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The Autonomous Gap

Environmentally, Economically, and Socially Sustainable?
The Aspirations and Reality of Autonomous Mobility Concepts in Europe, China, and the USA.

11 2022

Let’s talk Data

Inhalt

Key Findings and Future Predictions

72 %

A transport transition through autonomous mobility – 72 per cent of people can imagine replacing their own car.

Quote from automotive OEM: Widespread sustainability effects will only become apparent if the transport transition is successful and people no longer use their cars.

→ Car manufacturers and suppliers should slowly but surely prepare themselves for a time of lower car sales and discover new business models in the context of shared mobility.

→ Further information on p. 44

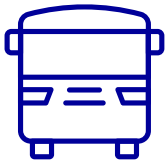
24|7

Mobility – Europe is striving for improved and more sustainable mobility for all.

Quote from mobility start-up: Autonomous driving is the game changer for public mobility services in rural areas.

→ Car manufacturers and suppliers should develop autonomous vehicle concepts specifically for the requirements (e.g., equipment, functions, quantities) of public transport.

→ Further information on p. 53



Public transport 2.0 – how autonomous mobility can be a second chance for American public transport.

Quote from business model expert: IT companies could take on the role of public transport operators in the USA and completely reshape public mobility.

→ Car manufacturers, IT corporations, and mobility providers must identify where autonomous transport services that resemble public transport can be operated in the USA and develop appropriate business models.

→ Further information on p. 94

Chinese commuting - China's desire for comfortable autonomous mobility to and from work.

Quote from automotive OEM: In the analysis of users, it became clear that Chinese users primarily want sole, personal use of autonomous vehicles.

→ Car manufacturers and suppliers should develop strategies, technologies, and concepts for operating autonomous vehicles used individually in times when the issue of mixed traffic is yet to be resolved.

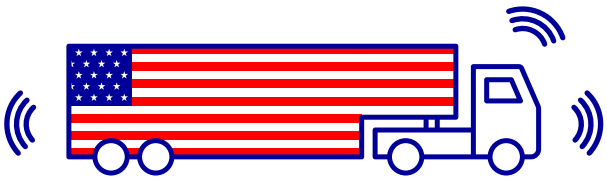
→ Further information on p. 68 and p. 98

From a silver bullet to a nonstarter? Small, autonomous, urban vehicles will only play a complementary role.

Quote from business model expert: Small, autonomous vehicles will not be a widespread mobility solution, but could be used in later phases as a complement to autonomous ride-sharing services.

→ Car manufacturers and mobility providers should in general identify the specific conditions under which the use of small, autonomous vehicles is sensible and viable.

→ Further information on p. 103

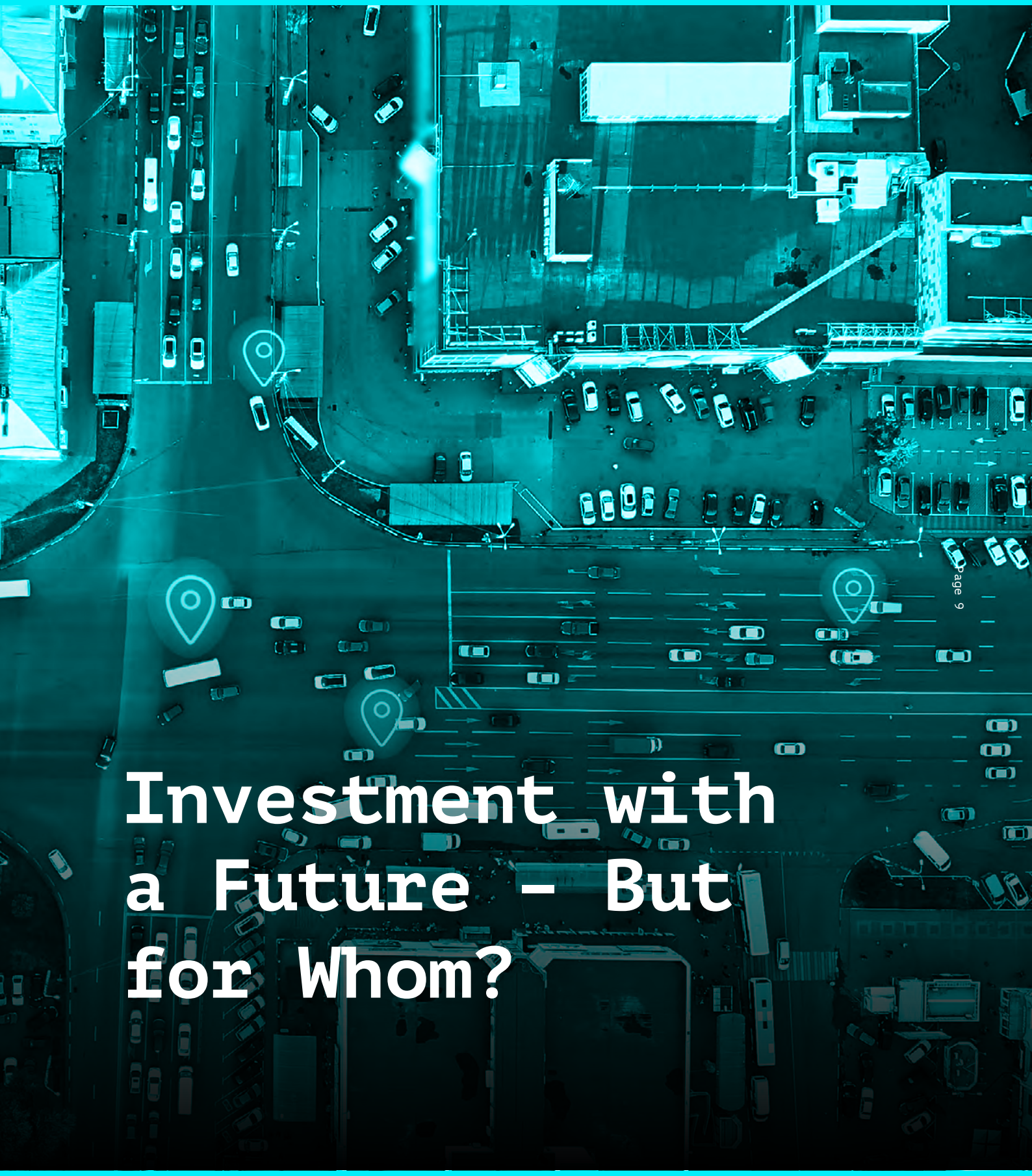


The end of the lonesome cowboys - autonomous trucks conquer the United States.

Quote from automotive OEM: American truck drivers are old, rare, and expensive - autonomous trucks will be necessary to cover the logistics requirements. The conditions for their use are good and business models are plausible.

→ Truck manufacturers and suppliers should define in concrete terms the areas of application and use cases for which their technologies should be designed and develop supporting TaaS concepts.

→ Further information on p. 12



Investment with a Future – But for Whom?

Autonomous driving – more than a question of automotive development

By switching from cars that are mostly privately owned and human-driven to shared autonomous systems, a completely new network of added value is created that opens up opportunities for established car companies and new stakeholders. Roles that until now have largely been taken over by the users themselves will need to be fulfilled by other stakeholders, such as those relating to maintaining and refueling/charging the vehicles or relating to driving operations, such as monitoring or parking. In addition, further growth potential may arise in relation to secondary activities or internal integration. Furthermore, technological growth markets are emerging. For example, ICT infrastructure or cloud services and the robust availability of these services are taking on new significance, as their reliability is of relevance for vehicle control and navigation. In an ideal scenario, a distinction can be made between different roles in the new value-added network, whereby specific stakeholders can also assume several roles:

Stakeholders in the ecosystem of autonomous mobility

Automobile manufacturers conceptualize, design, manufacture, and distribute the vehicles and try to design them in the most user- and operator-friendly way possible. They are responsible for the integration of the technologies and functions of the suppliers and thus the capabilities of the vehicles with regard to automated driving.

Fleet operators (hardware) are responsible for procuring and insurance as well as the maintenance and cleaning of the vehicles and for the availability of the fleets in service operations.

Operations control centers are responsible for monitoring the vehicles during driving operations and for taking any necessary action to handle faults remotely.

Mobility providers (software) represent the interface with the end customer. They provide app-based services that can be used to book, manage, and charge for travel. In addition, their algorithms enable the most efficient combination of different driving requests in the case of ride sharing, taking into account the customer's comfort.

Service providers integrate their end-customer-related services that go beyond the actual mobility solution into the service bundle and vice versa. This may include offering their own services in the vehicle or linking them with route information, as well as integrating mobility services into their own service platform.

Cloud operators are responsible for ensuring that the availability of data and computing operations for handling the services, travel monitoring, and – if applicable – connected fleet and driving maneuvers remains robust and reliable.

Communications technology companies, on the other hand, guarantee that a stable communication link is provided between vehicles and cloud services.

The market potential of the various roles and stakeholders differs depending on the mobility concept envisaged, the actual (road) infrastructure, addressed user groups, and use cases as well as global markets and their general conditions and stakeholder structures. The following study therefore presents a forecast of realistic connected and automated mobility concepts of the near future.

Quo vadis, automotive industry? Mass producers or solution providers?

Autonomous mobility is not only characterized by the emergence of new stakeholders, but can and must in the long term also mean the increasing abandonment of privately owned and individually used cars. Seventy per cent of the users surveyed in the study can imagine replacing their own vehicle with autonomous mobility solutions in the future. The experts surveyed, however, agree that the anticipated and desired impact on environmental sustainability can only be achieved through shared vehicles. The conventional automotive industry is therefore facing the difficulty of changing its underlying business models from scale-oriented sales of vehicles for end customers to the B2B business of smaller sales volumes or even the independent operation of transportation solutions. The opportunities and potential for repositioning in the competitive environment are strongly dependent on the respective regional market.

Europe: ride sharing as the basis for hybrid value creation

In Europe, larger, autonomous shuttles or specific autonomous ride-sharing vans are expected in the future. As the people movers differ significantly from passenger cars and their operation is largely integrated into public transport structures with regard to procurement, maintenance, operations, and user access, opportunities mainly exist for suppliers with regard to automation technologies and for commercial vehicle manufacturers with regard to the sale of vehicles. From a car-oriented perspective, however, the ride-sharing market is an interesting prospect that is operated by many regional or local suppliers, each of whom requires very specific vehicles. In addition to the individual equipment of the vehicles, as well as user- and operator-oriented equipment, there is also potential with regard to the technology-oriented design of the routes, monitoring of the vehicles, usage-dependent sales models, and the insurance included with the vehicles via captives, as well as with regard to monitoring them while driving and offering user apps as white-label solutions. Car manufacturers can thus become integrated solution providers of hybrid services between hardware sales and service business for regional operators by bundling the aspects in a solution-oriented way and by integrating additional, specific stakeholders into their own new ecosystem.

China: a focus on strengths

The Chinese market is strongly dominated by domestic stakeholders in terms of both new vehicle concepts and service platforms. In contrast, the strong customer demand for individual premium mobility in China can open up the opportunity for established (premium) automobile manufacturers to build on their existing capabilities and further develop their comfort- and quality-oriented vehicle products toward autonomous driving. In addition to the quality- and end-customer-oriented mindset, advantageous core competencies also lie in the fundamental orientation as a system integrator – for example, both the cloud services of the operators and the V2X information provided by local infrastructure operators must be integrated homogeneously into the vehicle and software in order to facilitate autonomous driving functions or even enable them in the first place. In addition, the existing after-sales service network for privately used or leased passenger cars could be further developed with regard to the fleet business..

USA: transformation potential of TaaS

In the USA, the lack of functioning public transport structures creates a gap when it comes to the role of the mobility provider. However, domestic service and IT companies have already positioned themselves strongly in this respect and could integrate mobility into their service platforms in the future. However, they need support not only in the provision of the vehicles, but also in the maintenance and operations control of the vehicles. With regard to passenger transport, various vehicle concepts seem conceivable, from simple, small vehicles to comfort shuttles or large, tram-oriented public transport vehicles, which are expected to co-exist. The attractiveness of the market for established manufacturers lies above all in comfort shuttles, and for commercial vehicle manufacturers in the market area of autonomous minibuses. On the other hand, an early market is already emerging in the field of autonomous long-distance logistics. This gives car manufacturers the opportunity to position themselves as complete transport-as-a-service providers for autonomous delivery services and, in addition to vehicle provision, take over their route selection and operations control, as well as operation and maintenance if applicable, or purchase these from local truck fleet operators so that the logistics customer that posts the transport quotas only has to determine the times of inward delivery and outward delivery.

Autonomous Mobility at a Crossroads?

“Self-driving cars will enable car sharing even in spread-out suburbs. A car will come to you just when you need it. And when you are done with it, the car will just drive away, so you won’t even have to look for parking.”

Ten years ago, entrepreneur and former Google Vice-President Sebastian Thrun described the advantages of autonomous mobility in concise terms (Thrun, 2011). Today, these advantages are more relevant than ever: Autonomous mobility is seen as the next revolution in the automotive industry. It will not only have a huge impact on us as drivers, but will transform traffic as we know it today (Lu et al., 2020; Kockelman et al., 2017; Zmud & Sener, 2017). Shared autonomous mobility has more than just the potential to reduce individual vehicle ownership and thereby lower emissions (Friedrich & Hartl, 2017). It can guarantee mobility as a general service and connect areas that are currently isolated and do not have access to public transport systems (Walters et al., 2022). In the logistics sector in particular, new business and operating models are expected in which the rising costs for drivers can be eliminated and regulations can be adhered to (Willems, 2021). Ten years ago, there was a major wave of euphoria in which both the automotive industry and IT companies tried to outdo one another with announcements of future autonomous driving concepts, and start-ups were created that aimed to influence or even win the race for autonomous driving with their own technological developments. Transport and delivery companies entered these projects and hoped to optimize or even revolutionize their business models in the near future. Private pilot projects and test fleets were launched, as well as international test fields. It was not just companies but entire countries that seemed to have joined the race against each other.

“So, I believed in the past that the renewable energy cars or the smart cars would always been driven by the government or industry or OEMs. But just in the last two years it was more like driven by the product and the user experience by the customer himself.”

Hao Fei, CEO Banma Network Technologies

Some ten years later, this “R&D power” can still be felt, but autonomous mobility solutions have so far only been used under very limited conditions at the prototype level. In the meantime, research and development work has focused in particular on the requirements for autonomous concepts on the part of potential users (Niculescu et al., 2017; Stegmüller et al., 2019; Woodman et al., 2019). There are a number of studies and projects that focus on the ideal autonomous mobility concepts and their design. However, these requirements

are often at odds with the types of use and early market entry scenarios predicted by experts. The following study therefore deals with this gap between user requirements and technical and economic feasibility assessments by international experts. The gaps between aspirations and reality that have been identified provide information on the potential for viable business models in the area of autonomous mobility. Based on a large-scale, international online survey in the markets of Europe, China, and the USA with a panel that was representative of the population as well as validation by qualitative, international expert interviews, an analysis was made of where the development of autonomous mobility stands today, how to assess future potential, what contribution it will make to sustainability, and at what points a gap exists between vision, technical limitations, and customer requirements. From the insights gained, it is possible to determine which concepts have interesting future potential in the different regions under consideration.

Autonomous mobility in 2022

Autonomous mobility is one of the most prominent and controversial topics in the debate on the mobility of the future. One of the main reasons for the great interest in society is not only the technological progress in itself, but the expectation of a massive generation of added value for passengers. Autonomous mobility will be able to significantly enhance the user experience, since the most diverse needs and requirements of the mobile person can be addressed. The spectrum ranges from general requirements such as on-demand transport, basic needs such as eating, drinking, or sleeping while traveling, opportunities for interaction, communication, entertainment, or information reproduction, to the most extensive benefits for productive work or physical well-being (Becker et al., 2018; Dungs et al., 2016).

On the part of users, it is foreseeable that automation will give mobility a new significance. Motorized private transport is becoming more expensive for the individual as well as for the economy as a whole and will be reduced (starting in the inner cities). As a result, the need for private ownership is increasingly being questioned in relation to the needs-based use of shared mobility services.

Future-proof, strategic decisions need to be taken in order to build up the necessary development skills in companies and to critically rethink the hardware and, above all, software architecture of today's vehicles with a view to their future application. The market environment of traditional enterprises in the mobility sector is being penetrated by new competitors. Stakeholders need to adapt to changes in existing value chains and, as a result, identify the need for alternative business models and strategic partnerships in a timely manner.

As illustrated in the following figure, traditional vehicle concepts are being transformed into comprehensive mobility concepts consisting of hardware (the actual vehicle) and software (mobility services in and around the vehicle). The consumption of mobility is processed and organized digitally within ecosystems. In the course of its earlier research, the Fraunhofer Institute identified four stereotypes of autonomous mobility concepts for passenger transport. These differ firstly in terms of the vehicle dimension and secondly in terms of their use as a private or shared vehicle.


EXPO 2020
People Mover
SER
RTA
DUBAI bus
2423

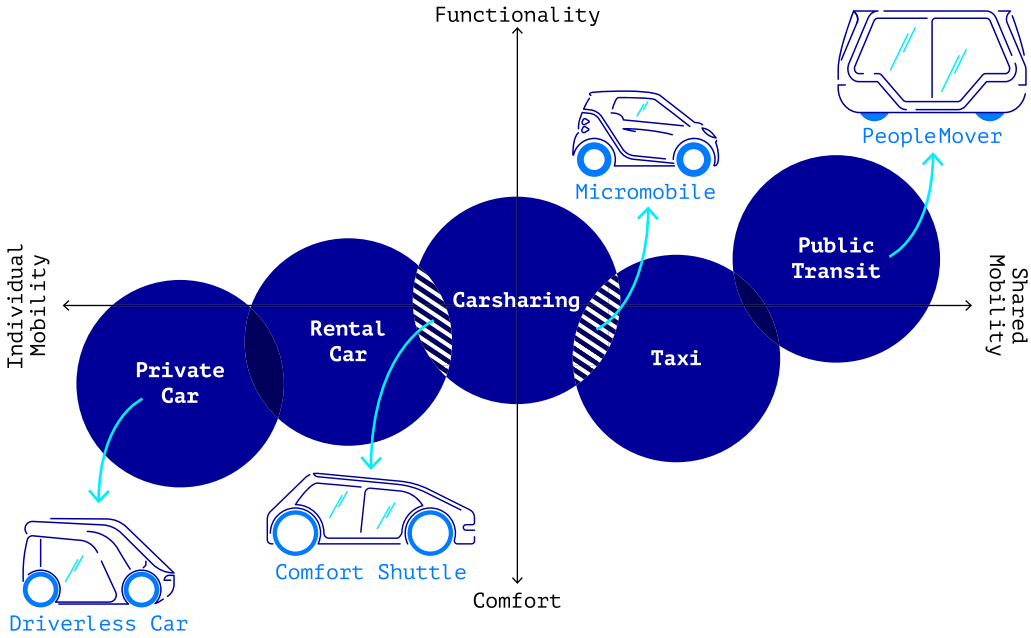


Figure 1: Example of the classification of autonomous mobility concepts based on equipment and purpose (Stegmüller et al., 2019)

Accordingly, as a concept for individual mobility, the driverless car is equipped with a correspondingly comfortable interior, whereas the people mover intended for use in public transport is primarily designed for functionality in the passenger compartment. In addition, two mixed forms were identified that are conceivable for both exclusive and shared use. The larger comfort shuttle is similar to the use of a car rental today and the micro vehicle as a particularly small vehicle for urban areas is similar to today's car sharing solutions (Stegmüller et al., 2019).

However, autonomous mobility is not solely geared toward the transport of persons. There are also promising applications in the field of logistics, particularly with great potential for long-distance logistics on motorways or highways. As significant cost factors in today's logistics chain, the reduction of driving personnel or the independence of working or driving times may represent a major gain. One area of application is a technique known as platooning, which is understood as a convoy of semi-automated or fully automated vehicles (DHL Trend Research, N/A; Volkswagen, 2019). In semi-automated operation, this reduces the workload for the drivers. In the case of fully automated platooning, the vehicle automatically follows the leading vehicle. Logistics can therefore be mapped fully automatically on specially designed routes within a designated ODD (operational design domain).

The state of the art presented here forms the basis of the potential assumed in this study distributed over five autonomous vehicle concepts: VIP shuttle, micro vehicle, comfort shuttle, people mover, and distribution logistics. The concepts are classified in Chapter 6.

