Digitalisation and automation of transport

Regulatory framework for sustainable development

Für Mensch & Umwelt

Umwelt Bundesamt

Imprint

Publisher
German Environment Agency (Umweltbundesamt)
Section I 2.1
Postfach 14 06
D-06813 Dessau-Roßlau, Germany
Tel.: +49 340-2103-0
buergerservice@umweltbundesamt.de
Internet: www.umweltbundesamt.de

/umweltbundesamt.de
/umweltbundesamt
/umweltbundesamt
/umweltbundesamt

Authors
Dr Tim Albrecht | fairkehr Verlags GmbH, Bonn
Benjamin Kühne | fairkehr Verlags GmbH, Bonn
Björn Verse | Umweltbundesamt I
Section 2.1 Environment and Transport

With contributions from
Annett Steindorf and Martyn M. J. Douglas | German Environment Agency I Section 2.1 Environment and Transport

The texts are largely based on the publications:
Thaller et al.: Final report on the digitalisation of transport. Potenziale und Risiken für Umwelt und Klima [Potentials and Risks for the Environment and Climate] UBA 2023, 3716 58 1030
Bruns et al.: Final report on the digitalisation of transport. Vorschläge für Regelungskonzepte und Rahmenbedingungen zur Realisierung einer nachhaltigen Mobilität [Proposals for regulatory concepts and framework conditions for the realisation of sustainable mobility], UBA 2023, 3718 58 1000

Editorial
fairkehr Verlags GmbH, Bonn, Germany
Benjamin Kühne

Translation
Wort für Wort GmbH & Co. KG, Cologne, Germany

Typesetting and layout
Mike Communications, Cologne, Germany

Publications as PDFS
www.umweltbundesamt.de/publikationen

Cover image source: HOCHBAHN

As at: February 2023

ISSN 2363-832X

Digitalisation and automation of transport

Regulatory framework for sustainable development

Contents

Steering digital, automated and connected mobility towards environmental and climate protection

Overview of topics, issues and solutions

Digitalisation of transport is ubiquitous. Digital applications on smartphones provide real-time information on connections, delays and cancellations in local and intercity transport and enable easy booking of tickets. Digital navigation devices and driver assist systems in motor vehicles have become standard equipment. They not only provide information on traffic congestion and recommend optimised routes as and when required, but in future will impact traffic flows by networking with other vehicles.

Meanwhile, technological developments in automated driving are making further progress. As early as this year, the first vehicles with Level 4 automation (see p. 9) will be tested for use in on-demand traffic on our roads. Such vehicles require no driver at all, but initially will have a person on board to assist.

The digital transformation is changing the everyday lives and mobility of many people and is affecting planning and infrastructures as well as business models. While modern communication software and employment practices such as working from home and co-working are making long commutes unnecessary, more and longer leisure-time journeys are being taken instead. At the same time, platformisation in transport is emerging. Innovative start-ups as well as established transport operators are developing digital mobility platforms on which different transport modes and new mobility services, such as sharing and pooling, can be booked. However, the dream of an app pooling all transport modes and providing mobility from a single source for users has yet to come to fruition.

A 'digital space' has long since evolved in transport, where data on infrastructure, vehicles and users is being generated at varying detail and resolution, and frequently in real time. This increasing mobility data trail can also be used for traffic planning and management.

Digitalisation of transport – Driving the mobility transition?

The above developments should make mobility more sustainable and be a key driver of the mobility transition. Digitalisation and automation of passenger transport are therefore often key components of local, national and international strategies on sustainable mobility and transformation of the transport system. Digital mobility services such as sharing and pooling concepts have the potential to make private car ownership superfluous in the long term.

Particularly exciting is the vision of highly automated and connected fleets of electric vehicles that are not only emission-free but also drastically reduce land use, the need for vehicles and therefore resource and energy consumption. There is also the prospect of automated vehicles removing access barriers and increasing social participation through mobility.

However, whether digital mobility services and connected automated vehicles will help to save land, resources and energy and thereby contribute to environmental and climate protection remains to be seen. There is uncertainty around issues of acceptance and technology costs to digitally equip and retrofit vehicles and infrastructure. By eliminating the need for drivers and thus personnel costs, automated driving could not only make individual mobility comfortable, but also cheaper over long distances.

Will automated vehicles supplement public transport in the future, thereby strengthening the established ecomobility options of buses, trains, bicycles and pedestrians in the long term? Or will 'robotaxis' make individual transport so comfortable and inexpensive that they crowd out more ecological means of transport, thereby reinforcing private motorised transport and its need for land, resources and energy?

An automated minibus operated by Hamburger Hochbahn as part of the HEAT (Hamburg Electric Autonomous Transportation) research and development project. Image: HOCHBAHN

Smart mix of instruments for a mobility transition

To steer the digital transformation of transport towards sustainability, environmental and climate protection, a smart mix of instruments that include relevant legal as well as economic and planning frameworks is needed. Such regulatory frameworks require a forward-looking approach to ensure early alignment with environmental objectives and to avoid any undesirable developments.

Section 1 of the brochure presents the main developments and applications of digitalisation in transport and outlines the opportunities and risks for sustainable mobility. Section 2 uses different development scenarios to present the impacts of automated and connected driving on the transport system, emissions and environment. Section 3 presents an overall regulatory framework and outlines how different regulatory instruments and components can interact to steer the digitalisation of transport towards sustainability and environmental and climate protection.

1

Development lines

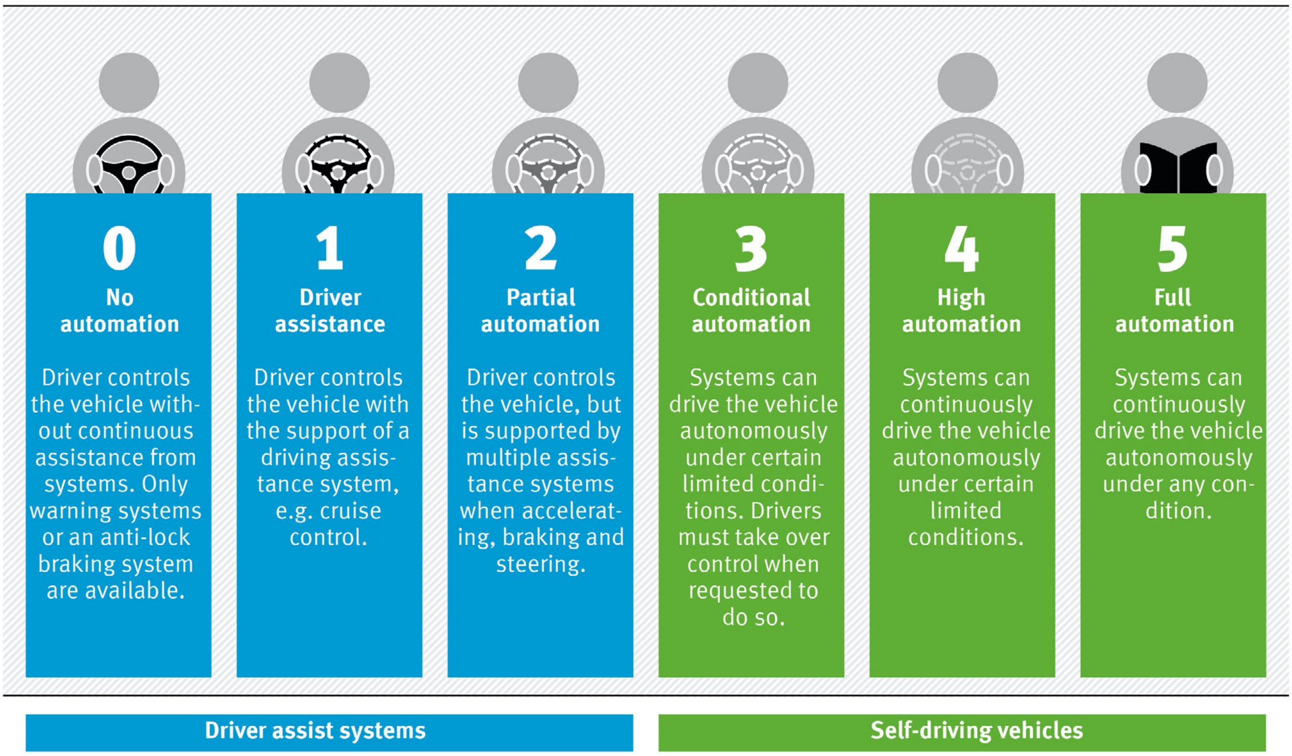
This section presents three applications for digital technologies in transport. They are described in the three subsections, along with the basic technology and infrastructure they require. Which stakeholders need to be brought on board in each of the three areas is also explained.

