles because of the former's sophistication and their relatively low capacities. Removing the need for a driver can, however, have drastic implications for the operating costs. Differences can be expected across the EU, depending on the level of drivers' salaries. In Finland, staff costs are responsible for half of the total cost of public transport mileage (Mäkinen et al., 2020). Bösch et al. (2018) carried out a detailed comparison of the cost structures of conventional private cars and taxis with autonomous cars and taxis. They conclude that automation raises the purchase price but reduces the operating costs. For taxis, the main cost component is the driver's salary (up to 88% in conventional cases) which can be completely avoided in the case of an automated unit. Bösch et al. (2018) conclude that automation only marginally changes the cost of private cars (from CHF0.48/passenger-km for conventional cars to CHF0.5/passenger-km for AVs) and rail services (from CHF0.47 to CHF0.44/passenger-km); however, taxi services and buses can gain substantial competitive advantage through automation. The costs for taxis in an urban setting decreases from CHF2.73 to CHF0.41/passenger-km and buses could see their costs halved. A recent study investigated the impacts of autonomous taxis for the city of Zurich (Hörl et al., 2021).

The introduction of AVs in general (not only SAVs) is likely to have substantial impacts on the wider economy, with significant impacts on the labour market (Alonso Raposo et al., 2018, 2022). There will be a reduced need for professional operators but the demand for information and communications technology (ICT) professionals will increase, with a shift in the skills needed. In parallel, an increase in productivity in the electronic and software sector and the telecommunication, data services, automotive and freight transport sectors could be expected, while insurance and maintenance and repair sectors are likely to be negatively affected.

A2.4.5 Structural and behavioural effects — transformational changes

By transporting people door to door, SAVs can reduce the demand for parking and improve the allocation of space in city centres. A study performed in Lisbon (ITF, 2015) estimates that 80% of off-street parking could be removed and on-street parking would become obsolete following the introduction of SAVs. Fagnant and Kockelman (2015) estimate that 11 parking spaces per SAV in operation could be eliminated. This frees up space for other purposes such as designated bicycle lanes.

SAVs increase the accessibility of the transport system and this can also lead to a wider effect. Mäkinen et al. (2020) estimated from a simulation that the share of the population within 30 minutes of the centre of Helsinki would increase by 36% following the introduction of a shuttle service, illustrating the effect it could have on urban sprawl.

AVs can substitute for conventional cars without affecting the current business model centred on the ownership of the vehicle as long as lower automation levels (2 or 3) are predominant. Level 4 automation could enable the development of shared urban vehicles providing door-to-door services. This has the potential to significantly change the mobility system, first in urban environments and later also in rural-urban connections (Alonso Raposo et al., 2018, 2019; Schmidt et al., 2021).

A2.5 Policy corner

Progressive development of the automation technology and its wider diffusion is expected to take place in passenger transport, following the general trend towards digitalisation. It offers some possibilities to increase the environmental performance and safety of the transport modes. It reduces the time cost of travelling and can also reduce the monetary costs. It also facilitates travel for a number of groups in society who are served less well by the current transport system. The general increase in transport demand (both in general and for the modes that are automated), due to cost reduction, is beneficial to society only if the external costs that remain are fully internalised. Additional details on this can be found in Factsheet 7 and Annex 7. The regulatory framework around AVs is currently centred around safety. It is important that environmental considerations are also taken into account, especially considering the potential impact on public transport and the modal shift. The impacts of progressive automation will also depend on the environmental policies for the transport modes that are already in place in the baseline scenario without automation (e.g. emission standards, renewable energy targets).

Related to traffic safety, even with lower automation levels the interaction of the driver with a partially autonomous vehicle remains an important factor. For higher level AVs and driverless cars, liability issues may occur. Another point needing consideration are situations in which there are interactions between vehicles with different levels of autonomy. There also is a risk related to cybersecurity, also explored in Chapter 6.

A2.6 Bottom line

Although the effects of AVs on safety and mobility are promising, the environmental impacts remain uncertain as the gain in fuel efficiency arising from automated operations could be outweighed by the extra energy needed for the onboard systems and the broader ICT network infrastructure. Moreover, the rebound effect in terms of extra vehicle-km generated can be substantial. Shared autonomous urban vehicles that are well integrated into the existing public transport system are the most promising, but at present the interaction between SAVs and existing public transport is not yet clear.

A2.7 Case study 2.1: L3Pilot project

L3Pilot was a European research project aimed at testing and studying the viability of automated driving on public roads (L3Pilot Driving Automation 2021a, 2021b). The main focus was testing SAE level 3 functions, with additional assessment of some level 4 functions, on a large number of vehicles under a wide range of conditions. Indeed, the project involved 1,000 drivers, 100 cars and 34 different partners, including manufacturers, suppliers, research organisations, small and medium-sized enterprises, insurers, one local authority and one user group. The pilot lasted 4 years, from 2017 to 2021, and developed across 10 European countries, including driving on cross-border routes.