General technical challenges – manageable but require even more development work

However, for the objective planning of autonomous mobility systems, the state of the art must also be kept in mind. The following are general assessments from the expert interviews: Computing complexity is considered to be extensive but unproblematic, especially considering the development of processing power in the coming years through the widespread use of autonomous mobility systems:

- The localization and navigation of vehicles is largely resolved or could be supplemented as required by external infrastructure.
- The greatest challenge lies in the handling of mixed traffic, especially with regard to the unpredictable driving behavior of people.
- A key challenge lies in solving complex traffic situations while maintaining the fundamentally defensive driving behavior of autonomous vehicles.
- Dealing with bad weather conditions (e.g., rain and fog) is still a major challenge that remains largely unresolved.
- However, passenger compartments and vehicle computers must be cooled in the case of high outside temperatures, which, with current battery capacities, limits the range of the vehicles and therefore operating times. The advantages for highway logistics arise since the same sensor and computer set used for smaller vehicles is sufficient for larger vehicle weights and battery capacities, but no interior air conditioning is required.
- Generally, the challenges for highway trucks are seen as the least significant, but their sensors and algorithms must be designed with greater foresight than for smaller vehicles due to their weight and the resulting braking distances and maneuverability.

Quote from automotive manufacturer: "The greatest challenges lie in everything that has to do with the perception and consideration of mixed traffic."

Quote from automotive supplier: "It is sometimes crazy how unreasonably and unpredictably pedestrians have reacted to our pilot vehicles, for example, to stop the vehicle in order to hop on."

Quote from automotive supplier: "The energy consumption of the technology is still immense – in warm weather, we have significant limitations in range and thus with the operating time of the vehicles."

Quote from business model expert: "Many start-ups and companies are active in California and the south of the USA because of the very stable and good weather conditions, but the technologies and algorithms developed there are only partially suitable for use in bad weather."

Within the study, further discrepancies between user expectations and actual expert assessment were identified, which are summarized on the following page.

4

Mind the Gap – Autonomous Mobility Between Aspirations and Reality

One objective of this study was to identify potential early autonomous mobility concepts and use cases that seem attractive and sustainable from the point of view of users while also standing up to the scrutiny of international experts from technology and mobility companies. Discrepancies between user requirements and expert assessments were identified in the form of seven gaps:

1. Subsidies gap:

The cost and thus competitive advantages of public transport (in Europe) are not achievable due to the lack of subsidies for shared autonomous mobility concepts. The different market conditions make it difficult for private providers to take advantage of opportunities.
→ Further information on p. 43

2. Trust gap:

Despite the fact that autonomous mobility is characterized as "high technology," potential customers trust well-known providers more than (digital) technology companies when it comes to operating autonomous mobility services.
→ Further information on p. 84

3. Expectation gap:

Experts predict cost advantages through the combination of passenger and goods transport with shared autonomous mobility. Users, on the other hand, are critical of such dual use and favor separated transport.
→ Further information on p. 118

4. Intent gap:

Respondents are generally very open to the replacement of private cars with shared autonomous mobility solutions. However, the proportion of people who would replace all car journeys is significantly lower. It can therefore be assumed that they were referring to partial substitution. Experts express doubts as to the extent to which shared autonomous mobility actually acts as a replacement for motorized private transport or is only used as a supplementary service. This could even result in more journeys being made and traffic increasing.
→ Further information on p. 44

5. Utilization gap:

The provision of 24/7 availability raises the problem of some journeys being empty. "Around-the-clock" availability reduces efficiency and cost benefits due to lower utilization.
→ Further information on p. 53

6. Business model gap:

Increased mobility provision through shared autonomous mobility will have the greatest positive social effects, especially in rural areas, where mobility systems (especially public transport) are not sufficiently developed. The challenge of such business models lies in ensuring economic operation in rural areas, since there is a smaller number of potential customers. Accordingly, there is a dilemma for operators between achieving the maximum social sustainability effect while also maximizing profits.
→ Further information on p. 54, p. 84

7. Pay price gap:

The willingness of potential users to pay for shared autonomous mobility lies between the prices of public transport and taxis. Experts agree that the operation of a shared autonomous service exceeds the costs of today's conventional concepts. There is disagreement as to which stakeholders (e.g., customers, operators, public authorities) should pay for the additional costs of shared autonomous mobility.
→ Further information on p. 41

Close the Gap – A Realistic View of Autonomous Mobility in a Regional Comparison

The relevance of the gaps described above and the challenges still to be faced differ between the regions. Among others, factors such as user acceptance and settlement structures, infrastructure development and public transport systems, as well as the climatic conditions and general traffic behavior are considered to be aspects that influence the attractiveness and application potential of different concepts. In the following, some particularly interesting directions of development are outlined that can be derived on the basis of the findings of the study, as well as a forecast of the role of various stakeholders:

Europe Is Striving for Universal Mobility

In Europe, the use of small autonomous vans in ride sharing is conceivable in conjunction with and as an expansion of public transport services in off-peak times or for areas not accessible by public transport. Particularly with regard to rural mobility, expectations on the part of users and mobility providers, as well as the need for regional solutions, are correspondingly high. This goes hand in hand with social aspects of mobility provision and environmental aspects in terms of supporting the transport transition by providing suitable alternatives to private cars. However, there is still a gap to be closed in terms of business models – for example, the busier inner cities are much more attractive for mobility providers than rural areas with their longer distances and fewer passengers. To be successful, the service would have to be designed in close cooperation between districts, cities, and municipalities as well as public transport companies and long-distance rail companies with new mobility providers – new cooperation models, traffic planning principles, and tools for the evaluation and monetization of sustainable values are needed. However, in rural areas in particular, some additional technological barriers still need to be considered. In order to implement early, route-based applications, it is therefore necessary to identify specific potential routes of operation, taking into account local mobility requirements and existing (technical) infrastructure, whereby, in view of its stable weather conditions, the south of Europe would be particularly suitable, with the northerly regions being characterized by increasing amounts of fog, rain, and snow, which must be taken into account in the selection and design of the use cases. However, this is offset by the usually higher traffic complexity and poor infrastructure quality in southern Europe.

Implications for stakeholders

Automotive manufacturers have the opportunity to contribute their automotive expertise in the field of van-oriented ride-sharing vehicles or to build on existing platforms and contribute their expertise in the field of user-oriented vehicle interior design. The potential can primarily be found in the modular design of vehicles, with the aim of efficiently establishing a wide range of possible setups that meet customer requirements. For a large number of expected, often smaller, local **fleet operators**, specially adapted leasing and insurance offers from vehicle manufacturers will enable them to focus on their core busi-

ness. The **operations control center** will be either managed by traffic control centers of (larger) municipalities or, for smaller fleets, operated in the service business by automobile manufacturers within the framework of bundled centers that support several fleets in parallel. The role of **mobility provider** will primarily be taken by established public transport providers that integrate autonomous mobility services into their apps and pricing as well as booking processes, building on white-label solutions for ride sharing and vehicle organization provided by mobility-specific or general **service providers**, depending on the offer. The underlying services of the **cloud operators** are expected to be booked directly by the service providers or integrated into municipal structures and existing partnerships. **Communication technology companies** will essentially play a role in the deliberate expansion of network coverage and will be involved early by municipalities in the planning of transport networks and their infrastructure requirements.

America's Longing for Public Mobility Services

In the USA, the development of a new public transport system as an alternative to private cars is the central development area for shared autonomous mobility. Respondents want mobility opportunities in the leisure sector and for commuting to work or for traveling to the airport. Small autonomous buses on a dedicated road network may represent an early solution concept. However, attractive prices have to be offered in comparison to ride-hailing services – combined business models, for example with restaurants or airlines, as well as corresponding services offered by employers, are conceivable and accepted by the users. Particularly in the northern USA, however, weather conditions (heavy snowfall in winter) would have to be taken into account if year-round availability of mobility services appears necessary and no alternatives are available. In addition to the social effects, positive ecological effects would also occur; these would then benefit users as alternatives to their private car. Particularly in the case of larger vehicles, it may be possible to use this technology in cooperation with truck manufacturers, especially as autonomous highway logistics in the USA are expected to be the first use case for autonomous vehicles. Furthermore, the experience of truck manufacturers will allow technology transfer to small buses. In future, this cooperation may also lead to the review and implementation of autonomous intercity buses. Long-distance buses are a proven means of transport in the USA, while the national rail network is poorly developed and unattractive. Autonomous intercity buses can therefore replace long passenger car journeys or domestic flight routes and promote the transport transition with a focus on environmental sustainability effects in the USA.

Implications for stakeholders

Automotive manufacturers with experience in commercial vehicles have the opportunity to define new vehicle concepts in the area of autonomous, smaller buses and to fill this gap. Although the urban fleets will initially be rolled out in a smaller size, they

can reach a large scale in the future as a substitute for public transport structures. In combination with more standardized, simple equipment, sufficient quantities for the established business models of commercial vehicle sales can probably be achieved in the foreseeable future. The growth potential of the American fleets in particular makes this market more attractive for the vehicle segment than the EU or China with well-functioning public transport structures. The role of **fleet operators** is currently still unfilled due to a weak public transport network and passive municipalities, which gives commercial vehicle manufacturers with corresponding local after-sales networks the opportunity to position themselves in this regard. However, it is also conceivable that the providers of cross-country bus journeys will enter the market or that local or future national start-ups will emerge, which in turn will need strong technology partners. The **operations control centers** could also be taken over by the cross-country bus operators, but also by the automotive industry. Regarding the role of **mobility providers**, private sector stakeholders are expected to take on a proactive role, although it remains to be seen how the domestic IT and service providers – which are particularly active in the area of smaller vehicle sizes – will position themselves. However, it would be conceivable for the cross-country bus operators to enter the market and form a network of their inter-city routes. The emergence of local start-ups also seems conceivable, provided that attractive regions and cities are not already occupied by other stakeholders. For specific routes, it is also conceivable that third-party companies, such as large employee or airport companies, may appear who wish to cover the specific mobility needs of their stakeholders. It remains to be seen how **service providers** will integrate their offerings into appropriate mobility solutions. However, it would seem logical for these stakeholders to also offer services of fleets with smaller vehicle sizes on an individual basis. The role of **cloud operators**, as well as **communications technology companies**, can develop into a cooperation model with the operators in order to build and operate the necessary local infrastructures independently of municipal efforts.

China's Dream of Comfortable Commuting in Privacy

Among the Chinese respondents, it is evident that there is a clear focus on the most comfortable way to get to and from work. Given the lack of benefit for the environment and social sustainability, this initially seems to be a questionable vision. In view of the increasing salaries of drivers in China and the mobility volume involved in commutes, this can become an economically attractive use case. It is conceivable that this could be implemented on specific routes or even on separate routes, linking company premises and office areas with park and ride parking lots or mobility hubs in residential areas and on the outskirts of the city. However, it is important to consider the objectives and mobility plans pursued by local administrators, who wish to characterize and promote such

concepts as solutions with the aim of reducing the volume of traffic. The key here is close cooperation between cities and municipalities and mobility providers, right from the time of planning new city districts or business areas. As far as the companies are concerned, ideal implementation models that are associated with geographical, traffic, ecological, and social effects should first be highlighted as a basis. In addition, depending on the specific region of China, the consideration of the rainy season – which is different than in Europe or the USA – and the development of custom strategies to meet the emerging challenge are considered critical to implementation. For example, it is especially important in the context of daily commuting that a continuously available service is guaranteed or that alternatives such as public transport are considered as a contingency. As weather influences are still seen as a major challenge by technology experts, technology manufacturers should determine the requirements for autonomous driving in the rainy season and develop concrete, robust solutions.

Implications for stakeholders

For traditional **car manufacturers**, especially from the premium sector, these vehicles offer them the opportunity to build on their current vehicle concepts, which gives them an advantage over new stakeholders in terms of comfort and luxury, but also in terms of brand relevance. However, they need to shift their business models to lower volume production and B2B sales. The premium requirements of the service as well as the larger number of fleets, which are mostly used on an individual basis, create more challenging requirements for **fleet operators** in terms of vehicle maintenance and cleaning, as well as for **operations control** with regard to stable operation and rapid, user-specific intervention, including for smaller inquiries and messages if necessary. However, with regard to **mobility providers**, there is an opportunity to conclude premium subscriptions with end customers or special contracts with third parties such as restaurants or theaters for bundle offers. For **service providers**, there is the opportunity to seamlessly integrate their services, e.g., in terms of entertainment, communication, or shopping, as users want their time in the vehicle to be as pleasant as possible. For example, a partnership in the electronic entertainment sector would be conceivable, with functions such as automatic suggestions of suitable series or other entertainment and wellness offers. Due to the high data volumes for the corresponding content as well as for the stable operation of the vehicles expected to be on the road, there is a high demand and a strong need for stable availability of the services provided by **cloud operators** as well as **communication technology companies**. In particular, the second group could be involved in the planning of mobility systems with regard to the development and expansion at road level of dedicated, stable communications networks.

Forecast: Shared Autonomous Mobility Is on Its Way

The concepts listed demonstrate the diverse application potential of shared autonomous mobility as well as the heterogeneity of the markets with regard to user wishes, business models, and general conditions. There is a broad consensus among experts that, on the one hand, the technological challenges can be solved, but this is highly dependent on the relevant conditions (e.g., traffic, weather, infrastructure), meaning that, on the other hand, the widespread use of autonomous mobility is still a distant target.

"[…] Mixed operations are of course very difficult, because you have to be prepared for all eventualities […]. It is precisely these unpredictable, random situations that make it all so challenging."

Dr. Jan Becker, CEO & Founder of Apex.AI

This makes it all the more clear that autonomous mobility concepts do not have to be conceived and developed as a generic solution, but with reference to dedicated use cases. Business model experts, technologies, mobility providers, and political stakeholders should be involved in the early concept phases, in order to identify dependencies and subsequently design them as a comprehensive solution.

Shared autonomous mobility will diversify and be available to experience selectively by the end of the decade as part of viable business models in selected urban areas. Sustainability effects will primarily be found at a social level, resulting from the improved availability of mobility. In the long term, it is precisely this improved public offering that may lead to people needing their private cars less or even dispensing with them completely, which in turn will support the overall transport transition and have significant positive environmental sustainability effects in the long term.

Logistics:
key cost calculation

Comparison of ODD, technology, and costs

Creation of a more uniform framework

GAP

There is currently no consistent legal framework in place across US states

USA:
opportunity for better public transport

Identification of suitable routes that can be introduced in the near term

Potential expansion and implementation of popular routes

GAP

Current focus is primarily on private car fleets in the USA

EU:
connection of rural areas

Determining of requirements, opportunities and (technical) costs

Integration of tariffs and planning with public transport and rail networks

GAP

Today, the trend is strongly toward inner-city, sustainable offerings

China:
comfortable, premium commuting

Analysis of cities regarding concentrated commuting needs

Analysis of whether and where private commuting makes sense

GAP

Uncertain to what extent this will be backed by Chinese policy, perhaps more shuttle-focused

Figure 2: High-opportunity use cases, prerequisites and obstacles in each region

Recommended actions for all of the stakeholder groups involved can be made with the aim of achieving sustainable, autonomous mobility.

Technology providers and suppliers:

- Improvements to sensors and safety mechanisms in terms of increased robustness of driving functions (e.g., with regard to weather).
- Design, testing, and definition of strategies, algorithms, and technologies for dealing with mixed traffic in relation to the irregularities and unpredictability of the behavior of human road users.
- Development of energy-saving and heat-resistant sensors, chips, and computer architectures.

Automotive manufacturers:

- Design of a range of suitable vehicle concepts for different scenarios regarding vehicle sizes, operator concepts, and user requirements.
- Development of production and sales models for vehicles oriented toward public transport.
- Ideal classification of urban and rural structures with regard to the possible applications and barriers for various autonomous mobility concepts.

Mobility providers:

- Calculation of business model concepts under explicit consideration of the technology costs incurred and the robustness of the service availability for specific use cases.
- Identification of cooperative planning and operating models with municipalities and public transport providers for the design of autonomous mobility services.
- Development of bundled business models with the participation of third parties, such as airports, event agencies, and employees.

ICT and service companies:

- Provision of highly robust cloud services for security-critical mobility applications as well as the expansion and guaranteed provision of the necessary bandwidths and network coverage.
- Integration of mobility services into proprietary software, platform, and technology infrastructures.
- Provision of proprietary services via defined interfaces to enable integration into vehicle architectures.

Political and municipal stakeholders:

- Preemptive, early consideration and integration of appropriate infrastructure measures supporting autonomous mobility into planning processes for neighborhoods and transport networks as well as infrastructure measures.

- Proactive provision of the necessary framework conditions for the use of autonomous vehicles and for enabling symbiotic service models by public authorities and the private sector.

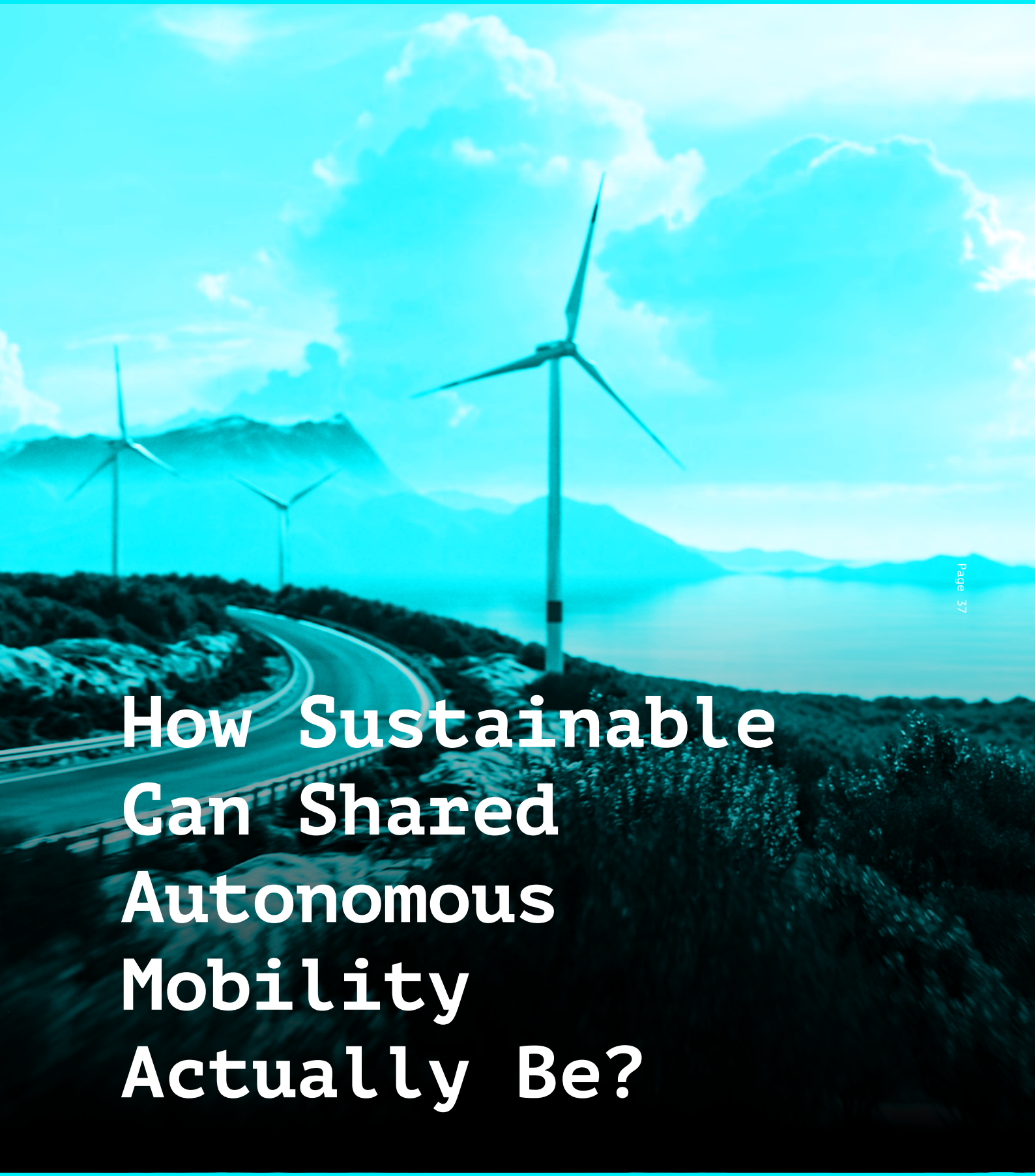
- Consideration and proactive planning of the connection of private business models to public transport networks, tariffs, and infrastructures.