A) Automated, connected driving in private motorised transport

Automation levels and share of vehicles: How automobility might look in 2040

Figure 1

Automation levels in vehicles (SAE Levels)



The automation levels shown in Figure 1 apply to both public transport and private vehicles. Source: own representation based on SAE International 2018, German Environmental Agency

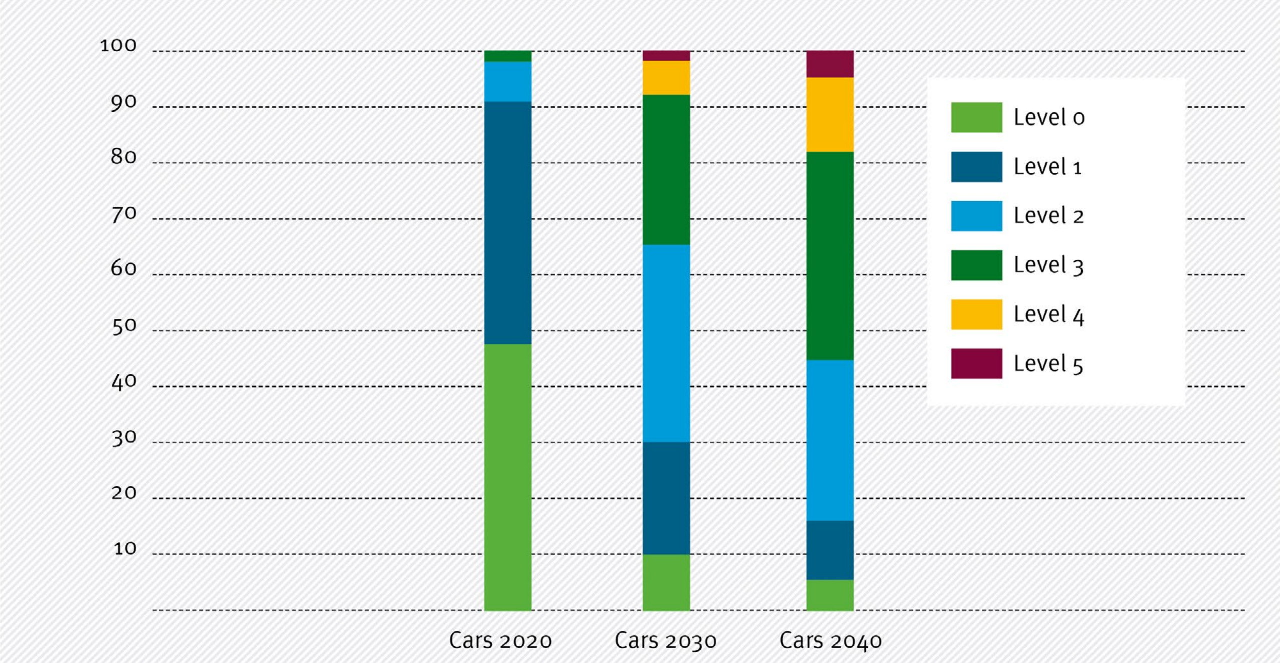
Automated and connected driving is a key development in the digitalisation of transport and is likely to result in significant changes in how people use transport. This will enable new business models in mobility that will significantly impact our transport system.

Many vehicles already assist drivers with certain tasks, such as steering (e.g. lane assist), acceleration and deceleration (e.g. adaptive cruise control) and monitoring surroundings (e.g. parking assist). Widespread driverless road traffic is, however, still a long way off. Experts predict that the global share of highly automated or fully automated cars will be 19% by 2040 (Lichtblau et al. 2021).

International research has established a nomenclature that defines according to which six levels of automation (SAE Level [Society of Automotive Engineers], see Figure 1). These range from Level 0 (no automation) to Level 5 (full automation). From SAE level 3 (conditional automation), we refer to self-driving rather than driving assistance systems. At this level, vehicles are controlled by automated systems – but only under certain, clearly defined conditions. A human driver must also be ready to take over the control at any time when prompted by the system. This kind of application would be conceivable, for example, on separate motorway lanes. SAE Level 4 has three main use cases: a motorway pilot, which can drive the car autonomously on motorways. A city pilot, which can drive the car autonomously in cities, neighbourhoods, or suburbs where the appropriate physical infrastructure, topography, and digital maps are available. And automated valet parking, where drivers steer their cars to the entrance of a car park, exit the vehicle, and the vehicle automatically locates and parks itself in an available space.

Figure 2

Automation levels in passenger cars by 2040 worldwide



Source: own representation based on Lichtblau et al. 2021, German Environment Agency (Umweltbundesamt)

At SAE Level 5, driverless driving has been achieved, no longer requiring any human intervention. Increasing automation requires high levels of connectivity between vehicles, infrastructure and digital networks. Real-time provision of data and information is the basis for optimal decision-making by the humans and components involved.

Requirements on automated and connected vehicles are particularly high in mixed traffic situations involving non-connected vehicles, pedestrians and cyclists. Level 4 vehicles are already capable of managing complex driving situations in mixed traffic, but these vehicles tend to operate very conservatively. This could change, for example, by having separate, dedicated, low-interference lanes for robotaxis. However, given the scarcity of space in our cities, this is an unlikely scenario.

Stakeholders – Actors and impacted parties

- Public sector
- Municipalities
- Citizens
- Drivers
- Vulnerable road users
- Car and technology industry
- Ridehailing/sharing/pooling enterprises

B) Automated, connected driving in public transport

Summary of key applications of automated vehicles in public transport

A first in Germany: The Nuremberg underground has been operating continuously without drivers since 15 March 2008.
Image: Markus Spiske/unsplash.com

Many different applications for automation are conceivable in public transport: from fully automatic, short-interval underground systems to ride-sharing services that take passengers to their destinations in automated minibuses. We present the five most important below:

1. Automation of existing public transport systems
Existing public transport becomes driverless. Level 4 automation is often sufficient for public transport road vehicles, because buses, for example, travel along fixed routes and dedicated bus lanes are sometimes available. Rail vehicles are much easier to automate than road vehicles because they generally run on separate tracks rather than in mixed traffic with cars, bicycles and other vehicles. For railways, Grades of Automation (GoA) are used rather than SAE levels. These have only five levels (Grades 0-4) with Grade 4 currently meaning that full automation has already been achieved. Advantages of automation here include a reduction in safe distances between vehicles and thus an increase in capacity. In other words, more trains or buses than before can operate simultaneously on the same section of track or bus lane.

2. Partial replacement of existing scheduled services
Buses and trams with low capacity utilisation, e.g. in rural areas or during off-peak hours, can be replaced by automated minibuses operating between fixed stops. Such minibuses will also be able to operate at shorter intervals than larger vehicles. This reduces passenger waiting times while also increasing the attractiveness of public transport. SAE Level 4 or 5 vehicles would be required, depending on the environment.

3. Expansion of existing public transport systems
Additional services using automated vehicles would be added to existing bus and rail services, for example, by an additional system or additional track specially designed for driverless railways. Increasing service frequencies and extending service hours using automated vehicles could also be considered. SAE Level 4 would be sufficient in many cases due to the services predominantly using dedicated lines/lanes.

4. Feeder systems to extend main public transport systems
New transport services can be developed in the coming years using automated and connected vehicles. For example, ridesharing or shuttle services, would provide access to peri-urban and suburban residential areas that were previously either insufficiently connected to or completely disconnected from public transport services. The new services could take on a feeder function to commuter rail, underground and tram stops as well as main railway stations. Ridesharing services (also called ridepooling) are on-demand shared car services that connect virtual stops (boarding points marked on an online map) and public transport stops along flexible routes. Software is used to plan and optimise routes for the vehicles and thereby bring passengers together. Level 5 automation would be required as the vehicles do not follow fixed routes.

5. Public transport accessibility in rural areas
Small, automated road vehicles could be used to provide full coverage of sparsely populated rural areas and to provide connections to public transport services in neighbouring areas. A very high level of automation (SAE Level 5, extensive connectivity with the environment) would however be required for this task to be undertaken by automated vehicles.

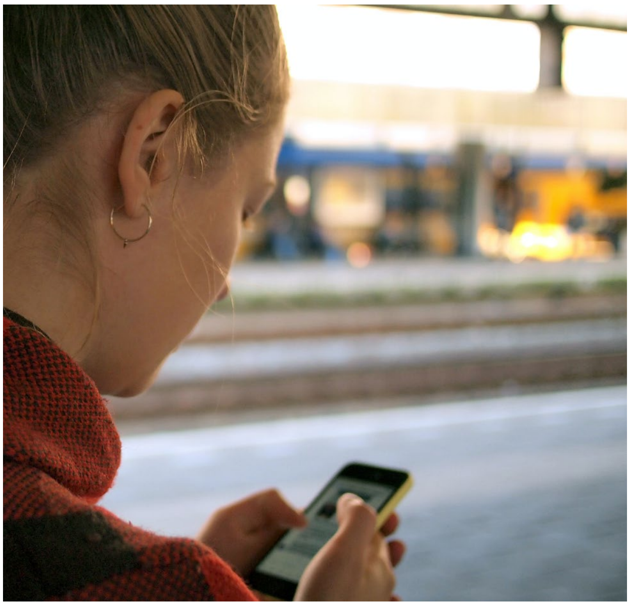
Scheduled bus and rail services would remain the core of public transport in the scenarios described above. It would not make sense to completely convert public transport to automated ridesharing services in urban areas and large cities, because road networks in many places would lack sufficient capacity to absorb the additional traffic. Energy demand would also increase.

Stakeholders – Actors and impacted parties

- Citizens as passengers
- Transport companies and municipal utilities as public transport providers
- Municipalities as owners of transport companies and municipal utilities as well as co-financiers of public transport
- Transport associations
- Private mobility providers
- Taxi sector
- Car sector
- Railway companies, especially Deutsche Bahn
- Federal and state governments

C) Digital, multi- and intermodal mobility services and platforms

Mobility services from a single source: prerequisites for multi- and intermodal mobility



The smartphone is a key technology making multi- and intermodal mobility platforms possible. But accessing services also needs to be possible without a smartphone.
Image: Daria Nepriakhina/unsplash.com

It is already possible to check on your smartphone whether your train will arrive on time, to book a rental bike for the journey to the station, to navigate to the location of the bike, to cycle to the stop and then quickly download a ticket to your mobile phone before boarding the train. Such digital mobility platforms have made it much easier to plan routes and to book and pay for mobility services and shared services. We look at two types of mobility platforms here and how they can be used:

1. Multimodal platforms primarily allow comparisons between different modes of transport. They answer questions such as: How long will it take me to get to work if I take the bus and train, a rental bike or an e-scooter, and how much will each option cost me? If you want to combine different transport modes, you need to plan the legs separately and make several separate bookings.