The project had four main objectives:

- to create a standardised Europe-wide piloting environment for automated driving;
- to coordinate activities across the piloting community to acquire the data required for evaluation;
- to pilot, test and evaluate automated driving functions;
- to innovate and promote automated driving to raise awareness and introduce it to the market.

In the testing phase, four different traffic scenarios were investigated: (1) traffic jams; (2) driving on motorways, including in traffic jam situations; (3) the parking environment; and (4) urban areas. In this way it was possible to collect a significant amount of data from various scenarios and to evaluate the behaviour of the automated driving system as well as to highlight areas for future development.

For the motorway scenario, the following observations were made. First, the AV drove at lower speed and allowing much greater leeway than in the baseline situation in which automation is deactivated. Second, the AV tended to remain longer in a stable driving scenario (i.e. free driving or following a vehicle). Similarly, lane-keeping behaviour was more stable than in the baseline case. Interestingly, the results indicated that, when the vehicle drove in an autonomous way, its energy consumption was reduced (up to 12% on average), probably due to the changes in driving behaviour (lower speed, more stable driving scenario, etc.). It should be noted, however, that the energy demand of the additional equipment was not considered.

In the urban driving scenario, because of its intrinsic variability, it was more complicated to evaluate the impact of autonomous driving. Nevertheless, some general points can be made. Urban AVs need more time to cross an intersection, suggesting more careful overall behaviour. No significant differences between the AV and the baseline situation could be identified when following a leading vehicle. This seems to suggest that deploying AVs would not interfere with the traffic flow. In general, autonomous driving reduced overall driving dynamics (i.e. longitudinal and lateral accelerations).

Lastly, in the parking environment, AVs were always slower than the baseline situation, taking more time to perform the task required.

In all scenarios, user acceptance evaluated through questionnaires was positive, although room for improvement in the overall experience was reported.

It is important to highlight that this pilot project was performed with individual cars in mind rather than urban shared vehicles. The study shows the extent to which travellers may be interested in switching from using public transport or active modes to an autonomous personal vehicle. More specifically, twice as many respondents expected to decrease their use of public transport (26-29%) than those expecting to increase their use of it (12-15%). This once again highlights the importance of policies encouraging a shift to collective and sustainable transport modes and the necessity of making public transport more attractive and accessible, also through automation, to avoid this unwanted modal shift.

A2.8 Case study 2.2: Sohjoa Baltic project

The aim of the Sohjoa Baltic project was to 'develop knowledge and competences required to organise environmentally friendly and smart automated public transport through research, promotion and piloting autonomous driverless electric minibuses as part of the public transport chain, especially for the first/last mile connectivity' (Mäkinen et al., 2020). During the Sohjoa Baltic project, which ran from to 2017 to 2020, autonomous minibuses were successfully piloted in six Baltic cities (Sohjoa Baltic Consortium, 2020). They identified situations in which autonomous minibuses could be part of the mobility solution (Mäkinen et al., 2020):

- First/last mile: especially for areas where the demand density for trips is low and first/last miles are distributed over a large area. On-demand services using autonomous shuttle buses are the most promising solution for this.
- Autonomous shuttle buses: these can also be deployed where there is a temporary high demand for transport (e.g. exhibitions, new residential areas that do not have a established public transport system).
- One of the more likely applications: in closed areas such as airports, hospital and campuses.

The project also identified the major impacts that can be expected after introducing SAVs:

- The role of SAVs can be seen as complementary to other public transport modes rather than a real substitute. The researchers therefore predict that it is not likely that SAVs will reduce the use of private cars but that they are more likely to be a substitute for cycling and walking.
- SAVs can replace traditional buses only in low-density residential areas, as currently they have a low capacity and operate at low speeds and thus are not suited for travelling long distances.
- SAVs can improve access to the existing public transport system and can make it more attractive, providing that the services are well synchronised.
- When used as feeders for trunk lines, SAVs can lead to a reduction in the number of stops on the trunk line and improve its efficiency.
- The cost structure of SAVs is still uncertain, but they are likely to have higher capital costs than traditional vehicles because of their sophisticated hard- and software. The operational costs are, however, likely to be significantly lower, as personnel costs are reduced.

In terms of acceptability, the overall user experience was very positive. The majority of the 837 respondents gave maximum scores when asked to rate their experiences (with 50% being the lowest score in Helsinki) and perceived the SAVs as safe, which is illustrated by the fact that between 40% and 60% of respondents considered the system suitable for children travelling alone to school.