Users:

- Openness for testing new, autonomous mobility services, as well as shared services Questioning the need for a private car depending on existing mobility services, particularly when a vehicle needs to be replaced or new vehicle must be purchased.

- Contributing appropriate citizen and employee proposals for the establishment and operation of specific proposed routes in municipal mobility planning or employer mobility concepts.

6



How Sustainable Can Shared Autonomous Mobility Actually Be?

Autonomous mobility systems can only be successfully implemented if the principle of sustainability is followed. This involves taking a comprehensive view of the three pillars of sustainability: economic, ecological, and social sustainability. The triple bottom line approach combines these very principles and ensures that sustainability meets all three dimensions (Mayer, 2020). The following graphic provides an overview of the ideal vehicle concepts studied and shows the sustainability potential investigated.

From robo-cab to robo-gap: to what extent can autonomous mobility exploit sustainability potential?

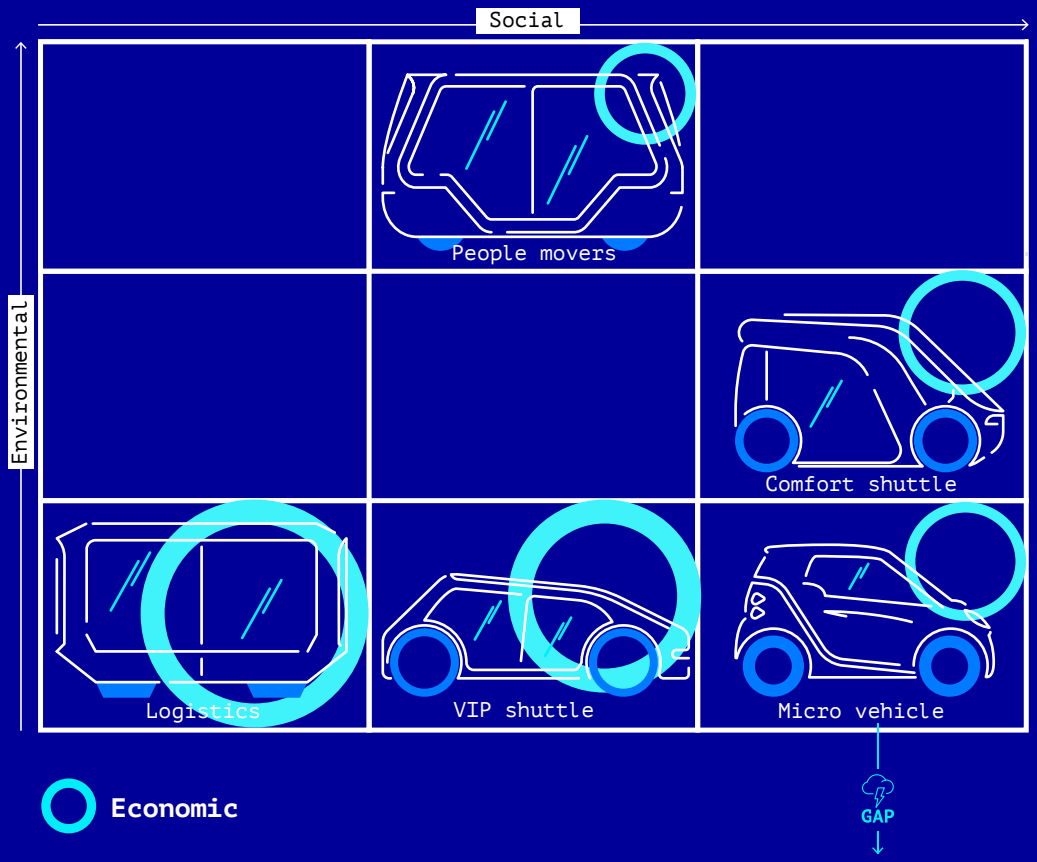
When autonomous driving emerged about ten years ago as a topic of innovation and a future market, the pilot projects and visions primarily spread the idea of small, urban vehicles that transport people in built-up areas in a flexible way in terms of time and space. They anticipated both ecological and social sustainability effects as well as high-revenue and high-yield business models. The prototypes of micro vehicles from that time have since disappeared. This study shows firstly that the interest of users in such micro vehicles is limited. Secondly, it shows that the anticipated sustainability effects are hardly being implemented.

"Sustainability is important but the most important target for stakeholders is industrial leadership, not sustainability. Global leadership is preferred but difficult to be significant outside China for local players and for US players in China"

Investment Manager, global Growth-Stage VC

Economic effects are attributed above all to the reduction of driver costs and the increased attractiveness of the services by enabling smaller, flexible vehicle sizes as well as round-the-clock availability. The economic potential therefore depends on the general availability of drivers (especially with regard to trucks in the USA), the development of driver seats (especially in China) as well as on the regulation of driving services and their working conditions (especially in the EU) and their development.

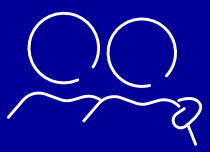
Environmental effects will only be achieved if a substitution of private cars is achieved, i.e., in the form of shared cars. Sufficient potential already exists, and commuting traffic could be particularly affected. However, these effects can only occur if there is actually a reduction in vehicle numbers. In addition to appropriate solutions being offered, this will also involve local authorities and politicians providing support, as well as users granting widespread acceptance.



Urban two-seater e.g. Google's egg-shaped concept car: GAP Not very relevant from an ecological/ environmental point of view, according to expert opinion. Useful as a supplement, if necessary

Economic sustainability: Mostly unattractive for private business models

Environmental sustainability: Effects will only become visible once traffic habits change



Social sustainability: Significant, early effects with high impact

Figure 3: Sustainability potential

Social effects are particularly evident in ensuring universal mobility and establishing a general service. The lack of coverage in regions with weak mobility indicates that there is great social impact potential for autonomous mobility, but this is not an attractive use case for early market entry due to the challenging technical implementation and lower demand.

In terms of the **competitiveness** of shared autonomous mobility, prices must beat those of ride-hailing services or subsidized public transport services, and simpler station- and route-based services must be weighed up against a more complex door-to-door service. Taking these aspects into account, the concept of small, urban vehicles in particular seems to be more of a long-term supplementary solution designed for contingency-based individual mobility than the basic technology of fleets that are rolled out city-wide, covering a large part of passenger mobility and representing a near-term solution to urban transport problems. Stakeholders who are or want to be active primarily in this market area should therefore carefully consider and identify the specific use cases for which these services can be offered economically. In principle, the business model must be planned in close coordination with the definition of the specific ODD, taking account of the resulting technology costs. A nationwide roll-out of fleets therefore does not seem attractive. In the following, comprehensive findings regarding the various dimensions of sustainability are presented in more detail as a basis for an early assessment of the potential of conceivable mobility concepts that is as objective as possible.

Economic Sustainability as the Basis for Viable Business Models

The economic dimension involves securing business models and long-term demand, increasing value creation and added value for all stakeholders, fulfilling customer needs efficiently, and developing high innovation potential along the entire value chain (Mayer, 2020).

Price expectations are based on public transport

- By eliminating drivers in autonomous vehicles, lower fares can generally be offered. According to experts, it would be possible for prices to be based on those of local public transport, or for them to even be cheaper.
- Across all countries, the majority of respondents declare a willingness to pay for autonomously driven vehicles at an equivalent level to current public transport rates.
- Almost a quarter of those surveyed are even willing to pay more for a shared autonomous car than for public transport.

- Shared autonomous mobility can be made available to the entire population at a public transport price level (social sustainability).

- **Pay price gap:** The willingness of potential users to pay for shared autonomous mobility lies between the prices of public transport and taxis. Experts agree that the operation of a shared autonomous service exceeds the costs of today's conventional concepts. There is disagreement as to which stakeholders (e.g., customers, operators, public authorities) should pay for the additional costs of shared autonomous mobility.

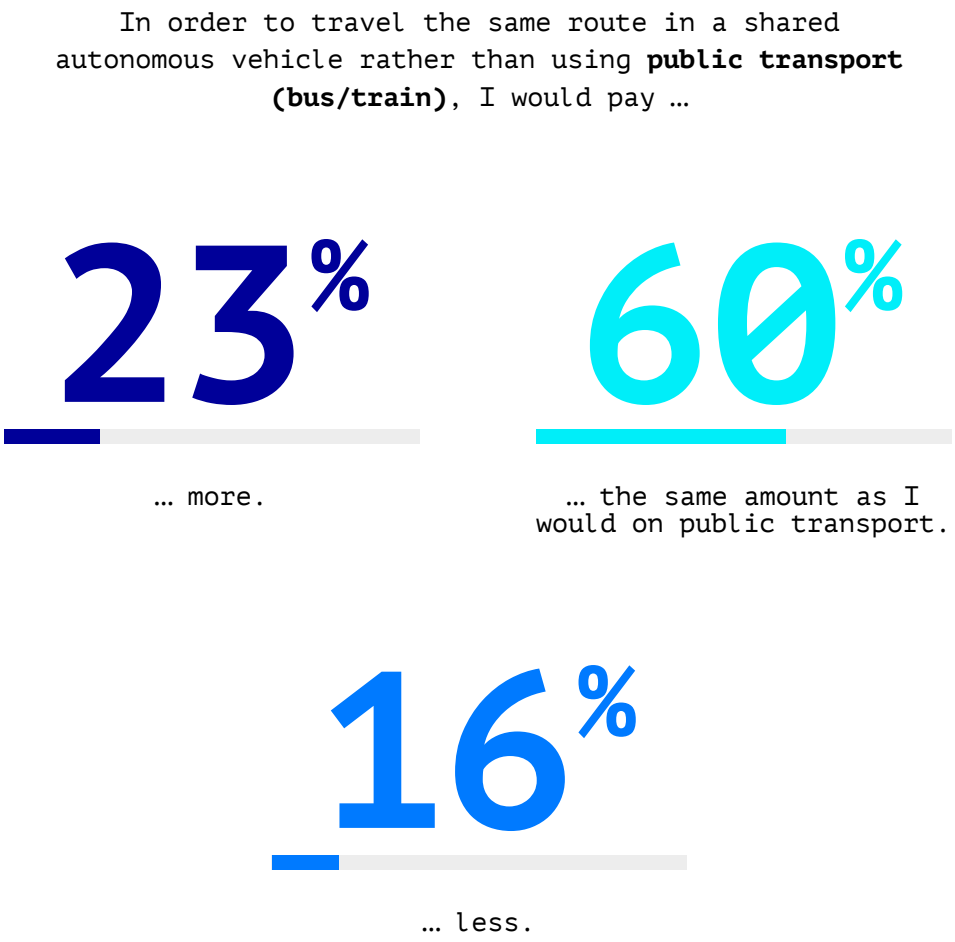


Figure 4: Willingness to pay for shared autonomous vehicles compared to public transport
n=4,868

Which **offers** or **events** would be more appealing to you if a **journey** in a shared **autonomous vehicle** was included for **a small fee**?

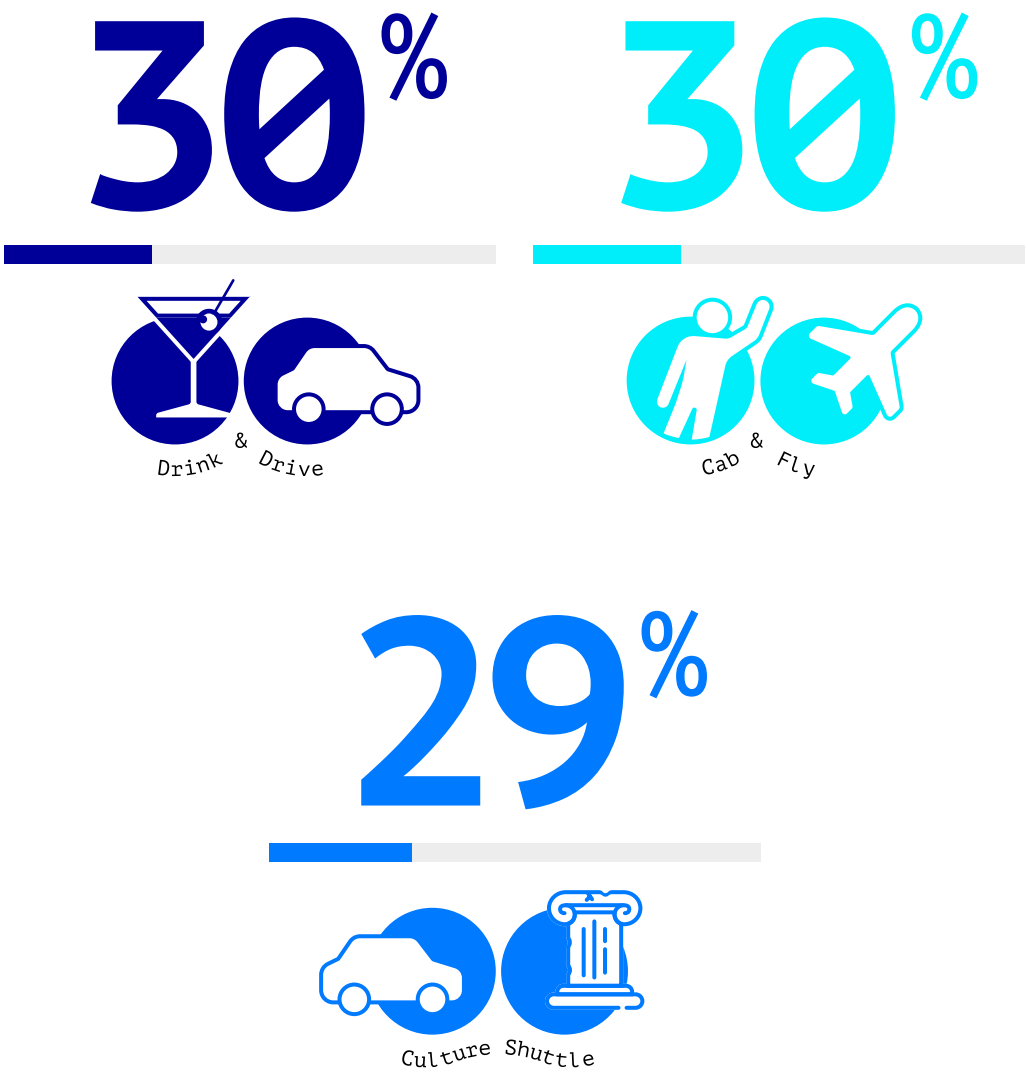


Figure 5: Cooperation possibilities with shared autonomous vehicles
n=4,868

Economic efficiency through alliances, networks, and partnerships

When analyzing offers and events that would become more attractive through cooperation with autonomous mobility services, the following three scenarios in particular have been shown to be promising.

- Almost a third of the respondents see a combination with airline tickets as the greatest added value and would pay a (small) surcharge ("cab and fly") for being dropped off and/or picked up from the airport by means of shared autonomous transport.

- "Drink and drive" describes the cooperation between restaurants and bars with shared autonomous mobility offers, which act as a drop-off service and make the use of private cars superfluous.

- "Culture shuttle" means shared autonomous mobility as a drop-off service to cultural events, such as concerts or theaters, for which users would pay a surcharge.

Economic value added through cooperation – experts warn against public transport cannibalization

- In principle, the experts see potential for viable revenue models in cooperation models. Cross-industry alliances open up new markets and target groups that can also benefit from the cooperation. The overall value chain can benefit.

- **Subsidies gap:** Nevertheless, it is clear that shared autonomous mobility and partnerships should not compete with public transport if they are to be operated in the private sector – the cost benefits and thus competitive advantages of public transport are not achievable for shared autonomous mobility concepts due to subsidies.

- In addition to the actual operation of the mobility service, additional costs for the ownership and maintenance of vehicles and the operation of operations control centers must be included. Partnerships with stakeholders that have already integrated relevant processes into their activities (e.g., traffic centers, car rental companies, public transport depots) become economically and strategically relevant.

- In principle, the economically viable operation of autonomous mobility services is regarded as a future scenario in which it is still unclear how quickly and at what cost the technological challenges of robust driving operations can be overcome.

- Companies making investments must therefore have staying power and sufficient capital as well as a long-term strategy.

Ecological Sustainability as the Cornerstone of a Climate-Neutral Future

Environmental sustainability is understood as the responsible use of natural resources, the preservation of ecosystems, and the reduction of greenhouse gases (Mayer, 2020). The long-term aim is to use only as many resources as can be reproduced or regrown in the same period (Brickwedde, 2010). Environmentally sustainable mobility is a key component in meeting the climate challenges of our time. The key points of a successful transport transition that achieves the 2030 climate goals are a reduction in motorized private transport and in the total amount of CO2 emissions and pollutants. In the following, we show how shared autonomous mobility can make a positive contribution to environmental sustainability.

Game changer for cars – 72 per cent of owners can imagine replacing their car

- People show a high level of willingness across countries to do without their own cars. In total, almost 70 per cent of the car owners surveyed said they could imagine completely replacing their own private vehicles with autonomous mobility solutions.

- Respondents in Poland are most positive about replacing private cars with autonomous vehicles. Participants from the USA, on the other hand, are the most reluctant to abandon cars.

- **Intent gap:** Respondents are generally very open to the replacement of private cars with shared autonomous mobility solutions. However, the proportion of people who would replace all car journeys is significantly lower. It can therefore be assumed that they were referring to partial substitution. Experts express doubts as to the extent to which shared autonomous mobility actually acts as a replacement for motorized private transport or is only used as a supplementary service. This could even result in more journeys being made and traffic increasing.

… of the respondents can imagine replacing their private car

Could you imagine completely doing without a car of your own once autonomous vehicles have established themselves enough to meet your expectations?