2. Intermodal platforms use algorithms to link different transport modes and automatically calculate, for example, the fastest or cheapest route to the destination. Users can book and pay for all modes and tickets in a single transaction. Mobility as a Service (MaaS) is the term used when intermodal services have been developed to the point where they make publicly accessible mobility available as an integrated service.

Intermodal mobility platforms can significantly increase the appeal of individual transport services, for example, compared to using your own car, for special transport purposes such as the weekly shop, or getting home from a late-night party.

In Germany, multimodal platforms for booking different modes of transport are currently the most common. Although some apps can also be used to book intermodal journeys using different public transport services including, for example, buses and intercity train services, options such as e-scooters or rental bicycles for the first and last mile are generally not included.

There are three main reasons for this:

- Lack of transfer points where conventional public transport can be linked with other modes of transport and services
- Lack of transport services
- Lack of shared mobility data required to operate mobility platforms

Insufficient infrastructure and mobility data

There is not only a lack of transport services at the moment. Many places also lack the infrastructure interconnecting modes of transport, such as mobility stations, where public transport stops are linked with sharing services, parking spaces and bicycle parking facilities. The networking of different mobility services in Germany is also failing due to a major need to expand and harmonise the required technical support systems, especially data platforms where the required mobility data can be accessed. The data required for multimodal and intermodal mobility services is also lacking, such as timetable data, real-time data, distribution data and mobility data from rural regions.

Many initiatives are currently in place to improve data provision and data networking, for example, Mobilithek launched in July 2022 by the German Federal Ministry for Digital and Transport (BMDV), and the Mobility Data Space operated by the firm DRM Datenraum Mobilität GmbH. Major improvements in the availability of mobility data can therefore be expected in the coming years. However, many legal issues, especially on data provision and collection responsibilities as well as data access for third parties, and funding matters still require clarification.

A combination of two factors is needed to significantly increase public transport passenger numbers. One factor is area-wide availability of transport services such as rental bicycles directly linked to buses and trains at transfer points. The other concerns technical support systems and end-user applications, such as smartphone apps, which make it as simple as possible to plan, book and pay for door-to-door transport services. Only by combining both factors can an attractive alternative to using private motorised vehicles be created for many people.

Digital systems for navigation, information and booking

Simple digital services can make public transport and e-mobility much more attractive. Reductions can also be made in parking search traffic, which can account for a considerable share of total traffic in our cities. Smartphone apps can generally be used for this purpose. Service providers basically use the same technical support systems as mobility platform providers. The following services are already available:

- Seat reservations on public transport
- Information on occupancy of trains and carriages
- Information on traffic conditions (current connections, delays, traffic jams, etc.)
- Parking space reservation via app (for bicycles and cars)
- Display/booking of charging stations for e-cars

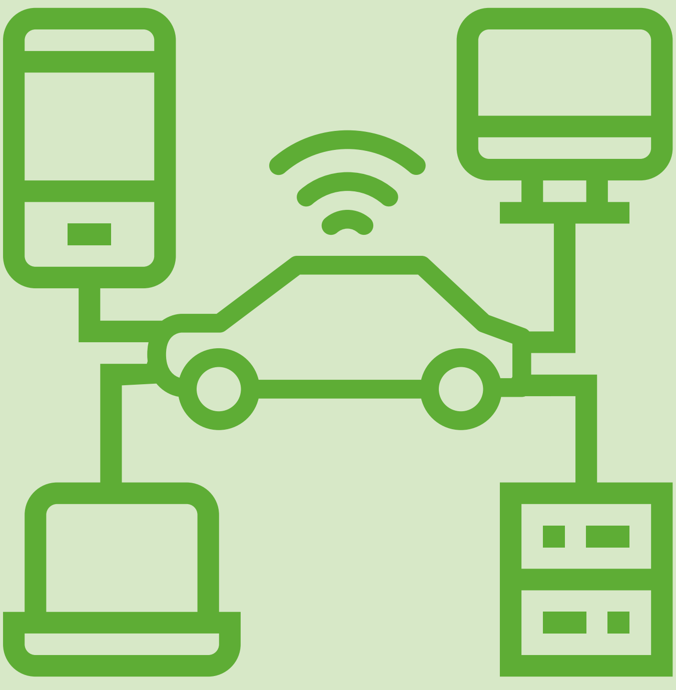
Stakeholders – Actors and impacted parties

- Citizens as users
- Transport companies and municipal utilities as public transport providers
- Transport associations
- Railway companies, especially Deutsch Bahn
- Companies providing mobility platforms
- Data platforms such as Mobilithek and the organisations behind them such as the BMDV as providers of mobility data
- The federal states as co-financiers of local passenger rail transport
- Municipalities as co-financiers of local public transport and owners of car parks
- Companies operating car parks
- Energy companies, municipal utilities and automotive companies as providers of charging stations for e-cars

2

Opportunities and risks of transport digitalisation

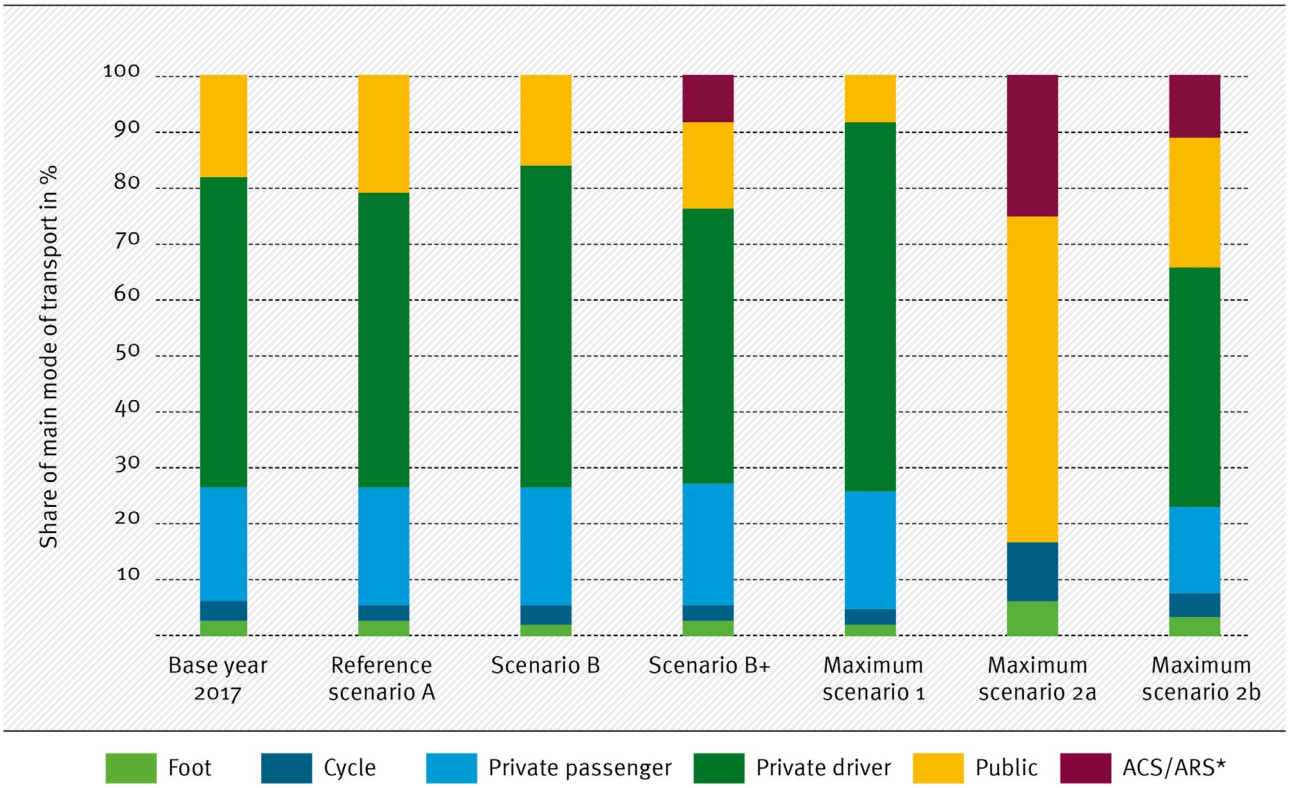
This section examines scenarios in the year 2040 to assess the impact of automated and connected vehicles on the modal split, transport performance, energy demand, road safety and infrastructure utilisation.



Different scenarios: How will we be mobile in 2040?

Figure 3

Scenarios: Share of main transport modes in passenger kilometres in 2040



* ACS/ARS: automated car- and ridesharing services

Source: Thaller et al. 2023 (own translation)

To assess the impact of automated and connected driving on the modal split, the authors of the UBA study '*Potenziale und Risiken für Umwelt und Klima*' [Potentials and Risks for the Environment and Climate] identified three development paths with a total of eight different scenarios. The scenarios primarily differ in how automated and connected vehicles are used and their share of all passenger cars. In this technical brochure, we only consider the scenarios for the year 2040, as the scenarios for the year 2030 differ only slightly from the base year 2017.

Development path A is based on the following assumption: in 2040, vehicles with automation levels 4 or 5 (see p. 9) will not yet be available for private purchase and privately owned cars will not be connected to their environment. Automated car and ridesharing services (ACS/ARS) will not be available. However, there will be an increase in the share of privately owned cars with automation levels 2 and 3. This scenario will not see any significant shift in the modal split apart from a minor increase in public transport due to a decrease in private motorised transport (cf. Thaller et al. 2023).