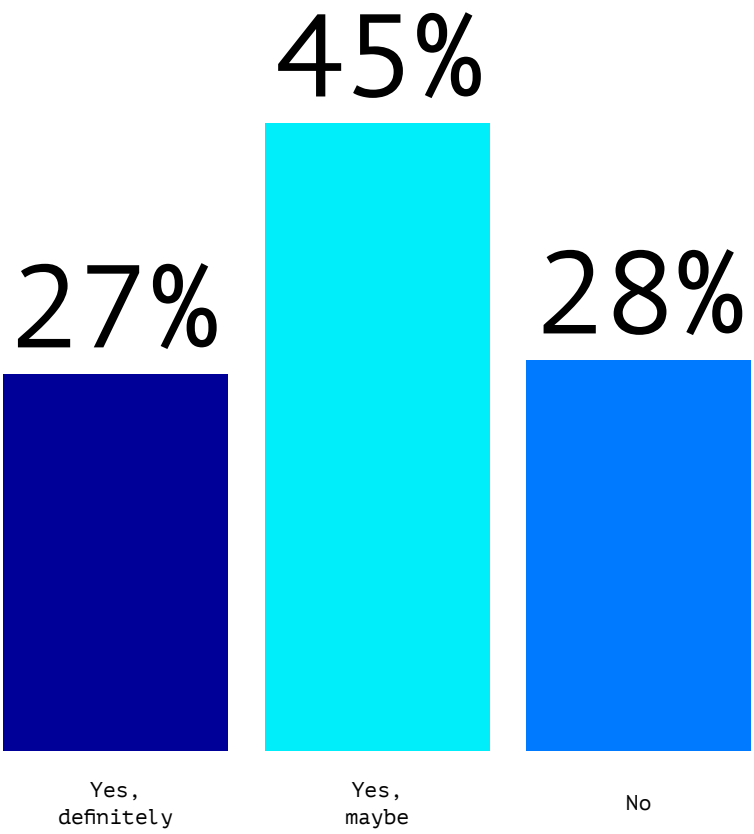


Figure 6: Replacement of passenger cars with shared autonomous mobility solutions
n=4,016 (car owners)

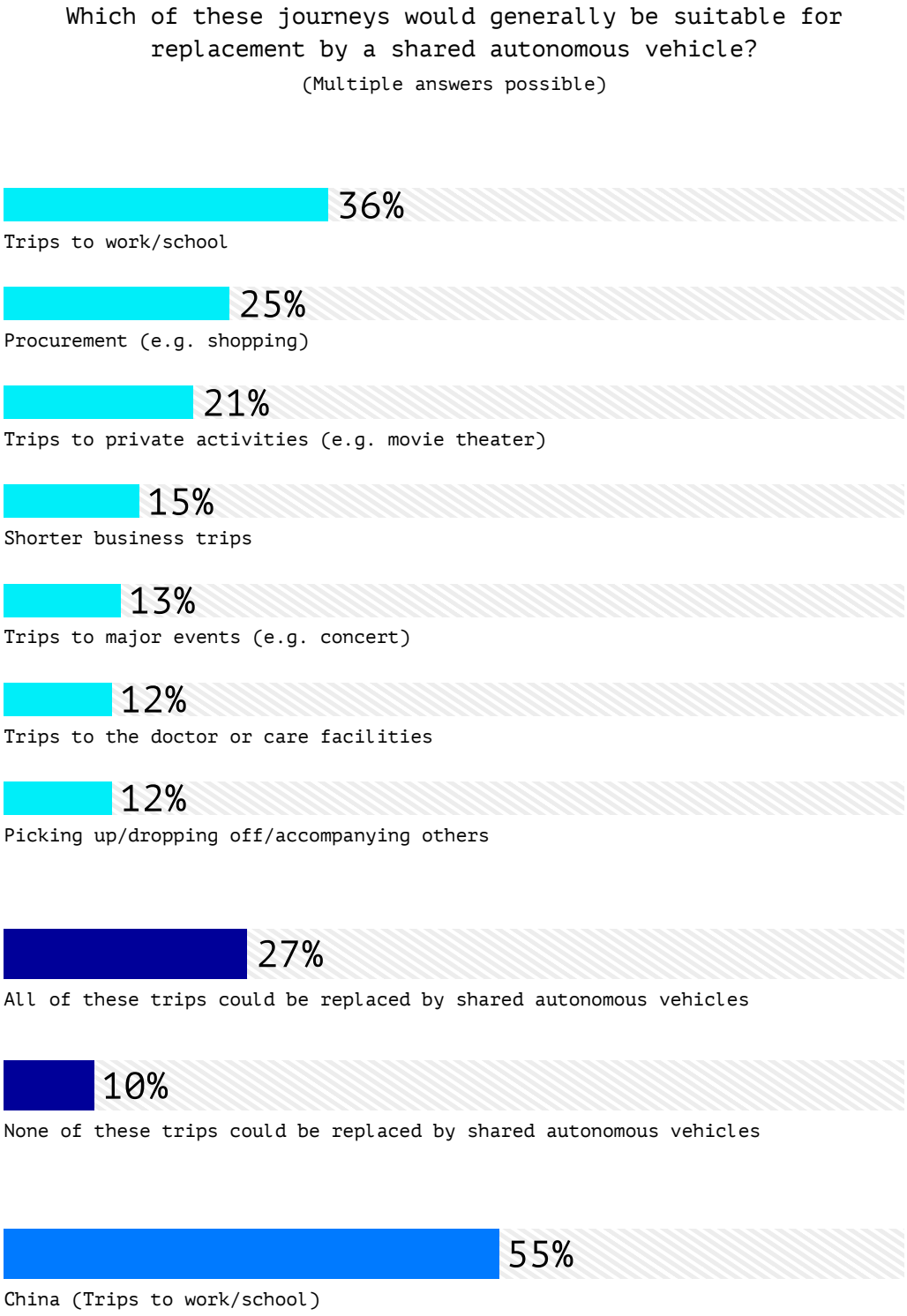


Figure 7: Passenger car journeys replaced by shared autonomous mobility
n=4,016 (car owners)

Commuter mobility to be shared and autonomous in future – especially in China

- Across all countries, it is apparent that the most frequent journeys are commuting (work/school). These are indicated as the most relevant for replacement in all countries.
- Overall, working generations in particular consider the replacement of commuting journeys to be particularly relevant.
- In China in particular, an exclusively purpose-related replacement of passenger car journeys with regard to commuting routes to the workplace or educational institution is indicated. More than half of the Chinese people surveyed agree with this. Only just under 18 per cent see the potential to replace all private car journeys with shared autonomous mobility. It is clear here that the specific example of commuting routes is most likely to be considered.

Greatest potential for replacement of all journeys in Europe with Italy's "heavy replacers"

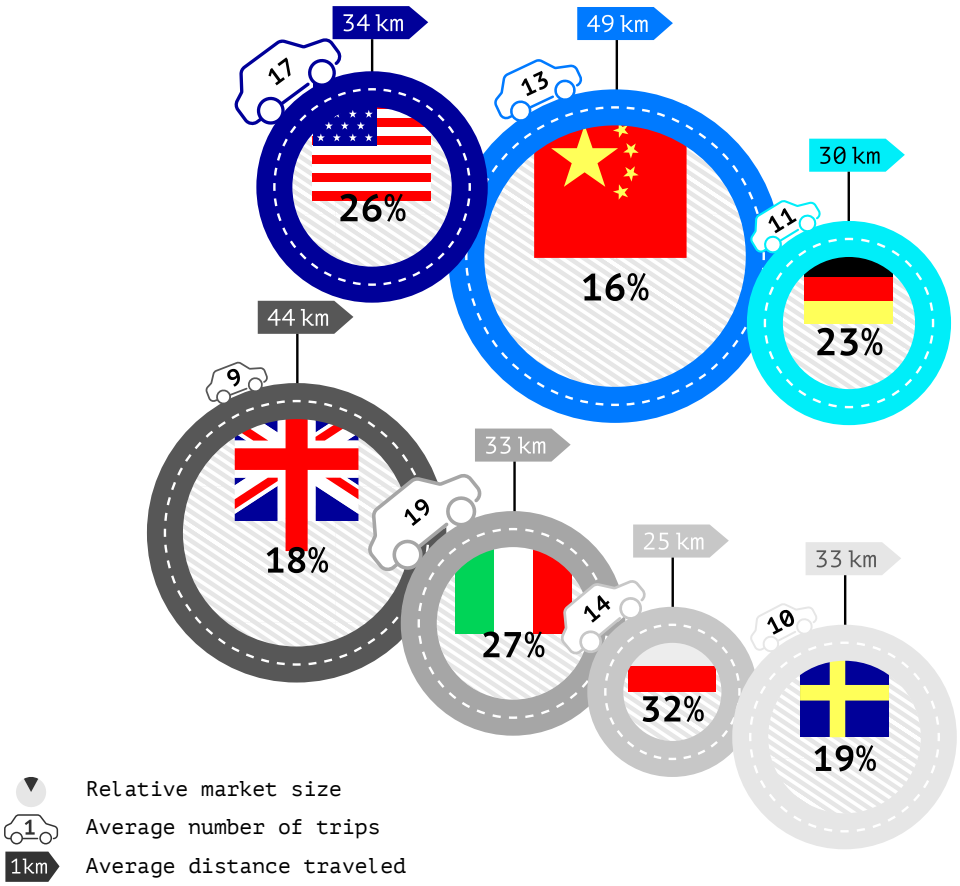


Figure 8: Heavy car replacers

- Looking at the number of "heavy replacers"[1] within a country, it becomes clear that in Poland, Italy, and the USA, more than a quarter of those surveyed would be prepared to replace all car journeys with autonomous mobility services.

- Due to the highly purpose-oriented replacement potential in China, the number of "heavy replacers" tends to be low. This should be taken into account in strategic market decisions because of the generally high replacement potential – not for all passenger car journeys, but especially for commuting routes.

- Heavy replacers are most common in Italy (just under 19 journeys per week on average) and the USA (more than 17 journeys per week on average). In these markets, heavy replacers can also be characterized as frequent drivers: Not only do they drive more frequently in an inter-country comparison, but they also drive more frequently than the total population within the country markets themselves (Italy: 18 journeys per week, USA: 15.5 journeys per week).

- The longest distance traveled on average per week in China is just under 49 km. In a European comparison, it is striking that the UK has the longest distances traveled, with more than 44 km. The heavy replacers in Poland, on the other hand, cover an average distance of almost 20 km less (the lowest in this market comparison).

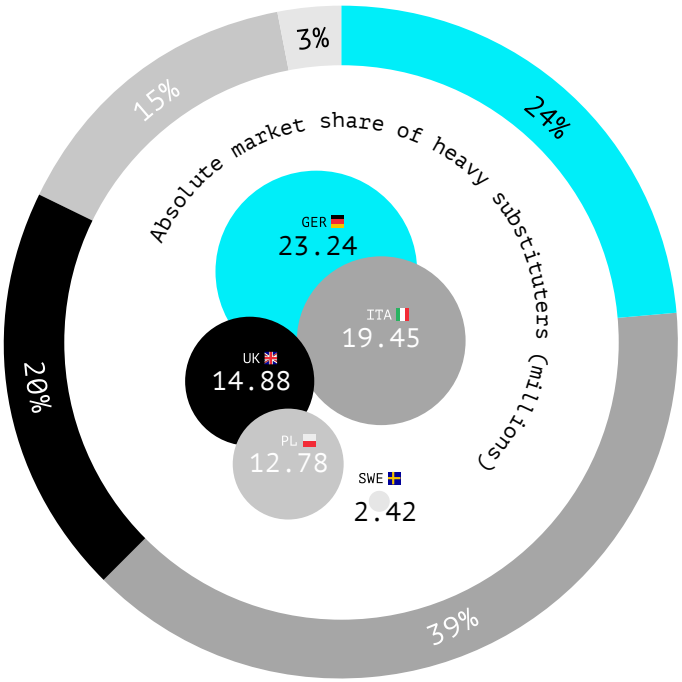


Figure 9: Potential of journeys to be saved in Europe (measured by absolute market size, i.e., number of inhabitants, and total distance traveled, i.e., number of routes times length of route)[2]

[1] Only surveyed car owners who could imagine replacing all car journeys with shared autonomous mobility.
[2] Calculation method: (Absolute market size of heavy replacers x average distance driven per week)/(TOTAL/Absolute market size of replacers for ALL countries x average distance driven per week for ALL countries)

- Taking into account the absolute number of heavy replacers per country,[3] the savings potential based on average routes in Europe shows that Italy has the largest share of journeys that can be saved: Thirty-nine per cent of the journeys made by heavy replacers can be replaced by shared autonomous vehicles.

- Despite having the largest number of heavy replacers in absolute terms, Germany is in second place with just under a quarter of the number of journeys that can be saved. Sweden performs worse in comparison.

Reduced journeys and fewer private vehicles through the use of shared autonomous mobility as environmental added value

- Overall, the expected aspects of autonomous mobility that contribute to the environment are complex. Only the energy-efficient driving of autonomous vehicles due to forward-looking and fundamentally defensive driving fairs poorly in the survey across countries and is therefore not considered by users as a relevant factor. It can be assumed that energy efficiency is understood as a fundamental basic factor of sustainable mobility. The majority of respondents see general potential in many functions and applications of autonomous mobility when it comes to creating ecological added value and believe in more sustainable usage. On the other hand, it is striking that essential driving-related factors are not expected to develop sufficiently. This could also be accompanied by limited trust in the technology.

- The analysis of the expectations of shared autonomous vehicles with regard to their contribution to environmental sustainability shows that China has considerably less faith in this compared to other countries. In general, ecological sustainability potential plays a subordinate role here.

- The greatest ecological potential through efficient driving (acceleration/braking) of autonomous vehicles is seen by the survey participants in China. This is in line with the greater faith of the Chinese in the systems and technology.

- In the USA, Germany, and Sweden, reduced emissions and energy savings due to eliminating the need to search for parking spaces and the general elimination of car use are the most important advantages of autonomous vehicles in terms of contributing to environmentally sustainable mobility.

- The energy savings through autonomous ride sharing show the greatest ecological added value in the US compared to other countries.

- Participants from Poland and Italy see the greatest potential for contributing to environmentally sustainable mobility in electric vehicle propulsion, both in comparison with countries and within the country.

[3] Calculation method: Number of inhabitants multiplied by the proportion of heavy replacers per country

Reduced journeys and fewer private vehicles through the use of shared autonomous mobility as environmental added value

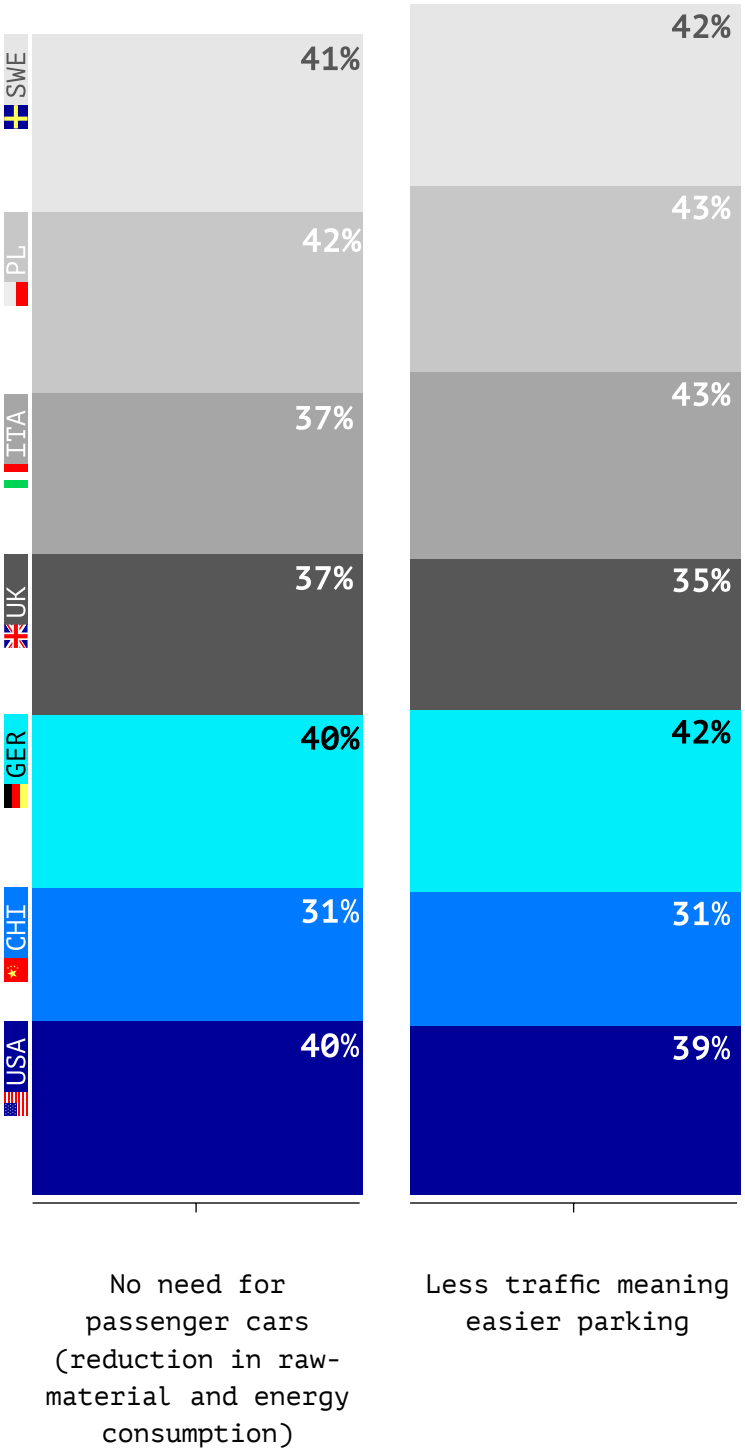


Figure 10: Environmentally friendly contribution of autonomously driven vehicles
n=4,868

Social Sustainability as a Social Responsibility

In addition to the economic and ecological dimension, the social sustainability dimension completes the triple bottom line approach. Within the social sustainability dimension, topics such as inclusion, diversity, and an improved quality of life (Mayer, 2020), as well as equal opportunities (Rüegg et al., 2021), are described. Alongside improved spatial accessibility, the time availability of the services and the reduction of traffic jams can also be cited as examples. The extent to which shared autonomous mobility brings about social sustainability effects is shown below.

- The country comparison shows large differences in the assessment of social sustainability. In particular, preferences in China and Italy differ from the rest of the countries: Access to mobility for financially disadvantaged people seems to play a subordinate role here.

- When analyzing age groups, it is striking that, across countries, older people are increasingly of the opinion that autonomous vehicles offer new opportunities for people with physical disabilities or children. This is not the case in Italy and China.

- In European countries, with the exception of Italy, it is evident that people from rural areas see potential above all in the connection of areas without adequate public transport services. Access to transport seems to be the biggest social concern here.

Overview of expectations regarding social sustainability

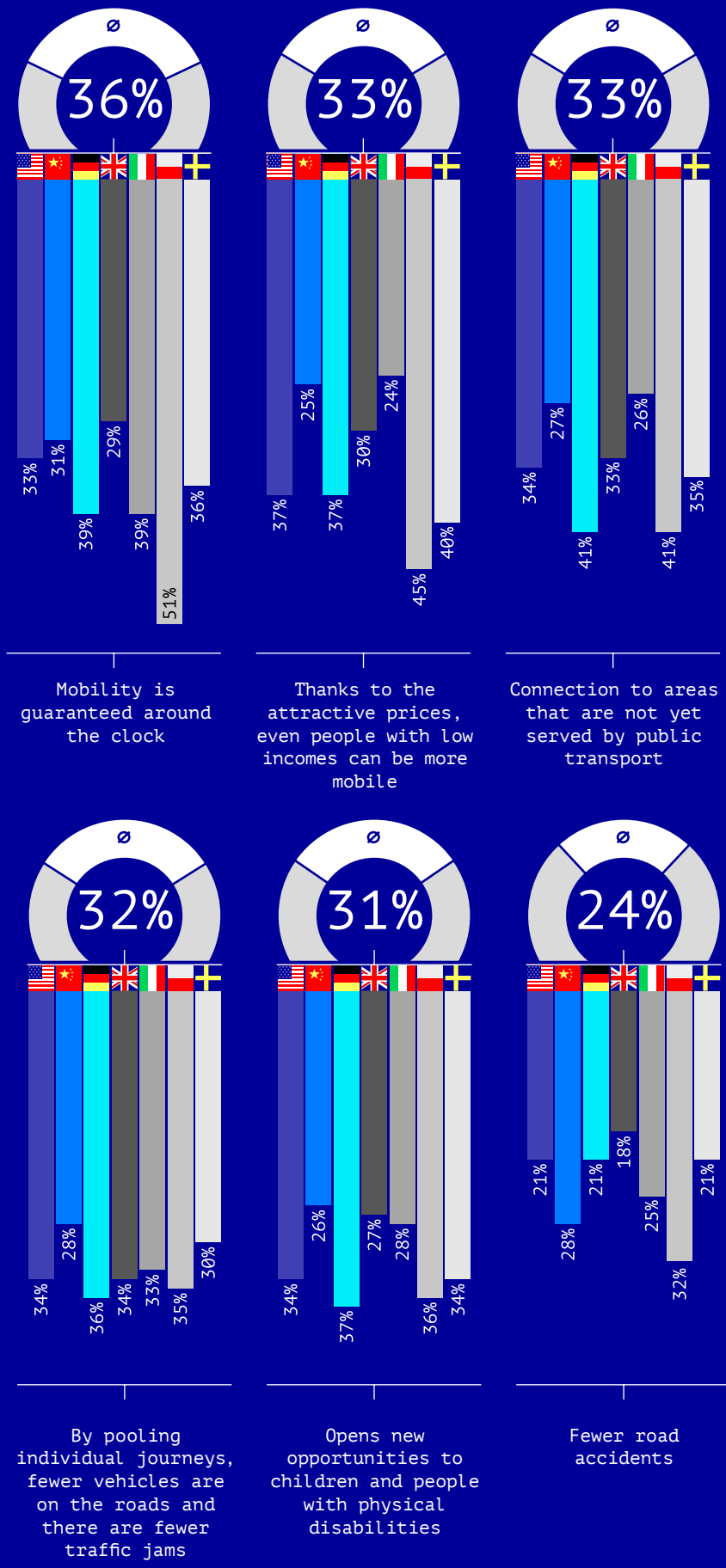


Figure 11: Overview of expectations regarding social sustainability
n=4,868 (China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

Availability of mobility beats traffic safety

How do you think that shared, autonomous vehicles could **contribute** to **sustainable mobility**?

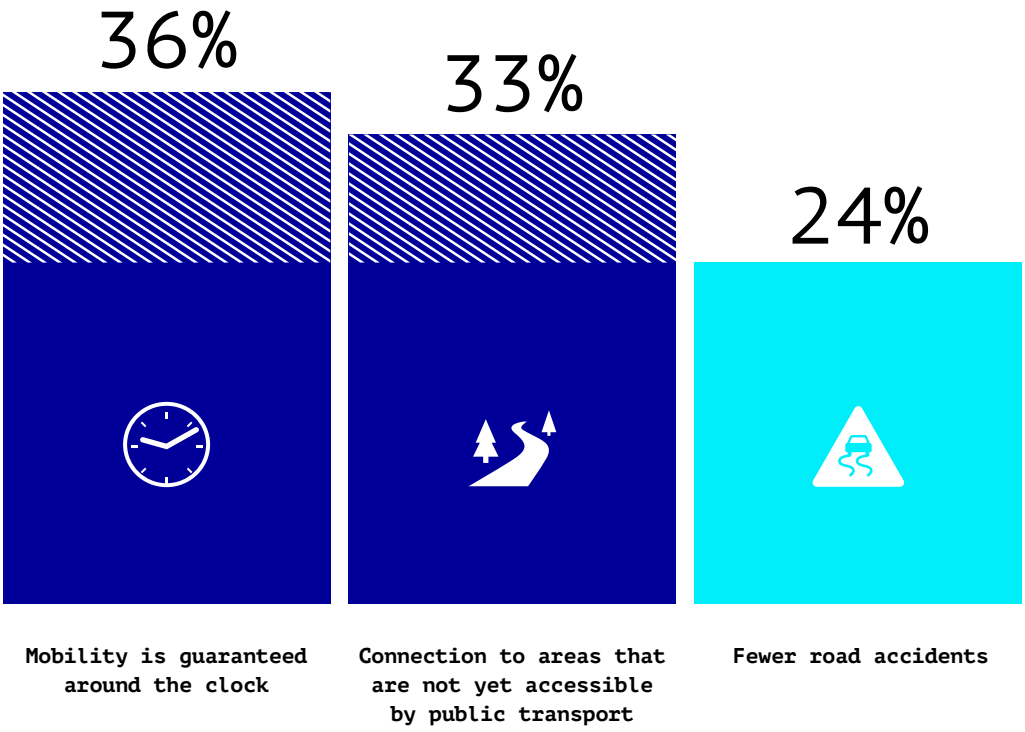


Figure 12: Comparison of social expectations
n=4,868

- Overall, shared autonomous mobility has the greatest potential to make mobility available around the clock. As a general service, a "guarantee of availability" can therefore be established.
- Across countries, a reduction in traffic accidents through shared autonomous mobility is seen as rather unlikely.
- The discrepancies make it clear that optimizing mobility performance as a requirement is above road safety.

However, experts see a number of challenges here:

- **Utilization gap:** The provision of 24/7 availability raises the problem of some journeys being empty. "Around-the-clock" availability reduces efficiency and cost benefits due to lower utilization.

Business Model Gap

- Increased mobility provision through shared autonomous mobility will have the greatest positive social effects, especially in rural areas, where mobility systems (especially public transport) are not sufficiently developed. The challenge of such business models lies in ensuring economic operation in rural areas, since there is a smaller number of potential customers. Accordingly, there is a dilemma for operators between achieving the maximum social sustainability effect while also maximizing profits.

Shared autonomous mobility in the USA – for the people!

- In the USA, it is striking that "human" aspects, inclusion, and those that directly affect an individual are in the foreground: In particular, the integration of low-income earners as well as people with physical disabilities/children through the use of autonomous vehicles is highlighted as a contributing factor.

- The main disadvantages of shared autonomous mobility are those with a direct social impact, such as the absence of direct interaction with a driver/emergency contact. In addition, there are doubts about unpleasant fellow passengers in a shared vehicle or concerns about a failure of the system.

- It is clear that the social and interactive elements are particularly relevant in the American market – both as an opportunity and a risk.

Comparison of expected **disadvantages** and **advantages** in the USA

	Disadvantages	**Advantages**
1	Risk of accidents due to technical malfunctions and defects	Thanks to the attractive prices, even people with low incomes can be more mobile
2	No official contact person in the vehicle in case of questions, emergencies, or breakdowns	Connection to areas that are not yet accessible by public transport
3	Potentially unpleasant passengers within a restricted vehicle size	Opens new opportunities to children and people with physical disabilities

Figure 13 Comparison of expected disadvantages and advantages in the USA
n=1,089 (USA)

Shared autonomous mobility in china – as comfortable as possible and as social as necessary

- Overall, social sustainability (as measured by the requirements for autonomously driven vehicles) plays a subordinate role in China. The evaluations of the social expectations of shared autonomous mobility are, on average, lower than in the other markets.
- In China, the focus is on the mobility system as a whole, while "human" aspects – with the exception of expected improved road safety – are considered less important.
- This is confirmed by the view of the anticipated benefits of shared autonomous mobility: Comfort, availability, and flexibility are at the forefront.

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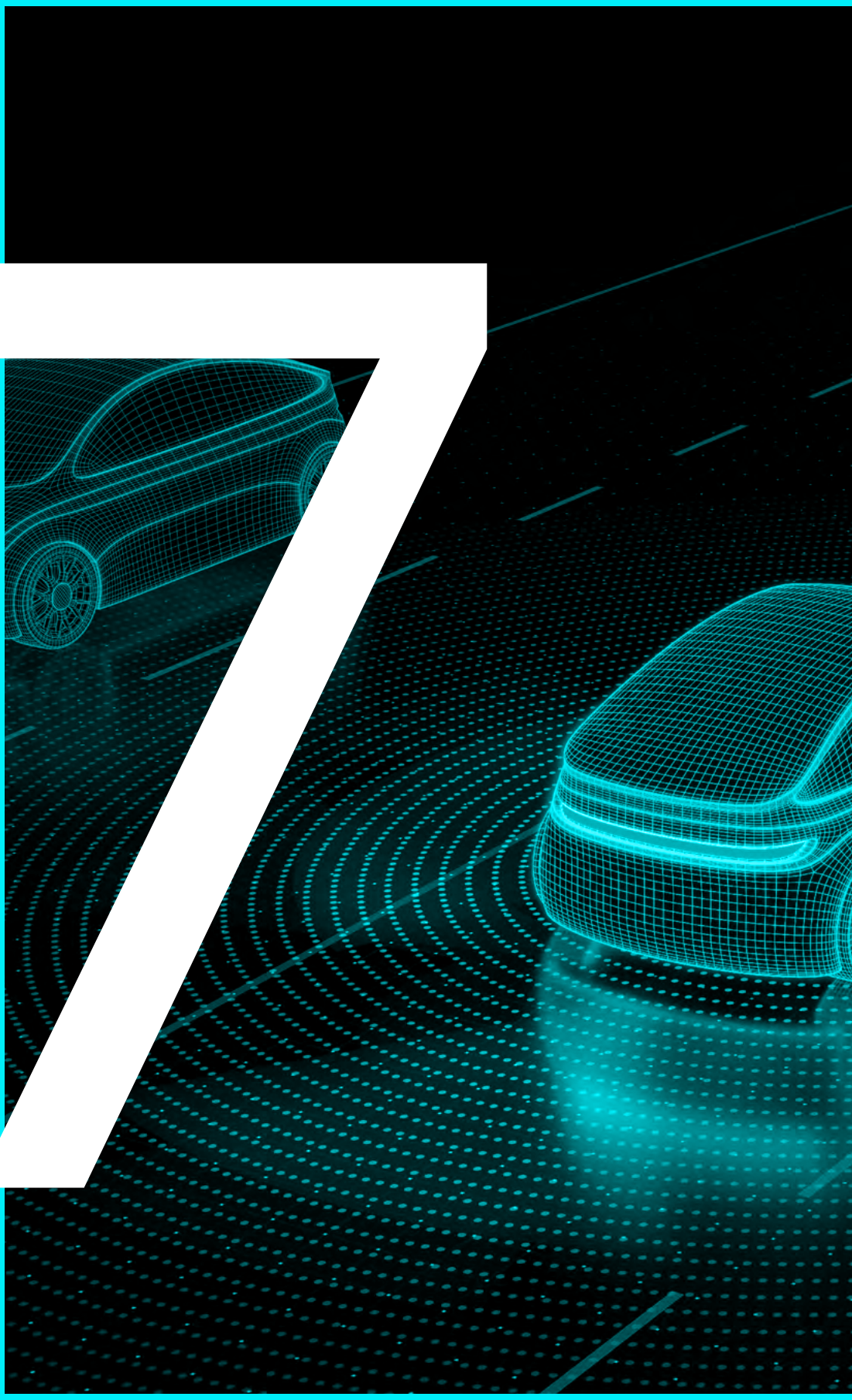
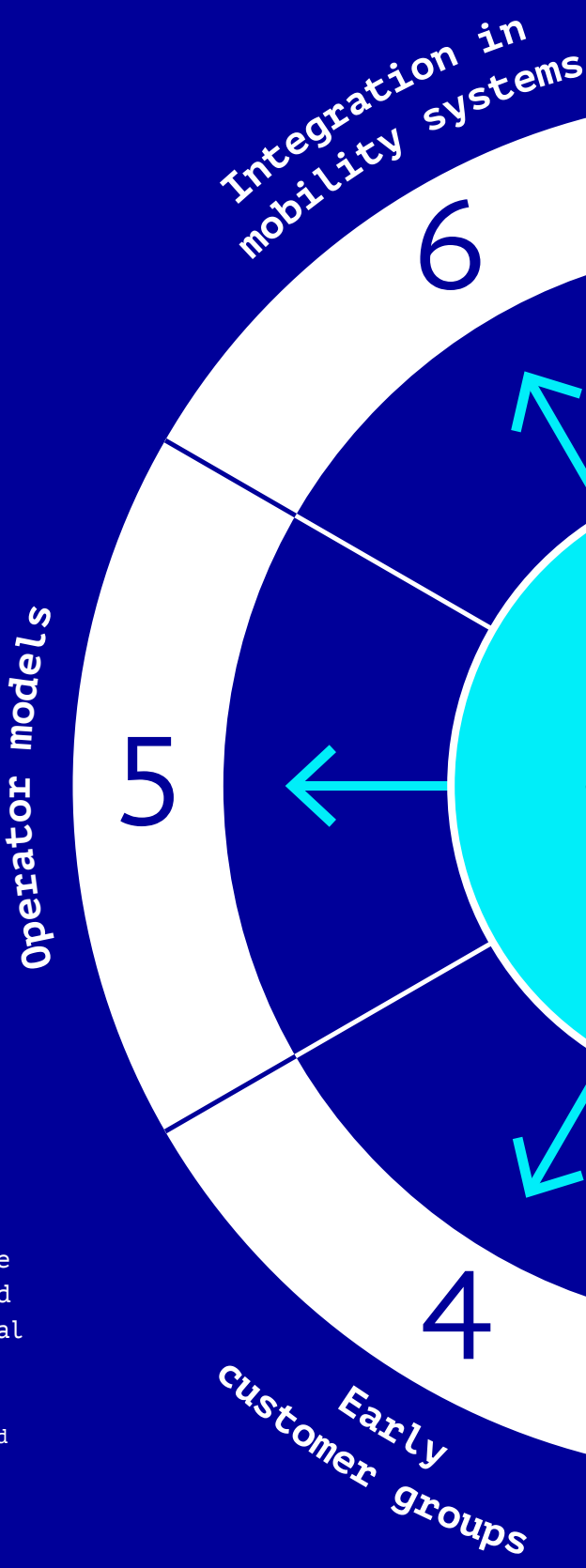


The Aspirations and Reality of Shared Autonomous Mobility – Perspectives in Comparison

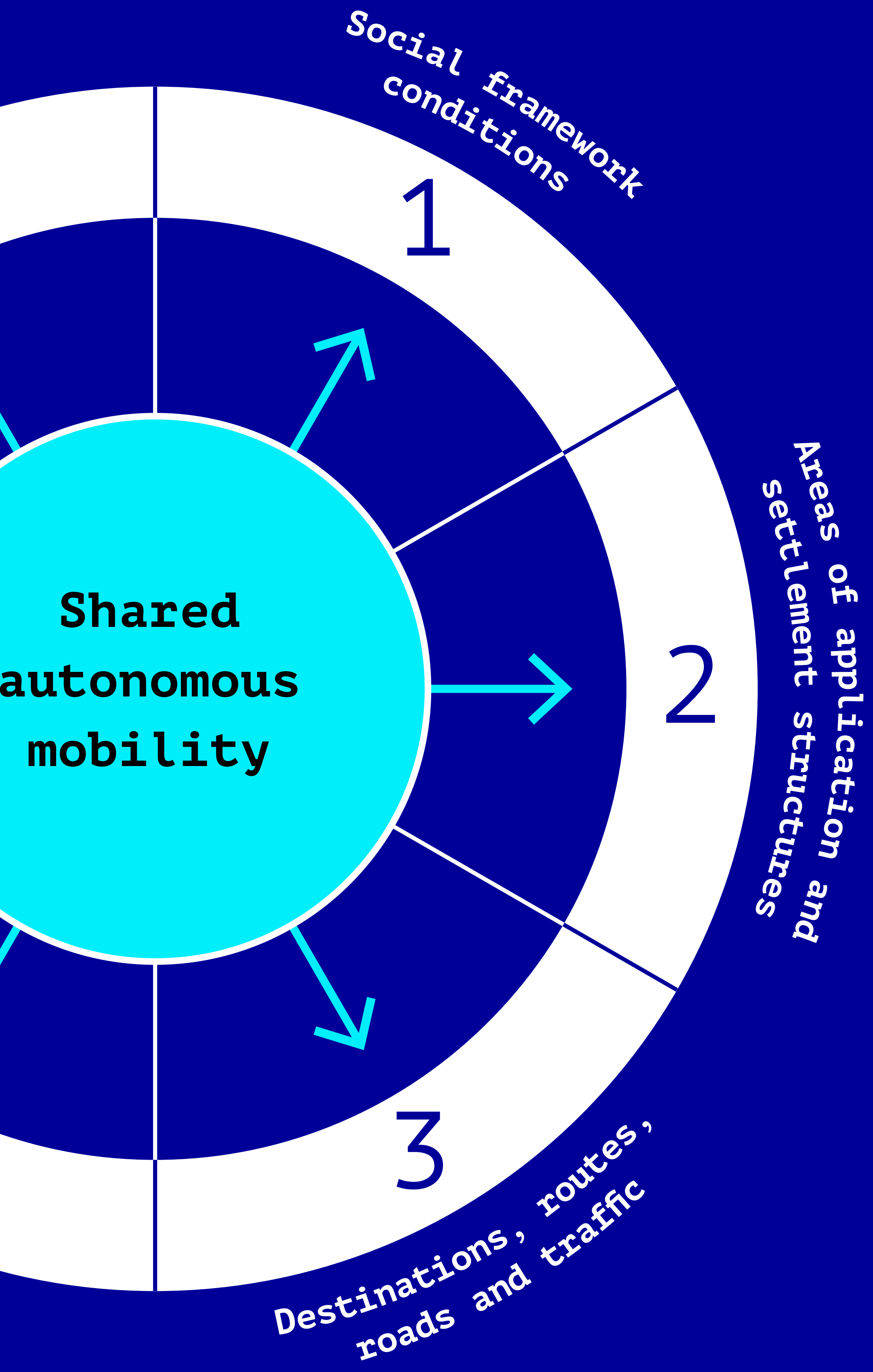
The extent to which shared autonomous mobility services are actually accepted and used depends on a number of factors. We look at six design areas that must be taken into account when developing business models and operating autonomous mobility services (see Figure 14). The results presented are mainly based on the survey of users.

The assessment and evaluation of the findings with regard to feasibility, viability, and technical implementation are mirrored with international experts and possible gaps are identified.



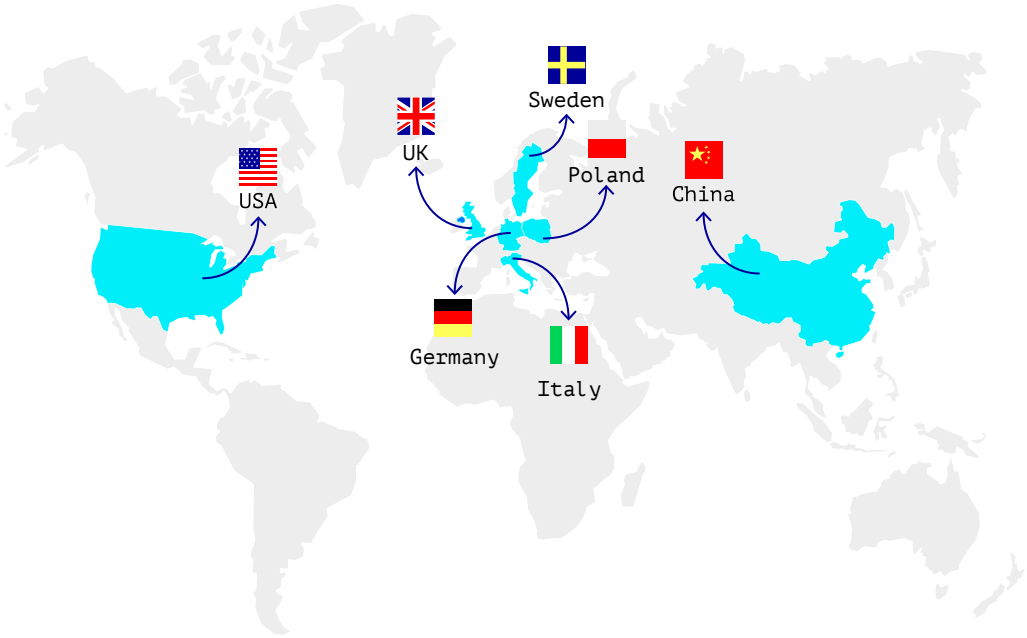
Reduced journeys and fewer private vehicles through the use of shared autonomous mobility as environmental added value.

Figure 14: Acceptance factors for shared autonomous mobility


Shared autonomous mobility
1
Social framework conditions
2
Areas of application and settlement structures
3
Destinations, routes, roads and traffic

Social Framework Conditions: Autonomous Mobility Is Promoted Worldwide

The social context plays an important role in correctly classifying the results within the regions of Europe, China, and the USA. Relevant country KPIs are presented below. Relevant country KPIs are presented below. For example, it becomes clear that the German sample is significantly older than the Chinese respondents due to its structure, which has an impact on the degree of openness to shared autonomous mobility and individual preferences and requirements.



The country-specific information on the classification of the respective market is compared in three categories:

- **Social KPIs**
- **Structural sample description**
- **Legal framework**

This background information is included in the interpretation of the results and reflects the current state of the markets in the field of autonomous driving and social developments in general.

Social KPIs

	Country	Population	Population growth	Share of urban population	GDP per capita (2020)
	China	1,410,539,758	+0.2%	63%	$16,400
	USA	337,341,954	+0.7%	83%	$60,200
	Germany	84,316,622	-0.1%	78%	$50,900
	UK	67,791,400	+0.5%	84%	$41,600
	Italy	61,095,551	-0.1%	72%	$39,000
	Poland	38,093,101	-0.3%	60%	$32,200
	Sweden	10,483,647	+0.5%	89%	$50,700

Figure 15: Social KPIs
Quelle: CIA World Factbook

Structural sample description

	Country	Average age	Vehicle ownership	Public transport satisfaction (average: 1 = not satisfied at all / 5 = very satisfied)	Already driven with an autonomous vehicle
	China	40.4 years	88%	1👎 — M=3.92 — 👍5	32%
	USA	46.3 years	84%	1👎 — M=3.19 — 👍5	13%
	Germany	49.2 years	78%	1👎 — M=3.43 — 👍5	7%
	UK	47.0 years	77%	1👎 — M=3.45 — 👍5	15%
	Italy	48.8 years	93%	1👎 — M=3.07 — 👍5	5%
	Poland	45.1 years	84%	1👎 — M=3.64 — 👍5	6%
	Sweden	48.2 years	67%	1👎 — M=3.65 — 👍5	11%

Figure 16: Structural sample description
Survey (China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

Current legal framework for autonomous driving

China	▪ Testing of automated vehicles on public roads permitted on defined sections under strict requirements and restrictions (Glueck & Wu, 2022). ▪ Directive on the commercial use of fully autonomous vehicles in public transport (Deng, 2022; Reuters, 2022). ▪ UN Regulation No. 157 (UNECE, 2022): Increase in the maximum permitted speed from 60 km/h to 130 km/h when driving automatically under certain traffic conditions.
USA	▪ No harmonized legal framework for all states: individual directives (CONNECTED AUTOMATED DRIVING EUROPE, 2022). Mostly different regulations (Bellon, 2022) ranging from limited testing to full use of the technology. ▪ Automated Vehicles Comprehensive Plan (U.S. DEPARTMENT OF TRANSPORTATION, 2021): Promotion of cooperation and transparency, modernization of the regulatory environment, preparation of the transport system. ▪ UN Regulation No. 157 (UNECE, 2022): Increase in the maximum permitted speed from 60 km/h to 130 km/h when driving automatically under certain traffic conditions.
Germany	▪ Law on autonomous driving (BMVI, 2021): Nationwide driver's license for automated motor vehicles (Level 4) in specified operating areas in public road transport in regular operation. ▪ EU Vehicle General Safety Regulation (European Commission, 2022): Regulatory framework for the approval of automated vehicles; technical requirements for Level 3 and Level 4 vehicles planned. ▪ UN Regulation No. 157 (UNECE, 2022): Increase in the maximum permitted speed from 60 km/h to 130 km/h when driving automatically under certain traffic conditions.