Development path B (scenarios B and B+) is based on the following assumption: automation will already be much more advanced compared to development path A and vehicles with automation levels 4 and 5 will also be available to individuals. Initially high prices will already have fallen so much by 2040 that the share of connected vehicles among privately owned cars will be relatively high. Scenario B+ has the same share of the different levels of automation in private car ownership as **scenario B** with the difference that ACS and ARS will also be available in **scenario B+**. In scenario B, the share of private motorised transport will increase to the detriment of public transport. In scenario B+, the share of private cars will decrease in favour of automated cars or ridesharing (cf. Thaller et al. 2023).

In **maximum scenarios 1, 2a and 2b**, the authors of the study consider how 100% automation at SAE Level 5 with full connectivity of both private and shared vehicles could impact transport:

- **Maximum scenario 1:** Private vehicles and public transport are fully automated and connected; no automated car- or ridesharing exists. The result is a very high share of private transport with low shares of public transport, cycling and walking (cf. Thaller et al. 2023).

- **Maximum scenario 2a:** Public transport and car- or ridesharing are 100% automated and connected, but there are no automated private vehicles. The result is a very high public transport share, a significantly increased share of cycling and walking and an ACS/ARS share of around 25% (cf. Thaller et al. 2023).

- **Maximum scenario 2b:** Private vehicles, public transport and automated car- or ridesharing services are fully automated and connected and exist side by side. The result is a share of private cars significantly lower than in the base year 2017. The share of ACS/ARS is 10%, the share of public transport increases by about 5% points, cycling and walking increase slightly (cf. Thaller et al. 2023).

Traffic volumes and sustainability

Without a policy framework there is a significant risk that driverless transport will lead to higher traffic volumes in passenger cars (cf. Agora Verkehrswende 2020a quoted in Bruns et al. 2023). This is evident in both scenario B and maximum scenario 1. The most obvious consequences would be an increase in traffic volumes and in energy and resource consumption for mobility, as well as the associated consequences for people, climate and environment.

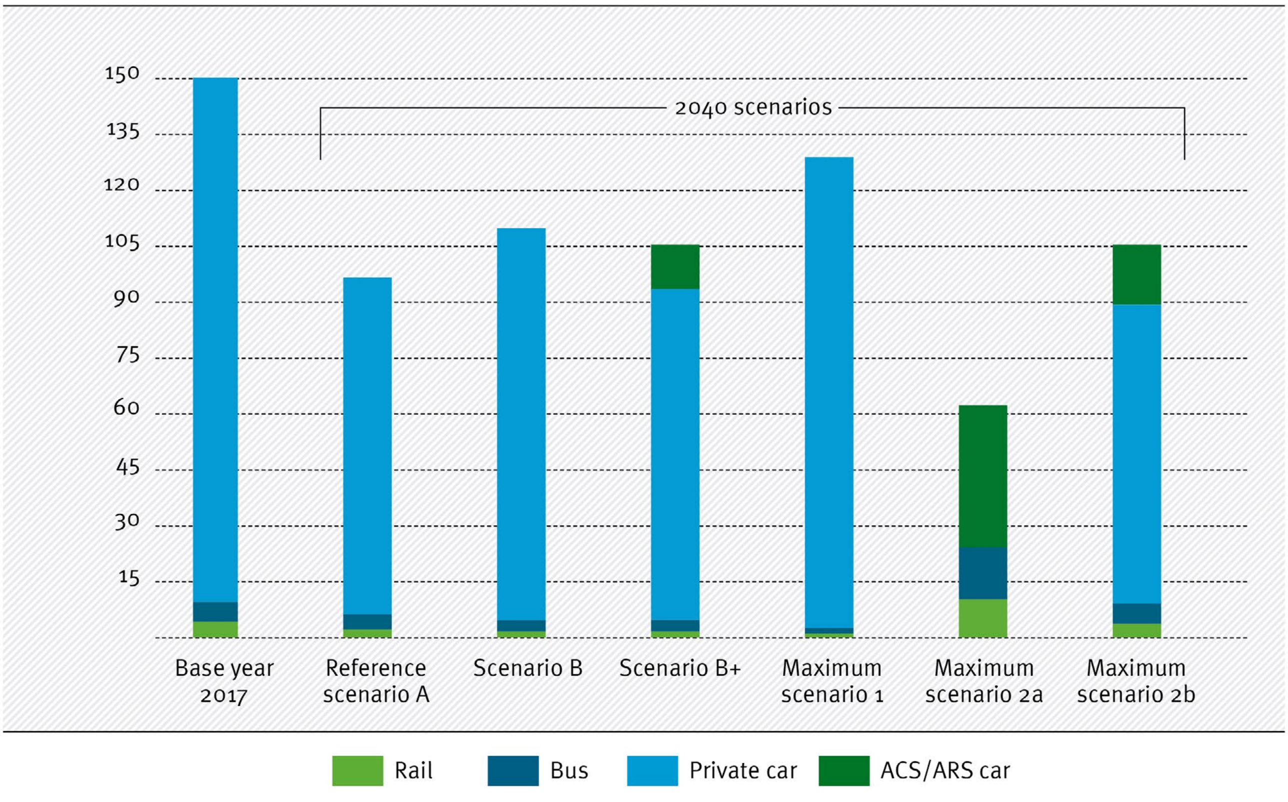
There are several reasons for increased private motorised transport in these scenarios. First, driving will become even more comfortable. Travelling by automated car means not having to steer and instead being able to read, work or watch a film. Moreover, groups will be able to use Level 5 vehicles who currently cannot, are not allowed to or do not want to drive: for example, children and young people, physically impaired persons or older people (cf. Anderson et al. 2014, Trommer et al. 2016, Zmud et al. 2017 quoted in Bruns et al. 2023). Automated vehicles will also be able to fulfil multiple travel needs at different times, e.g. by taking two people from one household to work one after the other – the teacher to school at 7:30 am and the engineer to the office at 9 am. Also to be considered are the distances driven between consecutive journeys without any driver/passengers (empty journeys).

One of the most important instruments for controlling private motorised transport is parking space management. Municipalities can significantly reduce car traffic in high-traffic districts by making parking spaces scarcer and charging parking fees. This instrument might be rendered useless in a proliferation of highly automated vehicles because automated vehicles can drive themselves to free parking spaces far away or simply cruise the streets near pick-up points. Legal regulations will be needed to prevent such practices, e.g. requiring vehicles to automatically drive to the nearest digitally indicated available parking space.

Current test vehicles already require as much energy alone for automation as for powering the drive system. Electricity is needed for sensor technology, sensor cooling, actuator technology (conversion of signals into movement) and data processing, as well as for infrastructure equipment (cf. Gawron et al. 2018, Lee & Kockelman 2019, Agora Verkehrswende 2020b quoted in Bruns et al. 2023). Reduced energy demand can only be achieved in mobility automation if the additional energy demand of the IT systems is more than offset (cf. also Agora Verkehrswende 2020b).

Figure 4

Greenhouse gas emissions in million tonnes CO_2 equivalent



Source: Thaller et al. 2023 (own translation)

Automation of motorised road traffic can improve traffic flows. Slipstream driving in convoys can save energy, and shorter distances between vehicles can increase road capacities, especially on motorways and trunk roads – but only when around 80% of vehicles are automated. Automated vehicles can also be programmed to drive at energy-optimised speeds of 70 to 90 km/h outside built-up areas, provided that appropriate regulations are in place. The combined effect of these won't, however, offset the energy needs of IT systems and the increase in private motorised transport.

In order to reduce the volume of traffic and thus energy demand without banning the use of private cars, it is necessary to achieve a transformation in transport, with people switching from private motorised vehicles to ecomobility modes of transport, rather than the other way around. New transport services such as autonomous car- and ridesharing are therefore needed. The scenarios from the 'Digitalisation of Transport' study clearly demonstrate this. However, driverless car services can only provide opportunities for reduced private car use and medium- to long-term decreases in car ownership in combination with Mobility-as-a-Service platforms (section 1C, p. 13 and cf. Fagnant & Kockelman 2015, VDA 2015, OECD &ITF 2016, Friedrich & Hartl 2016, Chen et al. 2016, quoted in Bruns et al. 2023) as well as push measures to reduce car traffic, such as time and area access restrictions for certain zones, and parking space management. However, opportunities can only be exploited when ACS/ARS trips can be sufficiently pooled and complement regular public transport services on the first and last miles, or bridge gaps in public transport networks. If they are instead used as low-cost taxis to cover entire or partial routes, they risk cannibalising regular public transport services or get used for shorter distances rather than cycling or walking.

Digital applications for supplementary mobility-related services (Section 1C, p. 13) can have positive effects, for example, by increasing the convenience of public transport via seat reservations, or by apps to locate parking spaces that will then reduce traffic volume searching for parking spaces. However, this requires that the apps do not increase the appeal of private car usage thus inceasing traffic. Municipalities can take countermeasures via parking space management and regulations on searching for parking spaces.

Participation in multi- and intermodal mobility

As mentioned in section 1C, smartphone apps have in recent years made it much easier to access car- and ridesharing services, plan routes and book and pay for public transport tickets. Nevertheless, smartphones should not be the only way to access such mobility products and services, otherwise users without smartphones will be at risk of exclusion. The authors of a study on the acceptance of Mobility-as-a-Service (cf. Bizgan et al. 2020) therefore argue in favour of providing telephone information and booking options for MaaS. Online platforms also need to be compatible with screen readers and have adaptable font sizes to ensure that visually impaired people are not excluded.