In addition to social KPIs, population-specific structures, and legal framework conditions, existing problems (pain points) in the general traffic situation can also have an impact on the acceptance and evaluation of shared autonomous mobility concepts. The following section presents the current challenges in the respective markets and offers the opportunity to reflect wishes and expectations with autonomous mobility solutions.

UK	▪ Testing of all levels of automation on public roads permitted under legal requirements (test drivers, vehicle safety, adequate insurance) (Kalman & Cooper, 2020). ▪ The Highway Code (UK Department for Transport, 2022): Section on "Self-driving vehicles" introduced: Permission to transfer the driving task to the vehicle in certain situations. ▪ UN Regulation No. 157 (UNECE, 2022): Increase in the maximum permitted speed from 60 km/h to 130 km/h when driving automatically under certain traffic conditions.
Italy	▪ Decree February 28, 2018 (CMS, 2020; Gazetta Ufficiale, 2018): Testing of Level 3 and Level 4 automated vehicles on public roads is only permitted after approval by the Ministry. ▪ EU Vehicle General Safety Regulation (European Commission, 2022): Regulatory framework for the approval of automated vehicles; technical requirements for Level 3 and 4 vehicles planned. ▪ UN Regulation No. 157 (UNECE, 2022): Increase in the maximum permitted speed from 60 km/h to 130 km/h when driving automatically under certain traffic conditions.
Poland	▪ Testing of automated vehicles on public roads permitted for Levels 3 and 4, provided that conditions are met, and it is guaranteed that safety drivers can take over the controls (Koryzma & Komorowska, 2020; Krawczyk, 2018). ▪ EU Vehicle General Safety Regulation (European Commission, 2022): Regulatory framework for the approval of automated vehicles; technical requirements for Level 3 and 4 vehicles planned. ▪ UN Regulation No. 157 (UNECE, 2022): Increase in the maximum permitted speed from 60 km/h to 130 km/h when driving automatically under certain traffic conditions.
Sweden	▪ Testing of automated vehicles on public roads is possible after approval by the transport authority. Approval requires proof that operation is carried out in a safe manner (Transport Styrelsen, 2021). ▪ Announcements regarding implementation of Levels 4 and 5 within five years in Sweden (WISTRAND, 2022). ▪ UN Regulation No. 157 (UNECE, 2022): Increase in the maximum permitted speed from 60 km/h to 130 km/h when driving automatically under certain traffic conditions.

Lack of (parking) space as a global driver of shared autonomous mobility

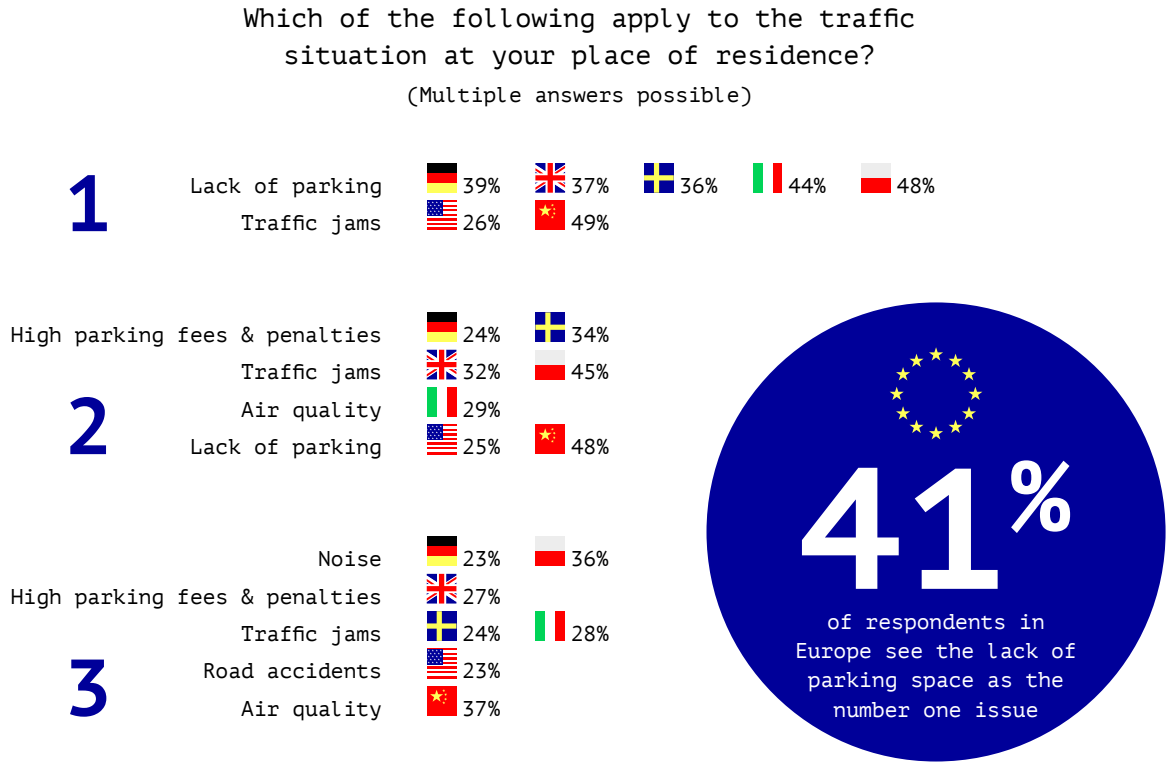


Figure 17: Pain Points Group comparisons/top three per market
Source: Fraunhofer (Variances of 100% due to 'none of the above')
(China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

- Across the different countries, it is clear that a lack of parking spaces is one of the most important problem areas in the traffic situation. The need for sufficient parking spaces for private cars is the top priority in Europe, but is also critical in China and the USA.
- Traffic jams play a major role, especially in the USA and China.
- In addition, it is noteworthy that in the USA, Sweden, and Germany, almost one third of the respondents state that they have no problems with the current traffic situation. Here, it can be assumed that there is a tendency for higher satisfaction. Poland and China, on the other hand, see significant potential for optimization; only under one in ten respondents sees no problems with the traffic situation in these countries.

- The comparison of pain points and the expected benefits of autonomous mobility also shows a high degree of congruence across countries.

- From the perspective of potential users, autonomous vehicles are therefore able to solve the current pain points and improve the mobility situation.

Expert reflection:

- There is consensus and broad agreement on the part of the experts: All regions or governments promote autonomous mobility in principle and allow for a regulatory framework to be implemented.

- This is achieved in different ways:
    - **Europe:** Deliberate and proactive creation of framework conditions for automated driving, as well as new mobility solutions.
    - **USA:** High level of freedom or flexibility to try out new technologies and business models.
    - **China:** Rapid adjustments and proactive government support to promote technology and business models.

Quote from automotive OEM: Europe is leading the way – passive support in terms of establishing a clear framework is more important than active support.

Quote from ride-sharing provider (private sector): Europe is establishing the necessary framework for reliable operator models.

Quote from automotive OEM: Autonomous driving is an important issue in China as a way to distinguish itself from "the West." This is demonstrated not only by the interest at a state level, but also by the high degree of openness in society when it comes to innovation and technology.

- Among the experts, there is broad agreement that the adaptation of legal framework conditions will not be an obstacle.

- The European market is slightly behind schedule in the country comparison due to its extensive processes. However, this is not considered problematic, as this will ensure legal certainty.

- There is fundamental agreement on data security. According to experts, data protection will not be a central problem. The European market is more careful and cautious in this respect, but such concerns can be removed or technically resolved.

With everything you know or even presume, what do you personally see as **general advantages** of **shared autonomous vehicles**?

Sweden

City → High parking fees & penalties

Town/small town in an urban area → High parking fees & penalties

Town/small town not in an urban area → Lack of parking

Rural area close to a town/city → Lack of parking

Top expected improvement

Affordable price

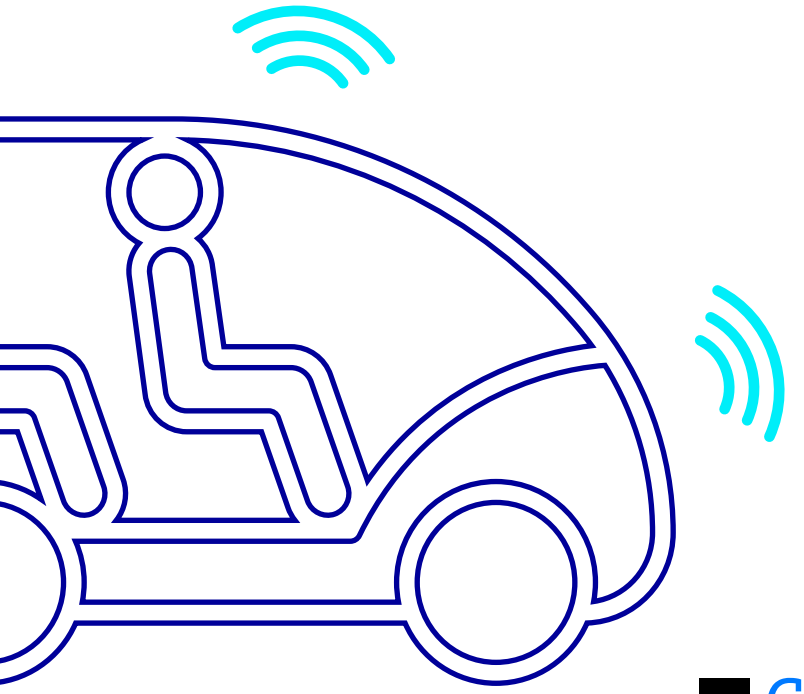
No difficulty finding parking

Top expected improvement

Rural area close to a smaller town

→ Lack of parking
→ It takes a long time to travel to go shopping, see a doctor, or visit a government office

Figure 18: Comparison of pain points and expected improvements
Top ranking by country and area type
Source: Fraunhofer
(Germany: n=512; Sweden: n=545)



Germany

City → Lack of parking

Town/small town in an urban area → Lack of parking

Town/small town not in an urban area → Lack of parking

Rural area close to a town/city → Lack of parking

No difficulty finding parking

Top expected improvement

Flexibility

Rural area close to a smaller town

→ It takes a long time to travel to go shopping, see a doctor, or visit a government office

Top expected improvement

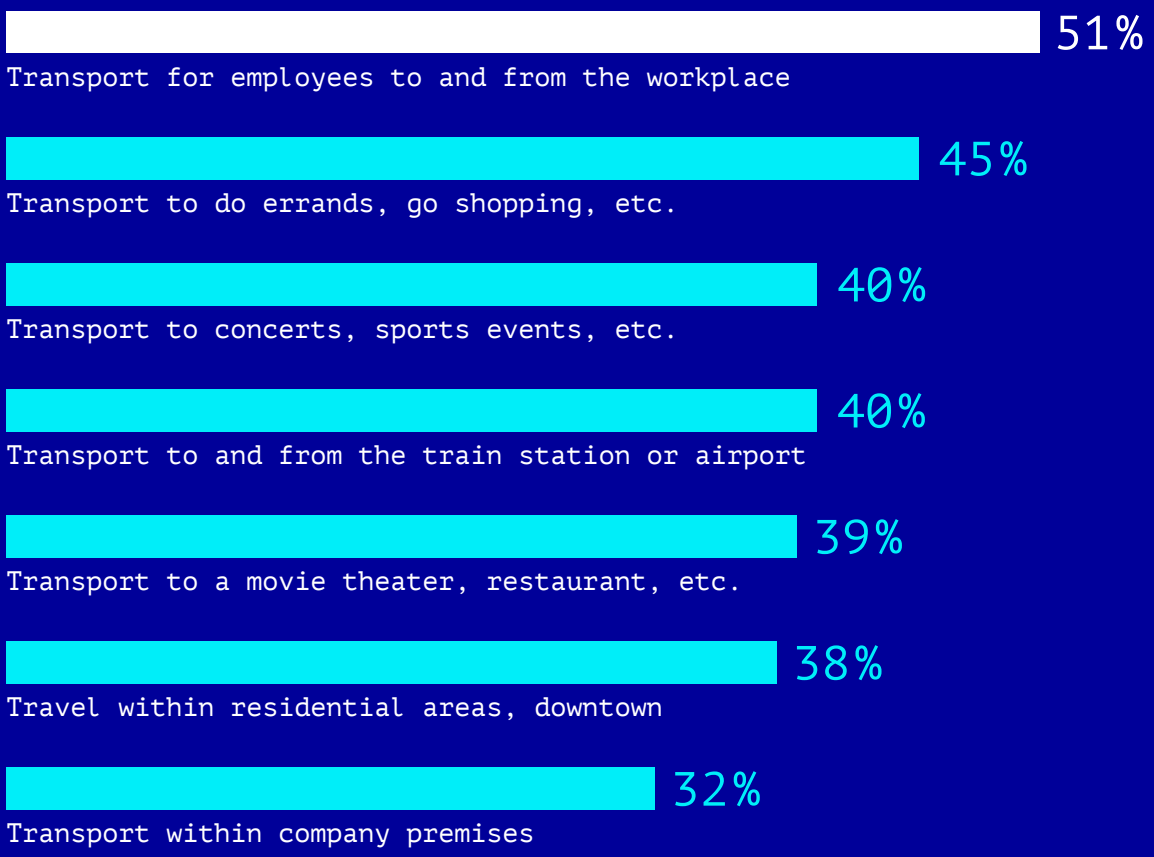
Areas of Application and Settlement Structures: Autonomous Mobility Is in Demand Everywhere – Differences in Requirements Between Urban and Rural Areas

At present, many projects and researchers are concentrating on the analysis and fields of application of shared autonomous mobility in urban areas, but rural areas in particular – which are often poorly connected – could be pioneering fields of application for autonomous mobility. The respective traffic situation, public transport infrastructure, settlement situations and the accessibility of offices, medical care, educational institutions, or convenience stores have a direct impact on possible uses of autonomous mobility. In the following, we show to what extent the urban and rural population differs in its demands and requirements and what this means for the use of shared autonomous mobility.

In China and the USA, the focus is on urban commuting – European countries prefer the connection of (urban) transport hubs

- The transport of employees to and from the workplace is the most frequently mentioned field of application of shared autonomous mobility for all countries.
- The use of shared autonomous mobility within company premises is the least frequently chosen by the respondents.
- A comparison of countries shows that journeys to and from the workplace are mainly preferred in Poland, Italy, the USA, and China. In Germany and Sweden, these journeys seem to have less relevance.
- Transportation within company premises only finds favor in China.
- The European respondents are more in favor of transport routes to the railway station or airport. This purpose received the least approval in China.

Below we have listed specific services in which shared autonomous vehicles could be used in the future. Which of the following services would you like to see?
(Multiple answers possible)



Figures 19: Desired fields of use for shared autonomous vehicles
n=4,868

Below we have listed specific services in which shared autonomous vehicles could be used in the future. Which of the following services would you like to see?
(Multiple answers possible)

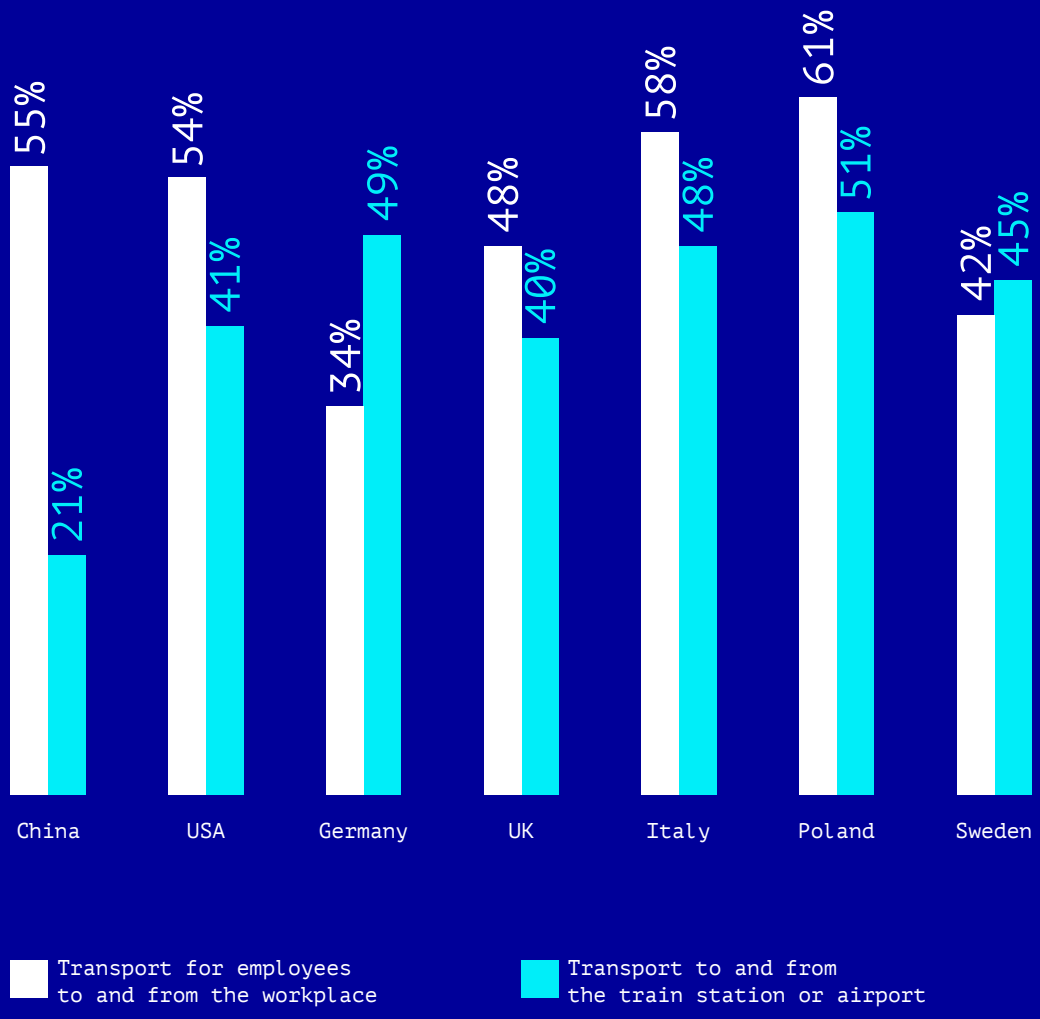


Figure 20: Selection of desired fields of use for shared autonomous vehicles
(China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

Flexible and punctual journeys to work - urbanites want autonomous mobility to commute in urban areas

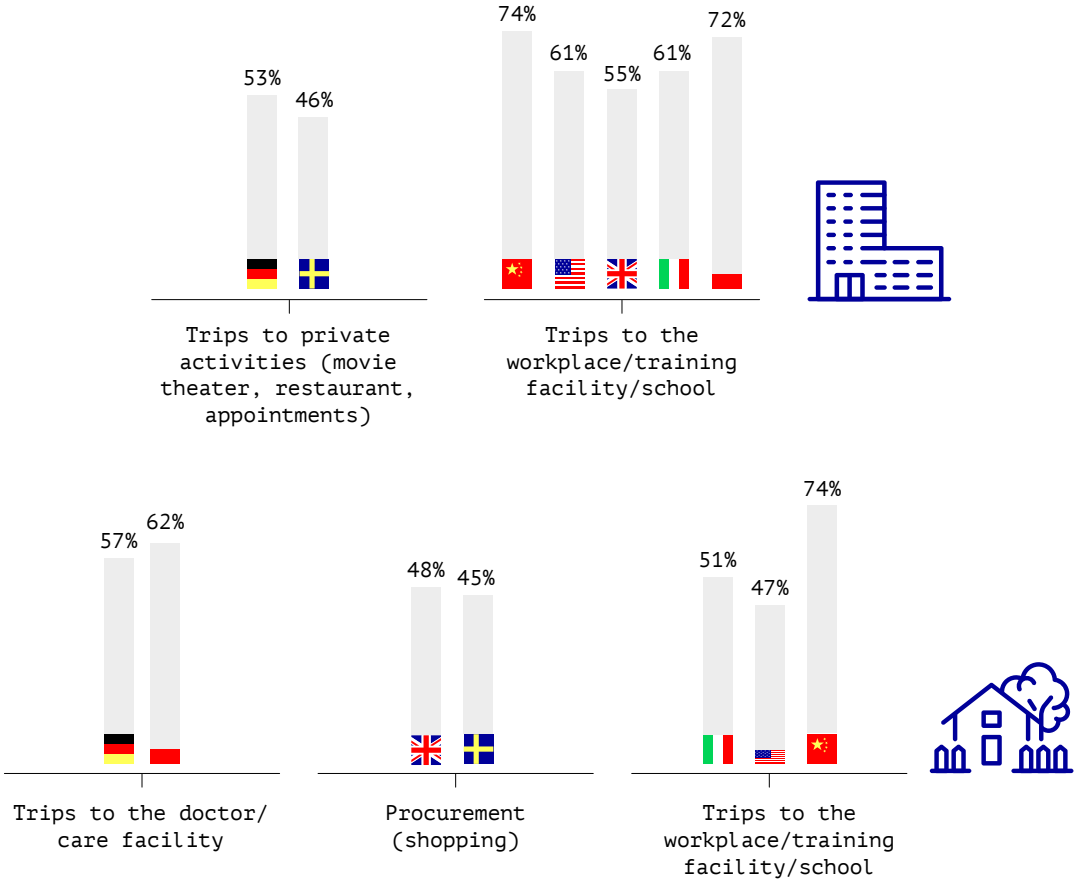


Figure 21: Desired journey types in urban and rural areas
(China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)
Note: Urban areas were defined by city type “large city,” while rural areas were defined by the city type “rural area near smaller cities”

- In urban areas, it is evident for all countries (except Germany) that journeys to reach the workplace/educational institution are generally the most suitable.
- This is also the case in urban areas in the UK. In rural areas, on the other hand, the use of autonomously driven vehicles is particularly suitable for errands.
- In Germany, a preference for journeys for the purpose of private activities is emerging irrespective of region. In rural areas, journeys (e.g., errands/doctors’ appointments) in particular are preferred. A similar pattern can be seen in Sweden.
- In rural areas of Europe, it is predominantly apparent that privately motivated journeys (e.g. errands/doctors’ appointments) are prioritized.

Expert reflection:

- The USA in particular is highlighted by the experts with reference to suburbs (wide roads, designed for cars) as well as inner cities (timed traffic lights, clearly defined residential blocks) as very suitable areas for the operation of shared autonomous mobility concepts.

- For China, it is pointed out that new urban areas are planned and built in a structured manner, whereas existing areas are only suitable to a limited extent.

- The assessments of European markets show a mixed picture: There is a fundamental suitability for the operation of shared autonomous mobility in urban areas, but with significant limitations when it comes to historic city centers. Due to historical construction standards (e.g., narrow streets), the infrastructure here presents major barriers to the operation of autonomous mobility.

- In terms of the suitability of the infrastructure with regard to coverage in all three regions, rural areas are seen in a more critical light because roads, lanes, and traffic areas are often ambiguous, and telecommunications coverage is patchy in many places. Furthermore, there may be external influencing factors such as dirty roads, wild animals, and tractors. However, setting up selected routes in rural areas is considered realistic.

- Within Europe, rural areas in southern and eastern Europe in particular are considered by experts to be unsuitable for the time being due to the often poor quality of the infrastructure.

- China is seen by the experts as having an advantage when it comes to setting up Car2X infrastructures. The experts are rather critical of developments in Europe as well as in the USA.

Quote from automotive OEM: Autonomous driving will gradually spread in a way that is comparable to network coverage for mobile phones, only much slower. In rural areas, only selected solutions will initially be implemented, and it will take a long time for coverage to be as complete as possible.

Quote from automotive OEM: Autonomous driving is more a question of urban structures and transport infrastructures than of the global region.

Quote from mobility start-up: Depending on the route and time of day, it is conceivable that autonomous vehicles could operate at reduced speed in rural areas – for example, a speed of 50 to 60 km/h on rural roads should not be a major obstacle to traffic during journeys made at night.

Destinations, Routes, Roads, and Traffic – Market-Specific Fields of Application Vary Greatly and Require Demand-Oriented Design

A wide range of framework conditions still need to be defined for shared autonomous mobility services. One aspect that is currently under discussion is road use. Specifically, it must be determined to what extent autonomous mobility requires a segregated lane or whether the vehicles can operate in mixed traffic (Razmi Rad et al., 2020). However, to answer this question, it is first of all necessary to identify the travel purposes and journeys for which users would use shared autonomous vehicles in the first place and what influence segregated lanes have on the entire situation and route design.

Autonomous mobility as an attractive option for reaching a workplace or educational institution

- Respondents see the greatest potential of shared autonomous mobility across the board as commuting journeys to the workplace or educational institution.
- Shorter business trips are only considered significant in China.
- Overall, it appears that journeys in shared autonomous vehicles are considered to be less suitable for dropping off and picking up individuals as well as for children or adolescents traveling alone.

In your opinion, which types of journey would generally be well suited to travel by shared autonomous vehicles?
(Multiple answers possible)

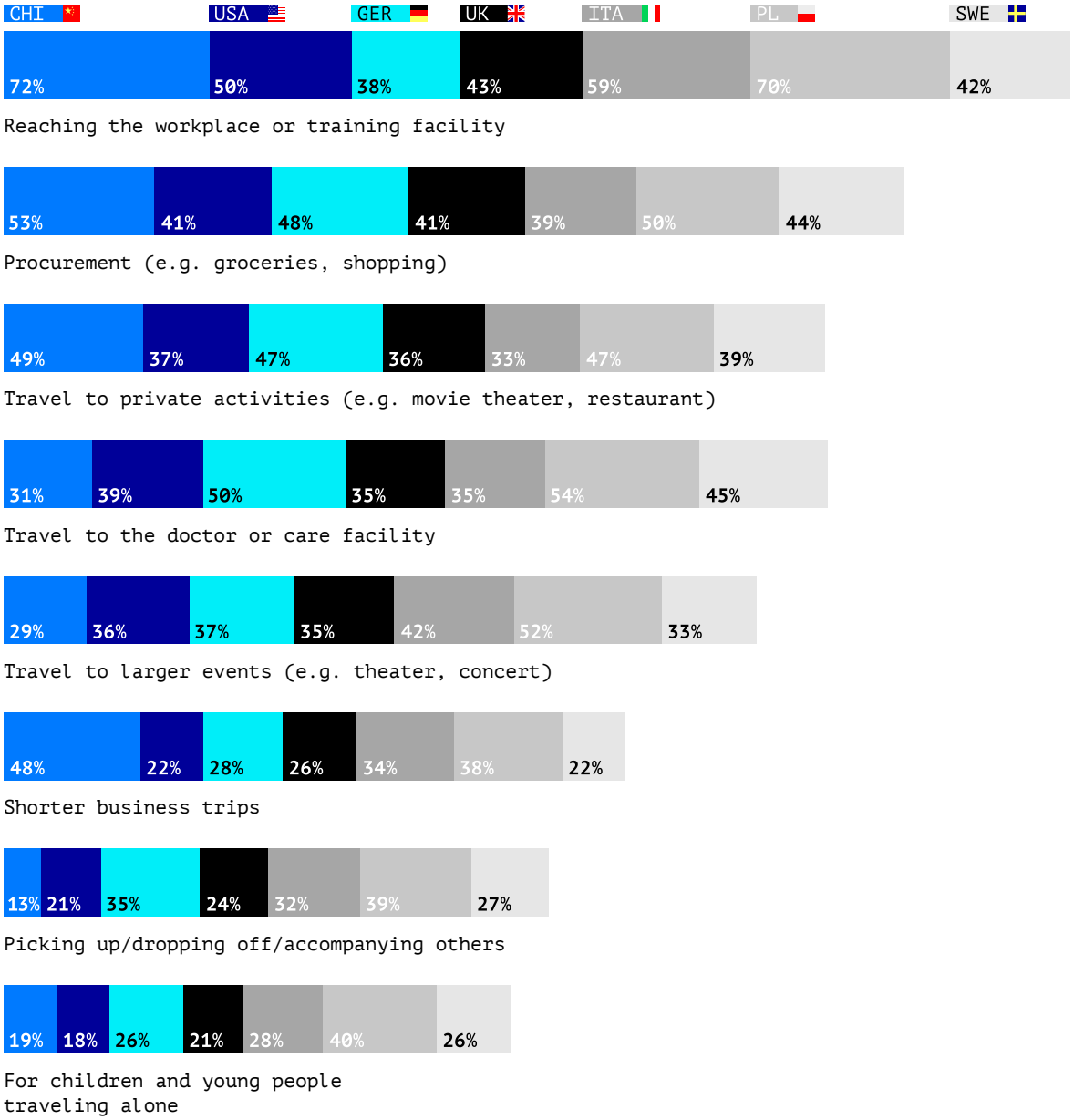


Figure 22: Suitability for autonomous travel
(China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

Shared autonomous mobility as improved public transport

When looking at the results, it becomes clear that: Shared autonomous mobility is to revolutionize the conventional public transport system and provide a more comfortable, flexible, and generally optimized range of services. The following figure shows the relevance of individual factors in comparison to conventional public transport:

How important are the following aspects to you when using a **shared autonomous vehicle compared to using public transport**?
(Top 2 Boxes)

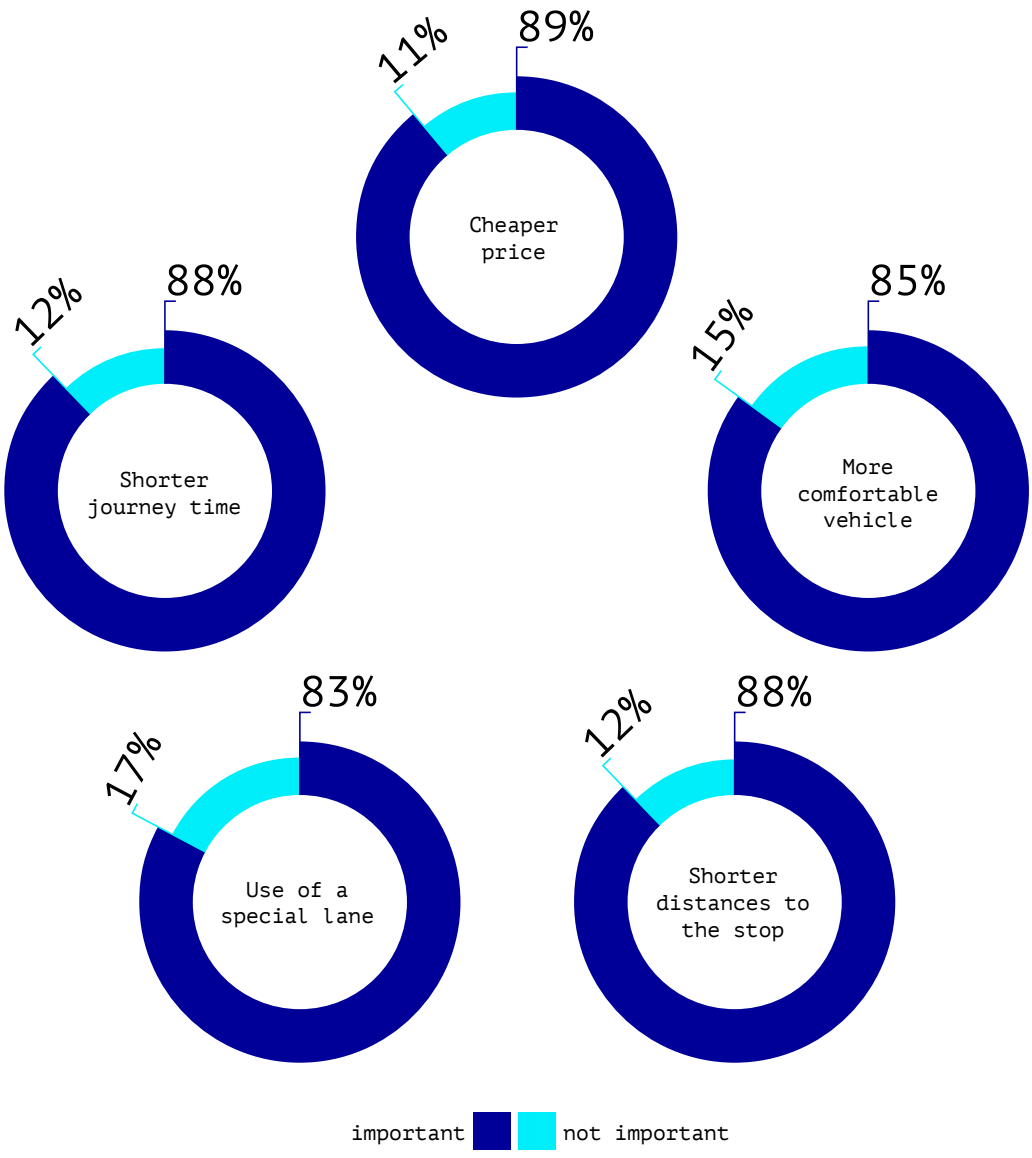


Figure 23: Shared autonomous vehicle vs. public transport
(China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

- For all countries, there is a clear acceptance that autonomous mobility can offer better performance in all categories than conventional public transport.
- It is noteworthy that, despite higher quality standards, there is no willingness to pay more. Four out of five respondents indicated that shared autonomous mobility should be cheaper than public transport in comparison.
- In China and Poland, it is perceived as more important that autonomous traffic has segregated lanes than in other countries.

Expert reflection:

- There is disagreement between the experts as to whether early autonomous vehicles should move freely in an area or on separate routes.

- The traffic behavior of Germans is perceived as very structured and regulated, which is regarded positively in the context of the implementation of an automated system. In China, mixed traffic is seen in a more critical light in terms of perceived traffic behavior, which tends to involve complex traffic situations.

- Separate lanes are favored mainly in China and only in special cases in the USA. This does not seem conceivable for Europe, especially as the high density of construction within cities would prohibit this in many places. In Germany in particular, the construction of additional traffic areas is generally not accepted by the population and must be supported by good reasoning. In China, too, the extent to which older urban building structures and road networks permit the integration of separate lanes is questionable.

- In all three regions, the use of bus or tram lanes by autonomous vehicles is considered by experts as a possible scenario, assuming the level of utilization is taken into account.

- Providers of ride-sharing services see an early need in services for autonomous factory mobility and are trying to offer mobility beyond the factory boundaries.

- Ride-sharing service providers have good experience with virtual stops, while automotive OEMs foresee door-to-door services.

Quote from ride-sharing provider (private sector): The users see our virtual stops very favorably; having to walk a few meters to them is well accepted. It is more problematic in terms of acceptance when virtual stops are frequently changed.

Quote from automotive OEM: Business trips typically run on dedicated routes, while private trips are more diverse. In early phases, business and company trips can therefore be covered more logically with dedicated and approved routes for autonomous vehicles.

Quote from automotive OEM: While Germans tend to be fast and aggressive drivers who are on the road a lot, almost no other country in the world structures and regulates its traffic and the behavior of road users as effectively. These are the optimal conditions for an automated technical system that primarily encounters issues in the event of irregularities.

Early Customer Groups: Multimodal Lifestyle as a Forerunner of Shared Autonomous Mobility

The early adopters of new technologies are crucial for the diffusion process and are called innovators (Rogers, 2003). In the scope of our study, we are looking at all those people who already believe that they will make a great deal of use of autonomous mobility. They are crucial for assessing a market approach and for identifying business potential. But what exactly do these innovators look like in the different markets?

CN

Sample size n=373
Share of total sample 53%

Male: 53%
Female: 48%

Age

18-24: 15%
25-34: 22%
35-44: 21%
45-54: 21%
55-64: 11%
65+: 11%

Place of residence

City: 79%
Town/small town in an urban area: 11%
Town/small town not in an urban area: 5%
Rural area close to a town/city: 4%
Rural area: 1%

Mobility

Car ownership: 9%
Use of public transport: 59%
Use of shared mobility: 68%

USA

Sample size n=118
Share of total sample 20%

Male: 63%
Female: 37%

Age

18-24: 17%
25-34: 28%
35-44: 30%
45-54: 16%
55-64: 6%
65+: 4%

Place of residence

City: 51%
Town/small town in an urban area: 19%
Town/small town not in an urban area: 11%
Rural area close to a town/city: 10%
Rural area: 9%

Mobility

Car ownership: 84%
Use of public transport: 30%
Use of shared mobility: 42%

D

Sample size n=69
Share of total sample 14%

Male: 49%
Female: 51%

Age

18-24: 17%
25-34: 17%
35-44: 23%
45-54: 15%
55-64: 12%
65+: 16%

Place of residence

City: 51%
Town/small town in an urban area: 16%
Town/small town not in an urban area: 7%
Rural area close to a town/city: 7%
Rural area: 19%

Mobility

Car ownership: 77%
Use of public transport: 61%
Use of shared mobility: 32%

UK

Sample size n=76
Share of total sample 14%

Male: 61%
Female: 40%

Age

18-24: 17%
25-34: 30%
35-44: 34%
45-54: 12%
55-64: 3%
65+: 4%

Place of residence

City: 63%
Town/small town in an urban area: 16%
Town/small town not in an urban area: 9%
Rural area close to a town/city: 5%
Rural area: 7%

Mobility

Car ownership: 86%
Use of shared mobility: 47%
Use of public transport: 53%

I

Sample size n=77
Share of total sample 14%

Male: 51%
Female: 49%

Age

18-24: 9%
25-34: 18%
35-44: 30%
45-54: 21%
55-64: 12%
65+: 10%

Place of residence

City: 42%
Town/small town in an urban area: 25%
Town/small town not in an urban area: 18%
Rural area close to a town/city: 4%
Rural area: 10%

Mobility

Car ownership: 94%
Use of public transport: 64%
Use of shared mobility: 49%

PL

Sample size n=127
Share of total sample 23%

Male: 52%
Female: 48%

Age

18-24: 12%
25-34: 21%
35-44: 21%
45-54: 19%
55-64: 17%
65+: 11%

Place of residence

City: 47%
Town/small town in an urban area: 31%
Town/small town not in an urban area: 15%
Rural area close to a town/city: 2%
Rural area: 4%

Mobility

Car ownership: 87%
Use of public transport: 72%
Use of shared mobility: 55%

SE

Sample size n=100
Share of total sample 18%

Male: 59%
Female: 41%

Age

18-24: 13%
25-34: 21%
35-44: 28%
45-54: 13%
55-64: 13%
65+: 12%

Place of residence

City: 50%
Town/small town in an urban area: 23%
Town/small town not in an urban area:14%
Rural area close to a town/city: 7%
Rural area: 6%

Mobility

Car ownership: 68%
Use of public transport: 59%
Use of shared mobility: 30%

Multimodality and sharing: drivers for innovators

China has the highest share of innovators compared to the total sample, with just under 35 per cent, suggesting lower barriers to market entry. At only 14 per cent, the share is the lowest in Germany.

- When comparing the age groups, it is apparent that Generation X (1965–1979) and Generation Y (1980–1994) are particularly receptive to shared autonomous mobility.
- For all markets, it is apparent that the early adopters of shared autonomous mobility come predominantly from urban areas.
- Public transport users as well as people who use ride-sharing services in their daily lives show a higher probability of use than people who do not use public transport or ride-sharing services. This effect is particularly pronounced among people who use active mode sharing services (e.g., bike sharing).

Expert reflection:

- For all three regions, the experts consider it necessary to develop autonomous mobility services for broad target groups in order to allow broad access to heterogeneous groups.
- In general, acceptance in Germany is thought to be a little lower due to general skepticism or at least caution with regard to innovation. It is noted, however, that this behavior can change very quickly, provided that corresponding technologies and services can be experienced in everyday life, so no disadvantage is expected here.
- On the one hand, potential users who cannot drive their own cars (e.g., older people, children) are identified as relevant by the experts, but on the other hand it is stated that these groups in particular often require a driver as a contact person or assistant (e.g., for loading baggage), which does not support the idea of autonomous mobility.