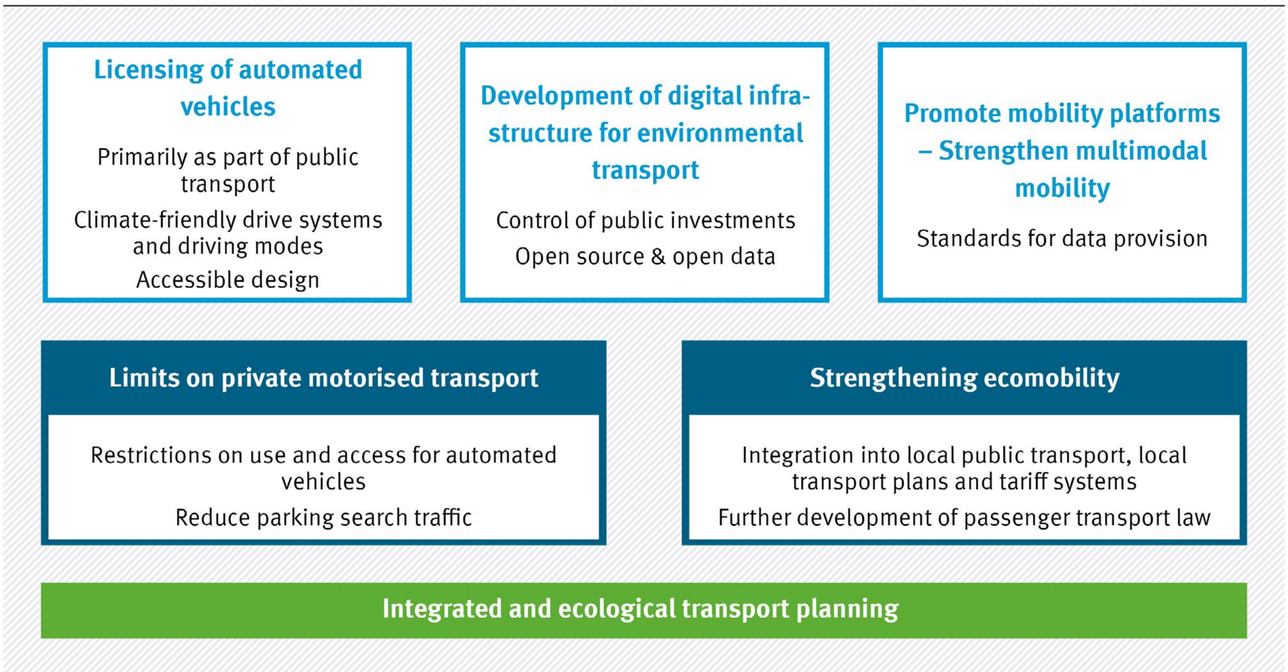
3

Regulatory framework for the digitalisation of transport

This section follows on from the opportunities and risks of increasing digitalisation in transport and looks at the need for legal changes and necessary adjustments to regulatory frameworks.

Figure 5

Making digitalisation and automation in (public) passenger transport sustainable



Source: own diagram, German Environment Agency

Transport must be more space-efficient, cleaner and more sustainable. The transport sector in Germany has not yet been able to significantly contribute to climate protection. While greenhouse gas emissions were reduced by 40.4% across all sectors from 1990 to 2022, emissions from the transport sector fell by only 9.1% (after correcting for an under-reporting of 635 kt CO_2 equivalents in coastal and inland navigation). A majority of the efficiency gains from technical innovations have been negated by rebound effects such as increased traffic and heavier cars. Legal frameworks therefore need to be reviewed to provide federal, state and local governments with a range of instruments and measures that can be used to align the transport sector with overarching goals such as improving road safety, environmental and climate protection.

The digitalisation and automation of transport is increasing the long-standing need for reform, and both developments urgently require regulation, otherwise the opportunities shown in section 2 could be squandered and the risks outlined there realised. Due to the distribution of competences at the state level, the federal government has the task of driving this regulation forward as a coordinating actor and legislator.

In reforming legal frameworks, the following points require consideration:

In passenger transport, ecomobility modes of walking, cycling and public transport must always be preferred and strengthened in contrast to private motorised transport.

- Automated vehicles can only be approved when they are guaranteed safe for all road users – especially cyclists and pedestrians.
- Additional energy demands for the required technology, both in vehicles and infrastructure, must be more than offset by the resulting savings.
- A legal specification of standards is relevant to the digital infrastructure for automated and connected driving as well as for digital applications for accessing transport modes. Such standards are discussed in more detail in the following. A consensus in society is required before any decisions can be made on establishing and/or supporting the relevant digital infrastructures by the public sector.

After completion of a two-year implementation phase starting in 2023, 15 highly automated SUVs with SAE Level 4 will be integrated into on-demand services in Darmstadt and the Offenbach districts. Image: Mobileye

At the action level, each specific case must be assessed, taking into account the advantages and disadvantages for environmental sustainability.

- New mobility services, such as driverless ride services and digital platforms providing mobility services, must be designed to promote inter- and multimodal mobility. They must in no way contribute to further increasing motorised traffic.

Actors such as the federal government, states, municipalities and their authorities can only undertake partial aspects of each of the regulations required for environmental sustainability. This won't happen on its own, but requires mutually consistent goals for sustainable development in transport and ultimately also a concerted approach to defining and implementing specific measures.

Responsible authorities must find common ways to regulate digital solutions before transport markets embark on development paths that are contrary to climate protection goals. Goal coherence therefore needs to be created both horizontally across the different areas of law, and vertically across the different legislative levels (EU, federal and state), and conflicting goals need to be identified and resolved to the greatest possible extent.

Specific components for a consistent regulatory framework for sustainable digitalisation and automation in passenger transport are presented below.

Integrated transport planning as the basis

Integrated transport planning aligns transport services and infrastructure with ecological and social goals

In passenger transport, automated and connected driving without any regulation will likely lead to an increase in motorised traffic mainly due to private car journeys as well as automated robotaxis and the associated empty journeys between travel needs (see section 2, p. 15 ff.). Regarding climate and environmental protection, private motorised transport can be managed in an ecologically sustainable manner only to a limited extent and therefore needs to be urgently reduced.

This requires the design of transport infrastructure and mobility options to be supported by integrated transport planning oriented towards ecological and social goals. Examples of such goals are improved mobility but with less car traffic and more ecomobility, increased road safety, improved air quality and reduced traffic noise.

Integrated transport planning considers all modes of transport at the horizontal level. At the vertical level, the federal, state and local governments coordinate their actions to achieve the best possible overall result. Vertical coordination across the different levels must start from the federal government. Moreover, the authorities who plan and regulate traffic, e.g. road traffic agencies, civil engineering and building regulation departments, will need to digitalise and network their processes in order to speed them up.

For automated and connected driving, optimal climate-friendly outcomes require targeted, coordinated action, such as access restrictions for robotaxis and private (automated) vehicles in congested districts, as well as the expansion of public transport services and cycling infrastructure, and payment systems for empty journeys. Digital mapping can also help to capture dynamic changes in the travel area so that automated public transport vehicles can be controlled from operation centres. Components 1 to 5 on the following pages present the required legal reforms and measures.

Legal points of reference

- German Federal Climate Protection Act (KSG)
- 'Union guidelines for the development of the trans-European transport network' (Regulation (EU) No. 1315/2013)
- Directive 2008/96/EC on road infrastructure safety management as recast by Directive (EU) 2019/1936
- Road laws of the German federal government and the federal states
- Local transport planning and design of local public transport by the respective public transport authorities, local transport laws of the states
- Land financing of transport tasks of the municipalities, federal financing of transport tasks of the states and municipalities according to Article 106a of the German Basic Law, and Article 125c(2) of the German Basic Law (Law on the Regionalisation of Public Local Passenger Transport (RegG) and law on financing municipal traffic (GVFG))

Instruments and measures

- Prepare and implement noise action plans, environmental zones, clean air plans
- Support human and financial resources for creating transport development plans and sustainable urban mobility planning (SUMP)
- Initiate governance processes between federal, state and local governments, vehicle manufacturers, technology companies and associations to jointly discuss opportunities, risks, costs and benefits for society, companies, the environment and the climate
- Issue sub-legislative guidelines, publications and recommendations to supplement existing legislation on integrated planning
- Interdepartmental coordination in municipalities for transport planning that specifically promotes a shift from private motorised transport to ecomobility, e.g. within the framework of a municipal mobility management system
- Coordinate and implement available measures from public sector actors, e.g. road authorities, licensing authorities, supervisory authorities
- Design of public road space focusing on mobility, climate protection, energy efficiency, road safety, health protection and the reduction of traffic-related land use
- Physical connectivity of ecomobility (e.g. through mobility stations, bus stops, bicycle parking)

Further information:
www.umweltbundesamt.de/themen/verkehr/klimaschutz-im-verkehr

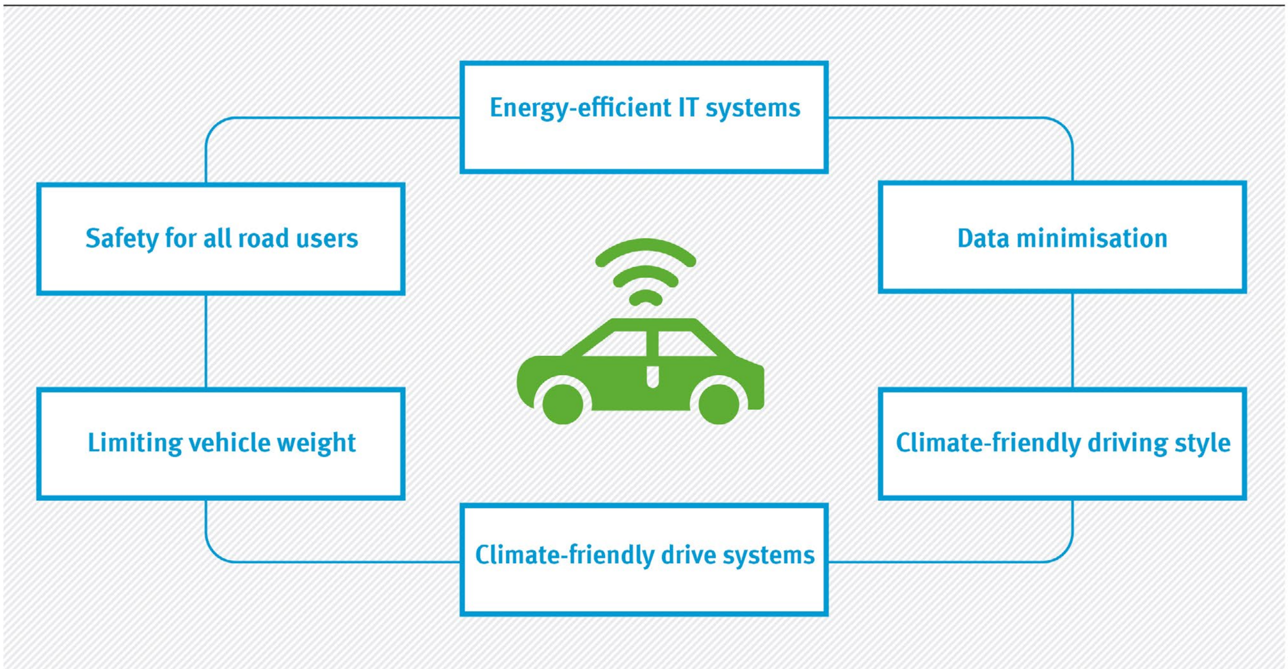
Component 1

Licensing of automated vehicles

Licensing of automated vehicles should be closely linked to how they will be used in public transport and the energy efficiency of their IT systems

Figure 6

Licensing criteria for automated vehicles



Source: own diagram, German Environment Agency

From a regulatory perspective, licensing of automated vehicles should be closely linked to their intended use. Authorities should primarily approve vehicles that are to be used as part of public transport and ridesharing services taking passengers from point A to point B.

Automated vehicles in road traffic have thus far primarily been used in experiments in tightly controlled settings e.g. as shuttle buses taking participants from an S-Bahn station to an event site at speeds of 20 km/h along low-traffic routes. Before automated vehicles are permitted to mix with conventional cars, buses and bicycles outside of test situations, the safety of all road users – including cyclists and pedestrians – must be ensured. This requires technology capable of detecting people and objects and avoiding dangerous situations, either independently or in interaction with other vehicles and infrastructure.

In the event of potential danger to other road users, vehicles must react appropriately. In mixed traffic situations, non-automated and automated vehicles should be able to communicate with each other in appropriate ways, e.g. by retrofitting or installing relevant vehicle components and by providing visual and audible signals to drivers. For the system to function, pedestrians and cyclists should not have to carry a technical device in their pockets that communicates with automated cars, buses or trucks.

Energy efficiency as a requirement for vehicle licensing

Energy efficiency should also be a criterion for automated vehicle licensing. A drive system that is greenhouse gas neutral, e.g. electric, is not the only relevant factor. IT systems in the vehicle also generate additional energy needs, which need to be kept as low as possible to achieve energy efficiency. Programmable driving modes from manufacturers also play a role. These should be energy-saving. Data collection and processing also requires energy. The systems should collect only user data that is relevant to safety and driving function, and of course to data privacy.

To compensate the additional energy demand from automation as well as from potential empty journeys to the next users or for parking space searches, legislators can, for example, impose weight limits on vehicles.

Legal points of reference

- EU and UNECE legal instruments
- Directive 2010/40/EU (known as the intelligent transport systems directive) and the delegated regulations of the European Commission based on it
- Vehicle licensing legislation and road traffic law (German road traffic law (StVG) and ordinances based on it)

Instruments and measures

- Requirements on limiting weight of vehicles
- Vehicle licensing only for fully functioning digital systems that ensure the safety of all road users, including cyclists and pedestrians
- Establishing appropriate standards for safe left turns by automated vehicles
- Specifications for technical standards for communicating with other road users – including cyclists and pedestrians – e.g. giving right of way, signalling of parking space searches, boarding and alighting, passenger changes
- Specifications or incentives for developing energy-efficient vehicles and components for automation (such as sensors, actuators and image processing)
- Specifications for efficient collection and processing of information, e.g. economy of data, priority/exclusive collection and use of safety and traffic-relevant data
- Programming specifications and implementation of environmentally and climate-protection-oriented driving modes enabled by automation and connectivity
- Specifications for defining the objective of connected driving and of a centrally co-controlled system, also from an ecological point of view
- Specifications on the sustainability of the drive systems

Component 2

Limiting negative effects of automated driving

Traffic management targeted at relieving residential areas and those with high traffic volumes

Figure 7

Access restrictions by area and time

Source: own diagram, German Environment Agency

If automated driving is not regulated, a significant increase in car traffic can be expected, for example, due to empty journeys (see section 2, p. 15). Road safety and air quality would then be negatively affected, and traffic noise would increase. It would also be harmful to the climate and the environment, and would consume additional resources and space. Space is scarce in cities, and moving and stationary car traffic already takes up an inordinate amount. Space is not only often lacking for adequate footpaths and cycle ways, but also for outdoor restaurants, for children to play and especially for plants, which play a key role in mitigating climate change impacts in cities. It is therefore necessary to reallocate road usage. This requires reducing road traffic. Among the most important current-day measures being taken by municipalities to limit motor vehicle traffic and the associated demand for space are making parking spaces scarcer and imposing parking fees. Parking management can also be used to manage automated vehicles – but it is a double-edged sword: if parking spaces are made scarcer, driverless car users might simply let their vehicles cruise the area until pick-up time. Such practices must be prevented and various measures can be taken by public authorities to counteract these and similar risks.

Municipalities can reduce the number of parking spaces in urban land use planning and at the same time charge for empty journeys or, for example, refuse vehicles entry to certain urban areas unless passengers have already reserved a local parking space. Temporary restrictions on (automated) private cars to congested roads or districts, managed by adapatable road sign systems, are also conceivable. This would require a legal basis to be created, for example, by adding a number 7 to Section 45(1) of the German road traffic regulations (StVO), which allows road traffic authorities to exclude certain types of vehicles from using a road or an area in order to reduce traffic. Section 45(9) (3) of the StVO would then require repeal to ensure that the new number 7 would not be blocked.

On whether a zone is deemed congested should be decided by the road authority, for example, based on comparative values of similar roads, safety and planning requirements of local authorities (e.g. local transport plans, transport development plans or – where applicable – climate mobility plans). The authority could be granted appropriate competences by adapting the administrative regulation for the StVO (VwV-StVO). Towns and municipalities would also need to determine who is always permitted access, such as doctors, postmen an -women or residents who have parking spaces available for their vehicles. Restrictions on car traffic must not, however, restrict people's access to a district or road. Municipalities therefore need to ensure that restricted access zones are well connected to bus or train lines and that parking spaces for cars are available on the outskirts of such areas.

One way of preventing unwanted traffic through residential neighbourhoods is Barcelona's well-known superblock approach. One-way streets and bollards and planters are installed to make it impossible for cars to drive through residential areas. The neighbourhood remains accessible to pedestrians and cyclists. Targeted promotion of driverless electric cars could lead to more people buying private cars than using ecomobility options. This also applies to digital applications that could stabilise or increase the attractiveness of private car journeys or less efficient transport services. Automated cars travelling with shorter distances between them might lead to more efficient use of space, but with rebound effects. For example, fewer traffic jams could mean more people willing to use their cars. Any progress here would also require a need to impose restrictions on private motorised vehicle usage.

Legal points of reference

- Traffic law orders according to German road traffic law (StVG and ordinances based on the StVG)
- StVO, in particular Section 45
- of the VwV-StVO, e.g. Sections 39 to 43
- Extension of the scope of Sections 1d to 1l of the StVG in conjunction with AFGBV – autonomous-vehicle licensing and operation ordinance (consideration of climate protection)

Instruments and measures

- Extension of the scope of road traffic law to include ecological objectives with corresponding authority to issue orders (amendment of Section 6(1) of the German road traffic law (StVG) and Section 45 of the German road traffic ordinances (StVO)
- Addition of a basis for authorising restrictions on the use of and access to privately used (automated) vehicles in congested areas or at certain times through the addition of a new No. 7 to Section 45(1) (StVO)
- End the preferential treatment of moving (car) traffic, repeal Section 45(9)(3) of the StVO
- Exclusive use of public road space for automated public transport and excluding private motorised transport on certain routes at certain times
- Regulations on maximum parking space search radius for automated valet parking, City Pilot and Level 5 applications
- Mileage-based levy for empty journeys
- Regulations/prohibitions on drop-offs/pick-ups in "hotspot" areas to prevent traffic congestion and conflicts with ecomobility options

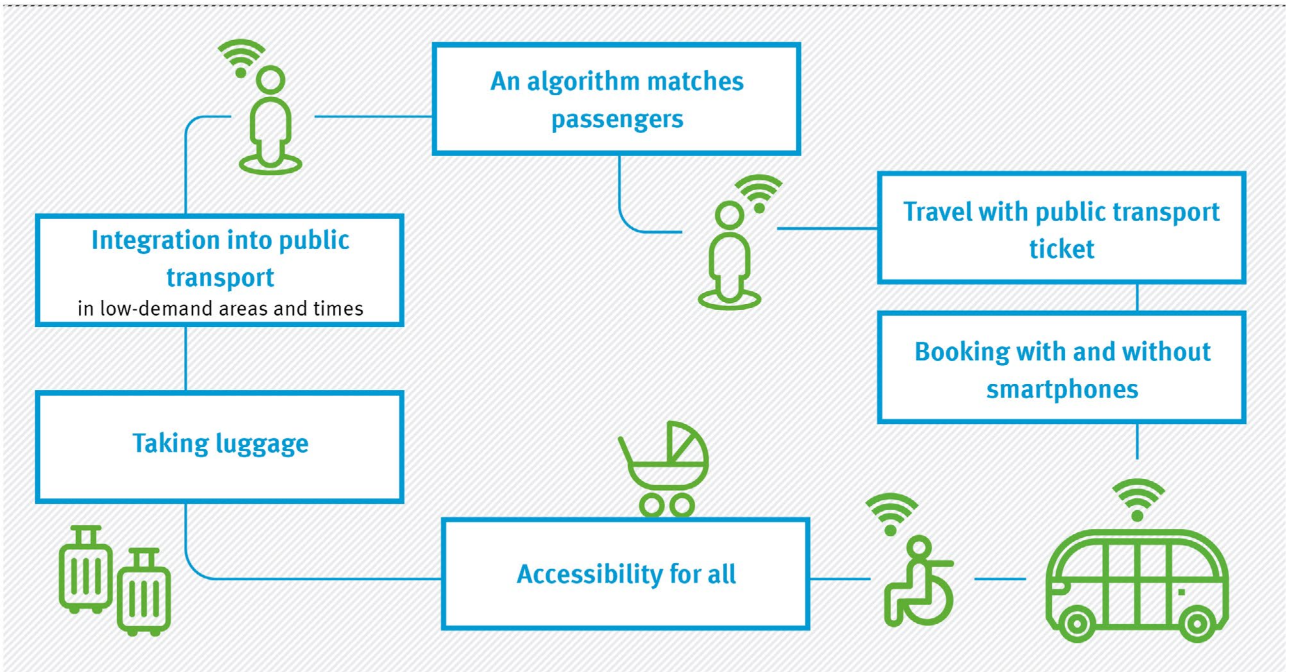
Component 3

Strengthening ecomobility

How integration of automated driving into public transport can succeed

Figure 8

Ridesharing in public transport standard



Automated ridesharing services must be accessible to all.

Source: own diagram, German Environment Agency

Digitalisation of transport provides opportunities to strengthen ecomobility in targeted ways, thereby reducing car traffic and enabling people to enjoy the same level of mobility as they do today. This would also protect the climate and improve road safety and air quality. Traffic noise, space and resource requirements would be reduced.

To strengthen ecomobility, federal, state and local authorities need to create a nationwide, inter-linked public transport system for both long- and short-distance travel with good connections to cycling and walking networks. The system's backbone will continue to be buses and trams, which will be increasingly automated and supplemented by automated, public transport standard ridesharing services.

Public transport standard means that ridesharing services may be used with public transport tickets for the appropriate tariff zone and that no one is excluded from using them. Alternatives to booking via an app must be available for people without smartphones, vehicles must be accessible for people with reduced mobility and families must be able to take prams. Transporting luggage and bicycles should also be possible. It is also important that ridesharing services are reliable during off-peak hours and not only during lucrative rush-hour periods.

In low-demand areas and times, economic operation of automated ridesharing services may not always be possible. Pooling journeys and avoiding empty journeys may also be limited at times. It can nevertheless still make sense to set up a service, e.g. to enable people in rural areas to become less dependent on private cars and thus discourage them from buying a second car. Various options are available here. The public sector could either establish its own ridesharing service as part of the public transport services, or provide incentives for commercial operators to set up a service, for example, by awarding concessions for lucrative service areas as packages including less attractive areas in rural regions. In lucrative, generally more densely populated areas, however, there is a risk of the cannibalisation of ecomobility.

Commercial public transport services often have high barriers to entry. They can often be used only by users of smartphone and credit cards, who can create customer accounts and are of a certain minimum age. They are therefore not necessarily congruent with public transport services. The state must then impose requirements on providers to ensure the quality of public transport.

Legal points of reference

- Land financing of transport tasks of the municipalities, federal financing of transport tasks of the states and municipalities according to Article 106a of the German Basic Law, and Article 125c(2) of the German Basic Law (Law on the Regionalisation of Public Local Passenger Transport (RegG) and law on financing municipal traffic (GVFG))
- Transport business law, in particular passenger transport law
- Local transport planning and design of local public transport by the respective public transport authorities, local transport laws of the states

Instruments and measures

- Creation of a nationwide, short-interval public transport system in which ridesharing provides feeder services for buses and trains; systematic further development of service quality in transport networks for ecomobility (analogous to the guidelines for integrated network design, RIN 08 of the German Road Traffic Association (FGSV))
- Specifications on passenger pick-ups (preference for ridesharing over commercial ridehailing)
- Universal access, e.g. for wheelchair users, families with prams and commuters with bicycles
- Creation of options for booking without a smartphone and payment without a credit card
- Development of recommendations on implementing automated and connected vehicles
- Subsidies for services, for example, via concession models in low-demand areas
- Communication and information measures that increase the uptake of public transport

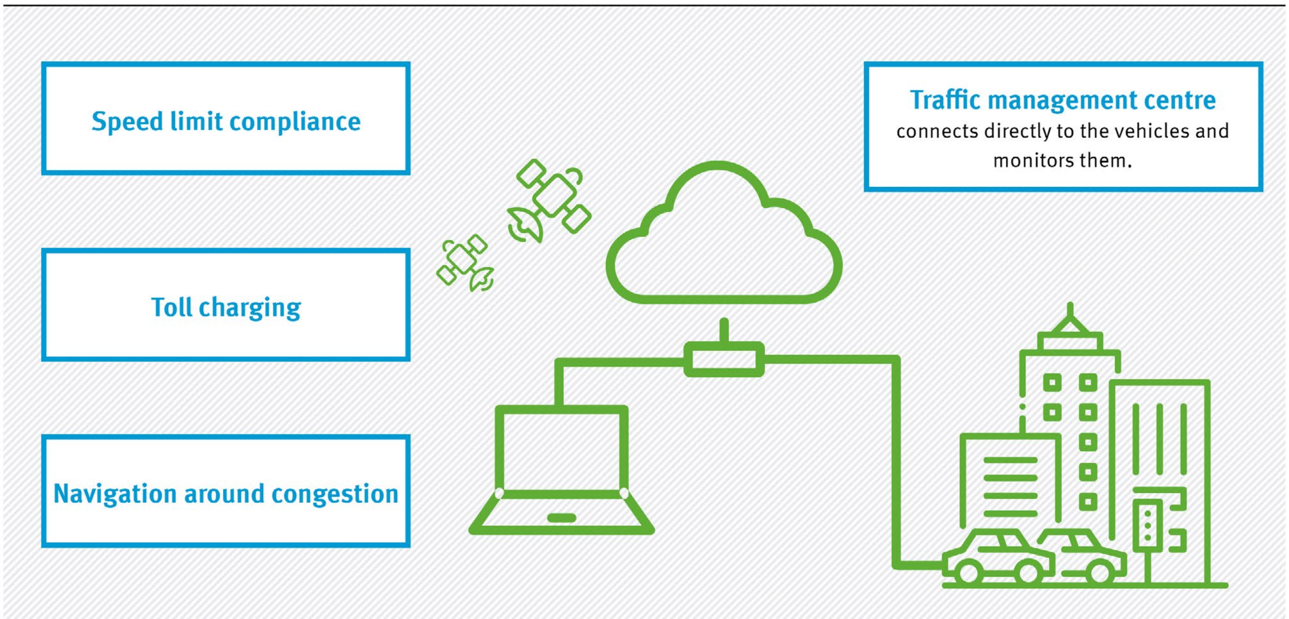
Component 4

Digital infrastructure

When creating digital infrastructure for automated and connected vehicles, the focus must be on the needs of ecomobility

Figure 9

Managing vehicles via digital infrastructure



Source: own diagram, German Environment Agency

Before the public sector can invest in or subsidise the upgrading and retrofitting of the necessary transport infrastructure for automated and connected driving, social consensus is required and infrastructure must primarily be used for sustainable traffic management. Sustainable traffic management can be used for example, to:

- Enforce compliance with road traffic regulations
- Charge a toll for driving on certain categories of roads or in certain zones and thereby create a financial incentive to switch to ecomobility
- Undertake traffic management of automated vehicles via a traffic management centre that promotes ecologically sustainable driving modes
- Relieve specific roads and areas via route selection suggestions

Before introducing digital traffic management, it is necessary to clarify who has overall and local responsibility for financing, setting up and operating the required digital infrastructure. This is not easy to clarify because digital infrastructure is closely linked to municipal, district, state and federal roads, which are the responsibility of municipalities, states and the federal government, respectively. There is a lot to be gained therefore in setting up a superordinate, central office.

As well as delineating tasks within the public sector, the exact scope of tasks in relation to the operators of automated vehicles must also be defined. There needs to be clear delineation between technical oversight, which operator's centre can access vehicles, and the overarching public digital infrastructure.

Legal points of reference

- Road laws of the German federal government and the federal states

Instruments and measures

- Development of adequate mobile communications infrastructure, especially 5G
- No public investment in digital infrastructure that primarily or exclusively benefits private motorised transport

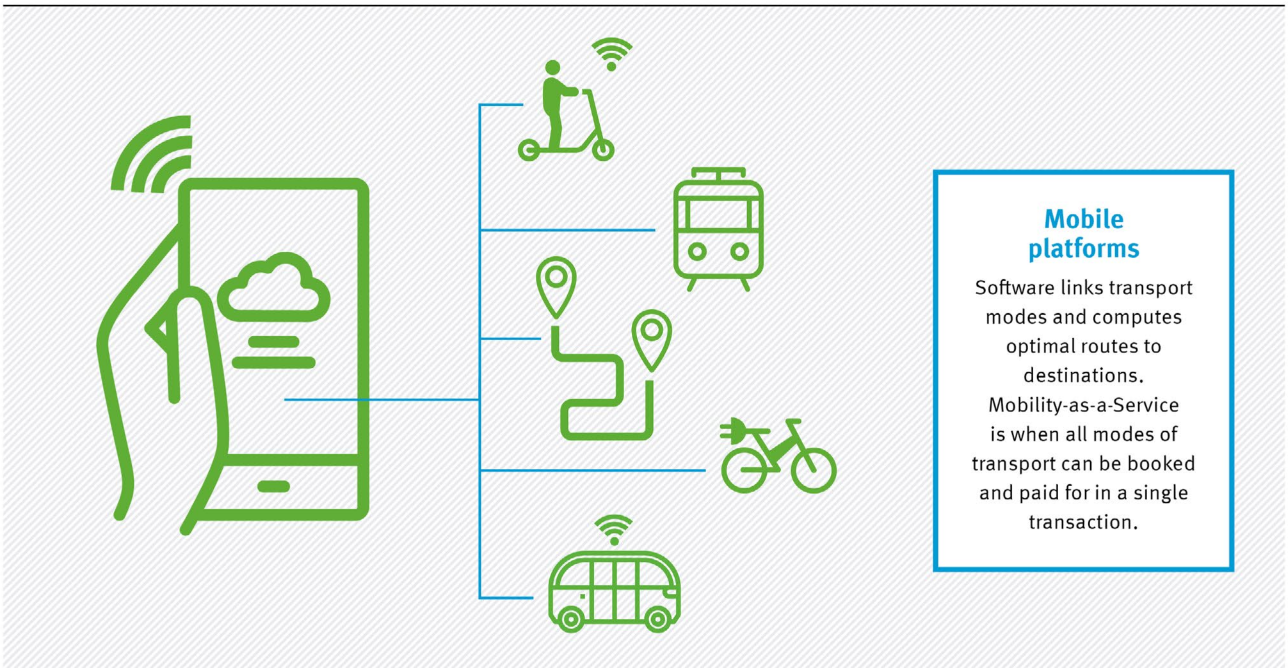
Component 5

Mobility platforms and Mobility-as-a-Service

Enabling Mobility-as-a-Service through uniform standards and interfaces as well as open data and open source approaches to the provision of data

Figure 10

Booking platforms for multi- and intermodal mobility



Source: own diagram, German Environment Agency

A wide range of mobility apps are available to download to smartphones. Behind these apps are new digital, platform-based business models. They pool and facilitate access to a variety of transport modes – from rental bikes and buses to trains and ridesharing vehicles.

When providers develop their products into 'Mobility-as-a-Service' platforms (MaaS, cf. development line C, p. 13), which make it easy to plan and book entire journeys using different modes of transport – opportunities arise to shift traffic from private motorised transport to ecomobility. Digital mobility platforms can then contribute to climate protection, land and resource conservation as well as air pollution control and noise abatement. In the longer term, MaaS could also make personal ownership and use of resource- and energy-intensive private vehicles obsolete.

To enable MaaS applications, the sharing of a wide range of mobility data must be ensured, in particular timetable data, real-time data, distribution data and mobility data from rural regions. Initiatives to improve the supply of data and data networking already exist, for example, Mobilithek from the German Federal Ministry for Digital and Transport (BMDV) and the Mobility Data Space from DRM Datenraum Mobilität GmbH. An improvement in the data situation is therefore to be expected in the coming years. However, numerous legal questions still require clarification, especially regarding data provision and collection obligations as well as data access for third parties and funding issues (also see p. 14).

However, if digital mobility platforms increase the attractiveness of private car use (e.g. by brokering private parking spaces) or increase the use of a less efficient transport service (e.g. taxi-like transport services), they will counteract the required modal shift to ecomobility. Digital mobility platforms do therefore not contribute per se to environmental sustainability in transport, but only when they fulfil certain criteria.

Legal points of reference

- Law on the Regionalisation of Public Local Passenger Transport (RegG)
- Transport business law, in particular passenger transport law
- Local transport planning and design of local public transport by the respective public transport authorities, local transport laws of the states
- Mobility data regulation pursuant to the passenger transport act

Instruments and measures

- Restrictions on providing mobility or additional services that have a lasting impact on environmental sustainability
- Avoiding any shift from cycling and walking to platform-mediated motorised transport (especially taxi-like services), e.g. by setting a minimum transport distance
- Preventing private parking space brokerage through digital apps
- Defining relationships between mobility providers and operators/intermediaries on mobility platforms
- Preventing one or just a few, especially private sector operators of mobility platforms from holding a dominant position in the market so as to avoid any transport pricing or supply pressure from platform operators to providers
- Equal access: booking of mobility services must also be possible via analogue ways
- Granting of licences/concessions or public procurement of mobility platforms
- Standardisation of communication technology and of message protocols as well as of interoperability between automated vehicles
- Mandatory standards for interfaces (data exchange formats and protocols) and frequency bands (standardisation for software, licensing for on-board hardware)
- Enabling open data and open source approaches to providing and sharing data: ensuring accessible and non-discriminatory provision of mobility services and enabling further use and analysis of generated data for non-commercial, public benefit purposes, such as sustainability-oriented infrastructure and transport planning
- Data minimisation: only safety and traffic-related data is collected

List of sources

Agora Verkehrswende (2020a): Auto tankt Internet: Auswirkungen des automatisierten und vernetzten Fahrens auf den Energieverbrauch von Fahrzeugen, Datenübertragung und Infrastruktur.

Agora Verkehrswende (2020b): Die Automatisierung des Automobils und ihre Folgen. Chancen und Risiken selbstfahrender Fahrzeuge für nachhaltige Mobilität.

Anderson, J. M.; Nidhi, K.; Stanley, K. D.; Sorensen, P.; Samaras, C. & Oluwatola, O. A. (2014): Autonomous Vehicle Technology: A Guide for Policymakers [Online], Santa Monica, Rand Corporation, www.rand.org/pubs/research_reports/RR443-2.html.

Bizgan, Lore; Hollings, Polly; Reynolds, Matt (2020): Mobility as a Service – Acceptability Research, Department for Transport.

Bruns, F.; Straumann, R.; Nobis, C.; Winter, M.; Kolarova, V.; Karl, A.; Burgdorf, C.; Werner, J.; Frölicher, J.; Regling, L. (2023): Final report on the digitalisation of transport. Vorschläge für Regelungskonzepte und Rahmenbedingungen zur Realisierung einer nachhaltigen Mobilität, German Environment Agency (publisher), 3718 58 1000

Chen, T. D.; Kockelman, K. M. (2016): 'Management of a Shared Autonomous Electric Vehicle Fleet: Implications of Pricing Schemes', Transportation Research Record: Journal of the Transportation Research Board, Vol. 2572, No. 1, pp. 37–46.

Fagnant, D. J.; Kockelman, K. (2015): Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations, Transportation Research Part A: Policy and Practice, Vol. 77, pp. 167–181.

Friedrich, M.; Hartl, M. (2016): MEGAFON – Modellergebnisse geteilter autonomes Fahrzeugflotten des öffentlichen Nahverkehrs: Schlussbericht

Gawron, J. H.; Keoleian, G. A.; Kleine, R. D. de; Wallington, T. J.; Kim, H. C. (2018): Life Cycle Assessment of Connected and Automated Vehicles: Sensing and Computing Subsystem and Vehicle Level Effects, Environmental science & technology, Vol. 52, No. 5, pp. 3249–3256.

Lee, J.; Kockelman, K. M. (2019): Energy implications of self-driving vehicles, 98th Annual Meeting of the Transportation Research Board in Washington, DC. 2019.

Lichtblau, K.; Kempermann, H.; Bähr, C.; Ewald, J.; Fritsch, M.; Kohlisch, E.; Zink, B.; Albert, F.; Herrmann, F.; Stegmüller, S.; Bickenbach, D.; Lämmer-Gamp, T.; Vogelskamp, S. A. (2021): Zukunft der Automobilwirtschaft in Nordrhein-Westfalen. Status quo, Trends, Szenarien, im Auftrag des Ministeriums für Wirtschaft, Innovation, Digitalisierung und Energie des Landes Nordrhein-Westfalen.

OECD; ITF (2016): Shared Mobility: Innovation for Livable Cities.
SAE International (2018): Surface vehicle recommended practice – Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles. USA; J3016_201806.

Thaller, C.; Blechschmidt, J.; Deineko, E.; Fremder, L.; Galich, A.; Hettich, G.; Kirsten, S.; Liedtke, G.; Winkler, C.; Vortisch, P.; Zeidler, V.; Heidt, C.; Helms, H.; Kraeck, J. (2023): Final report on the digitalisation of transport. Potenziale und Risiken für Umwelt und Klima, UBA (publisher) 2023, 3716 58 1030

Trommer, S.; Kolarova, V.; Fraedrich, E.; Kröger, L.; Kickhöfer, B.; Kuhnimhof, T.; Lenz, B.; Phleps, P. (2016): Autonomous Driving: The Impact of Vehicle Automation on Mobility Behaviour. ifmo – research institute of BMW.

VDA (2015): Automatisierung. Von Fahrerassistenzsystemen zum automatisierten Fahren. VDA Magazin. VDA – Verband der Automobilindustrie e. V.

Zmud, J.; Green, L.; Kuhnimhof, T.; Le Vine, S.; Polak, J.; Phleps, P. (2017): Still going … and going: the emerging travel patterns of older adults. Ifmo – research institute of BMW.

▸ **Download our brochures**
link: bit.ly/2dowYYI