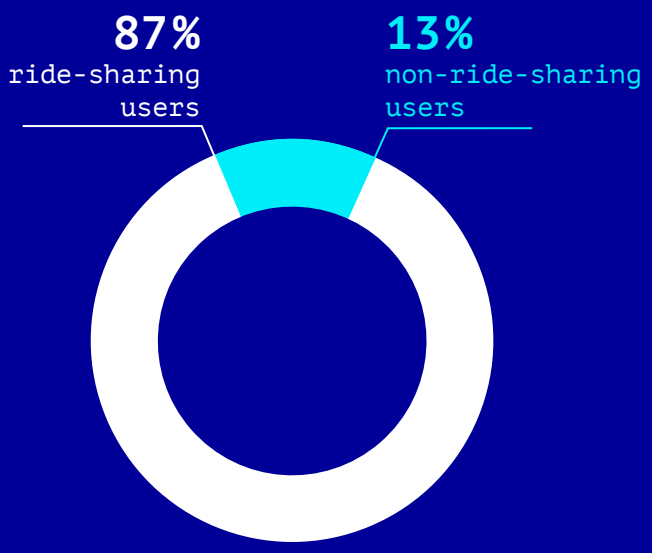
Quote from ride-sharing provider (private sector): Most of our regular customers are those who are open to new mobility services such as scooter sharing and who use them in a multimodal way.

Quote from business model expert: What is important for users when they make use of a mobility service? Comfort is usually of secondary importance, often it is time that is much more important.

Quote from technology company: Within the framework of a pilot project, we were able to observe that users accept the vehicles very quickly and perceive them almost as part of everyday life once they have used them.

“If it works and adds value, people will adopt it.”

James Gowers, CEO & CRO Matcha LLC



Expert confirmation:

Sharing customers = early adopters of ride-pooling services.

Trust transfer:

Increasing the willingness of non-sharing users to use public transport systems by integrating them.

Figure 24: Probable use of shared, autonomous vehicles by current sharing users
n=4,868; of which ride-sharing users n=1,432; non-ride-sharing users n=3,436

Operator Models: Partnerships Between Cities and the Private Sector as the Basis for Autonomous Mobility

in the following, we will identify relevant stakeholders and potential target groups and discuss possible operator and business models. Particular relevance is attributed to the stakeholders who are potential operators of shared autonomous mobility. We also discuss the relevance of strategic cooperation and the level of willingness to pay for shared autonomous mobility.

Municipal institutions as key to the operation of shared autonomous mobility

- Overall, cities and municipalities enjoy great confidence as operators of autonomously driven vehicles across all markets. The reasons for this can vary widely, ranging from the great influence of these institutions (especially in China due to the political system) and personal identification through to greater financial opportunities.
- Trust gap: Despite the fact that autonomous mobility is characterized as "high technology," potential customers trust well-known providers more than (digital) technology companies when it comes to operating autonomous mobility services.
- In the USA, trust in the public sector is lower compared with the rest of the world.
- Entertainment providers for major events and leisure activities enjoy the most confidence in China.

Which players would you trust if they offered such services?
(Multiple answers possible)

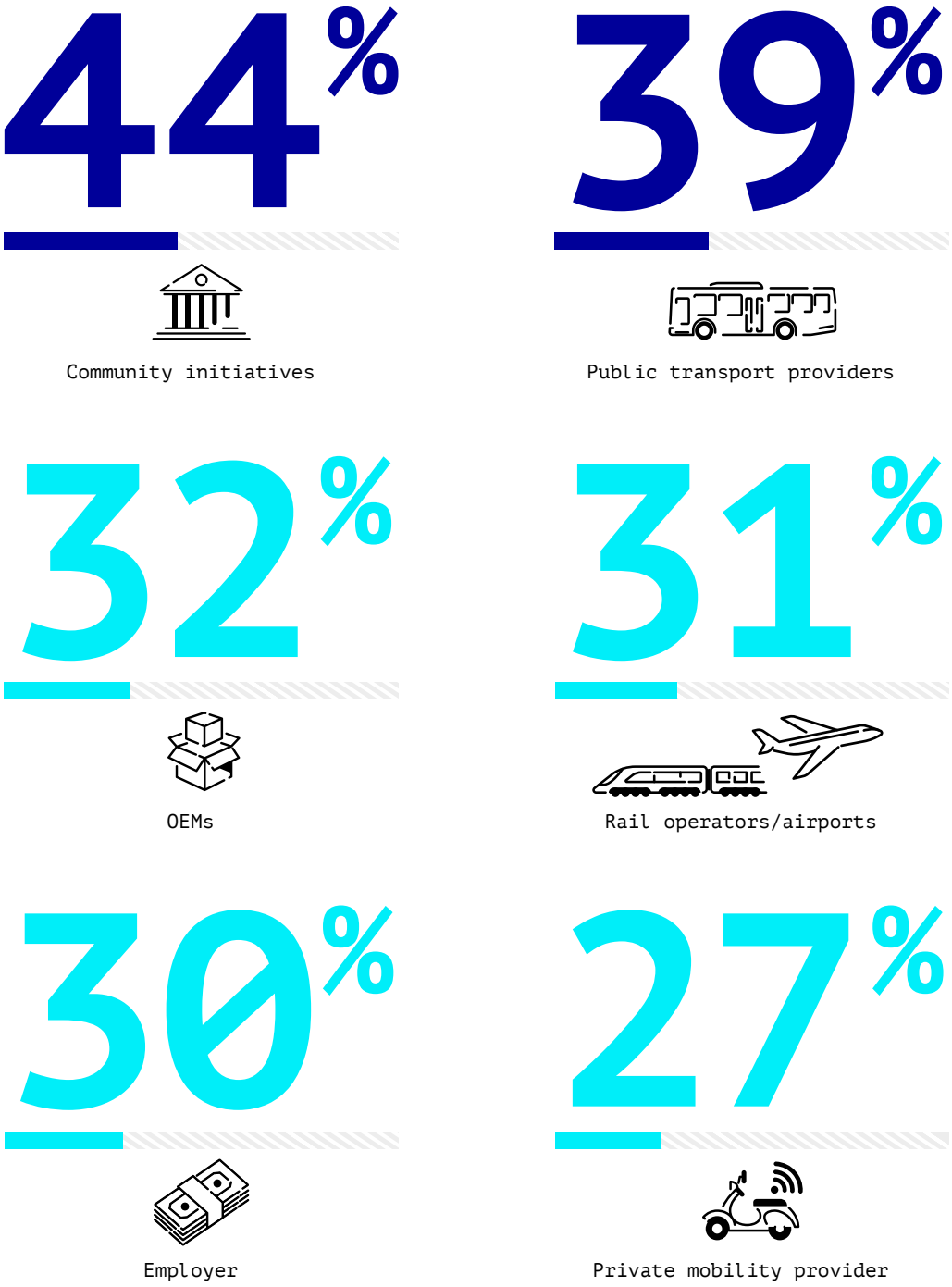


Figure 25: Top five desired operators of shared autonomous mobility
n=4,868

“Creating the right ecosystem and partnerships are the key. […] Partner with public transport operators, as they know how to run fleets efficiently.”

Amit Rosenzweig, CEO Ottopia

Employers enjoy the trust of employees

If we consider “employers” as a provider of autonomous mobility services, it is noticeable that they receive a trust bonus, especially among employees in the UK, Poland, and the USA, and receive the highest approval:

- It is clear that working generations have great confidence in their employers in offering autonomous mobility.
- This trend is particularly pronounced in the USA.
- In the UK, Poland, and the USA, young people entering the job market from the youngest age group are in favor of employers as operators of shared autonomous mobility.

“[Autonomous commuting solutions] could be a major aspect of increasing the attractiveness of the employer in the future whereas today other factors are defining the attractiveness.”

Giovanni Circela, USDAVIS

The preference of local operators as operators of autonomous mobility is also reflected in the price expectation. From the user’s perspective, the cost of a journey must be based on the public transport system.

Which providers would you trust if they offered such services?

(Multiple answers possible)

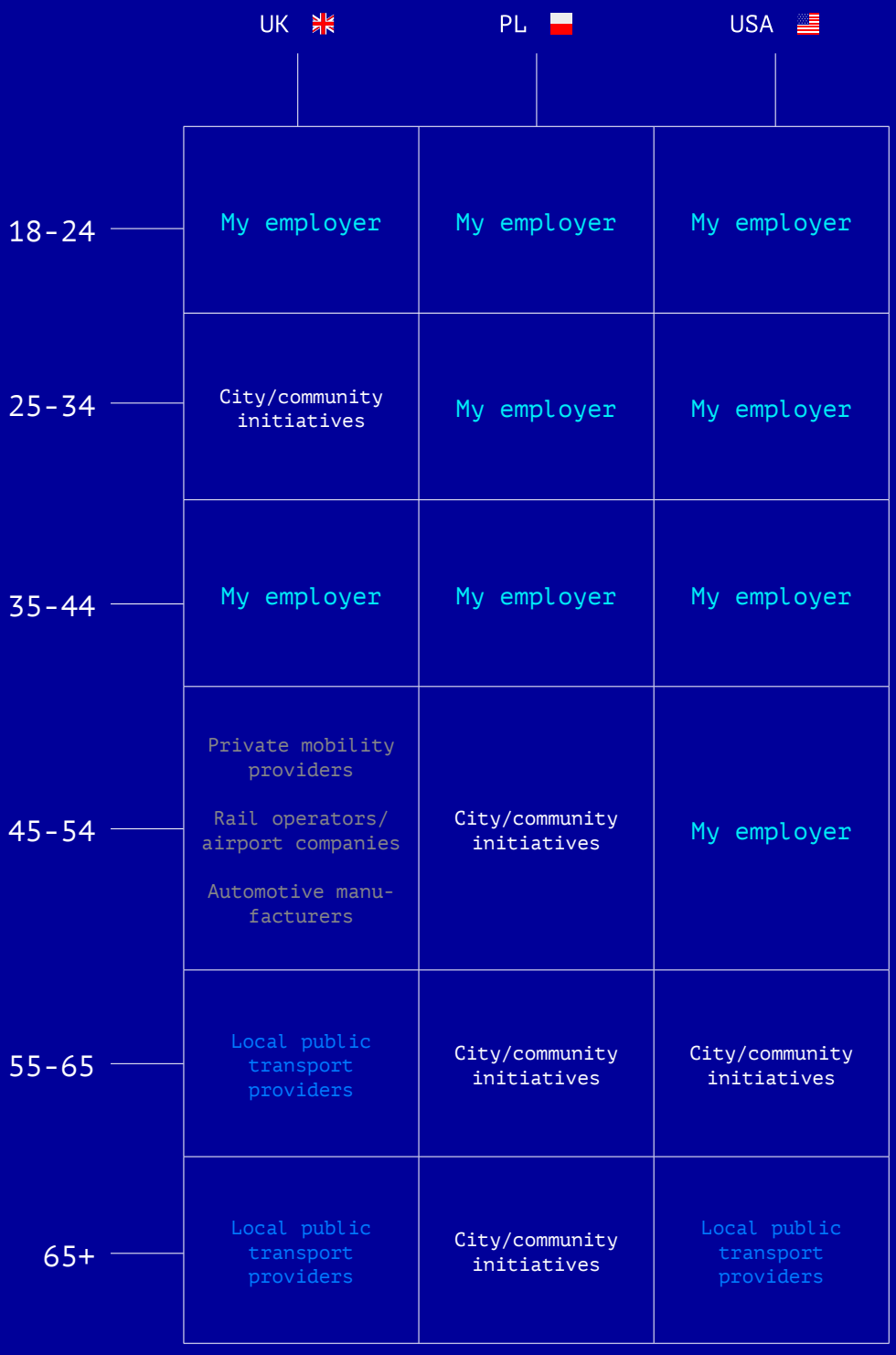


Figure 26: Ranking desired operators of shared autonomous mobility by age group (USA: n=1,089; UK: n=548; Poland: n=539)

Willingness to pay for shared autonomous mobility is based on known parameters: public transport ≤ autonomous mobility < taxi/ride-hailing

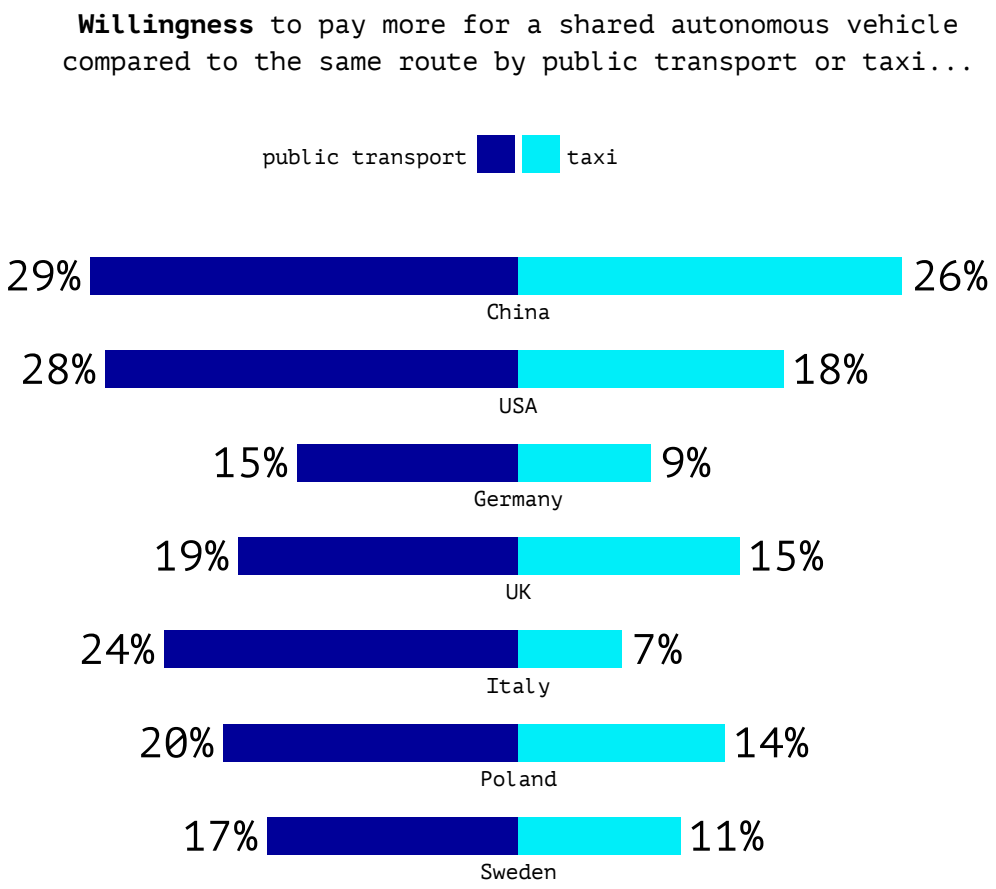


Figure 27: Willingness to pay more for autonomously driven vehicles compared to public transport and taxis (China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

Public transport providers

- Across all countries, the majority of respondents declare a willingness to pay for autonomously driven vehicles at an equivalent level to current public transport rates.
- Willingness to pay an additional price compared to the same route on the public transport system is roughly the same in the USA and China.
- In a market comparison, users in Germany are least willing to spend more money on autonomous mobility services than on public transport.

Taxi

- Compared to the willingness to pay for a taxi, it is clear across all regions that the willingness to pay more for an autonomous vehicle is lower.
- The ride-hailing users are an exception. They are willing to pay a higher price for the use of autonomous vehicles than for a regular taxi.
- In all European countries, younger generations are more willing to spend more on using an autonomous vehicle than on a taxi.

Expert reflection:

- The economic effects anticipated in all three regions, but above all in China and the USA, are seen as strong motivation for the introduction of shared autonomous mobility.

- There is disagreement as to the extent to which the availability of drivers is a relevant influencing factor. In principle, however, the reduction of drivers will lead to desired economic effects and/or a reduction in costs, as personnel still account for a large share of operating costs.
    - Countries with high salaries, such as Germany, are therefore potentially more attractive.
    - The size of public transport vehicles decreases in countries as driver salaries reduce, as more vehicles can be operated at once → Autonomous driving is therefore a factor in enabling smaller vehicle sizes and, by extension, greater flexibility.
    - Several ride-sharing providers (private sector) confirm that six seats are easily operated with current ride-sharing algorithms.

- Particularly in the USA, the scarcity of drivers is cited in relation to trucks, but also in rural areas in general, since autonomous driving enables 24/7 operation. With human drivers, it is difficult to do so at night while still covering costs.

- The drivers perform other functions that go beyond simply driving the vehicle. Accordingly, additional cost blocks must be considered, such as an operations office for live monitoring of vehicles, as well as operating yards and standardized processes for daily cleaning and equipment checks.

- In the USA, a comparison with ride-hailing services must be considered, whereby the costs for drivers not only tend to be lower, but also cover many other aspects of the business model, such as ownership of the vehicles.

- In general, it is expected that the salaries of drivers and logistics couriers in China will increase significantly, so that the availability and costs of drivers will also become a relevant topic in China.

- For Europe, primarily Germany, attention has been increasingly drawn to the special situation of subsidized public transport as well as the political task of general mobility provision, which will influence the business and operator models for autonomous mobility solutions.

Quote from business model expert: If ride hailing continues to be regulated in Europe, especially in Germany, this would create an advantage in terms of the use of shared autonomous vehicles. However, it is questionable whether this can be sustained in the long term.

Quote from business model expert: The ODD determines the necessary technology. This in turn determines the costs and thus the business model, which in turn can have an influence on the ODD.

Quote from automotive OEM: Traffic planners in Germany assume from the outset that public transport must be subsidized, meaning corresponding business models have to be calculated accordingly.

Integration into Mobility Systems: Public Mobility as a Springboard for Autonomous Mobility Solutions

(Dis)satisfaction with the public transport situation as a factor driving shared autonomous mobility?

In addition to the social concerns regarding problem areas in the traffic situation in each place of residence, we also present the opinions on the public transport situation as a whole. At the beginning, we provide an overview of the proportion of local public transport users in the markets, the extent to which respondents are satisfied with local public transport, and which aspects lead to dissatisfaction. Autonomous mobility services take these as starting points and close existing gaps.

Which of the following modes of transport have you used in the past month? (Shown: regional train/tram/subway/regional bus)
Share of **public transport users** per country

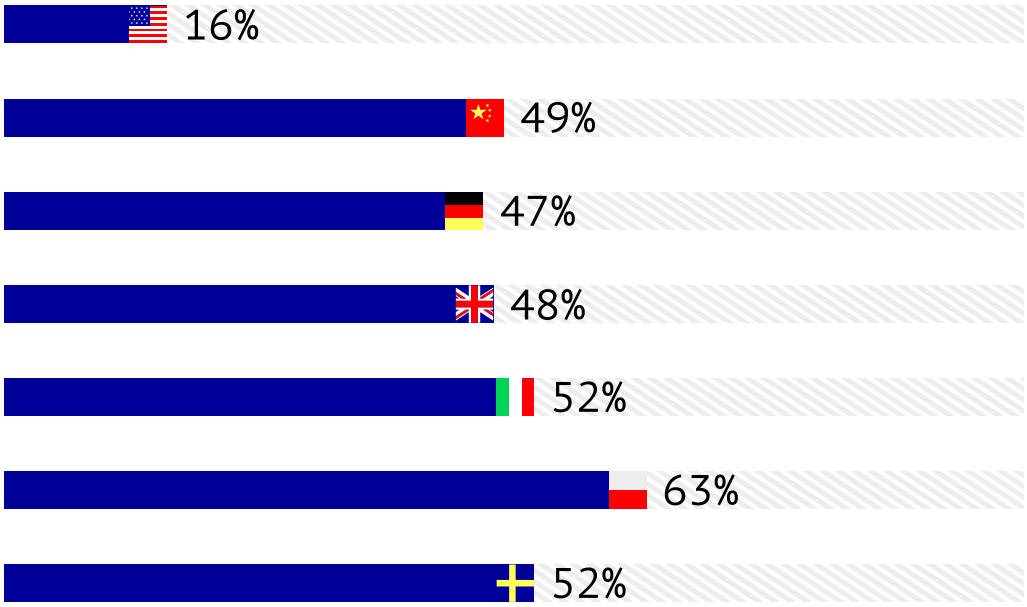


Figure 28: Share of public transport users per country
(China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

- In all the countries considered, almost every second person uses the regional public transport service. Only in the USA is there a clear rejection of public transport.
- Shared autonomous mobility can pick up from where existing services do not yet adequately cover needs. If we look at the relative proportions of those who are very dissatisfied with the performance of public transport, the highest proportion is seen in Italy and the USA.

How good is the public transport service in your place of residence? Share of **dissatisfied** public transport users per country

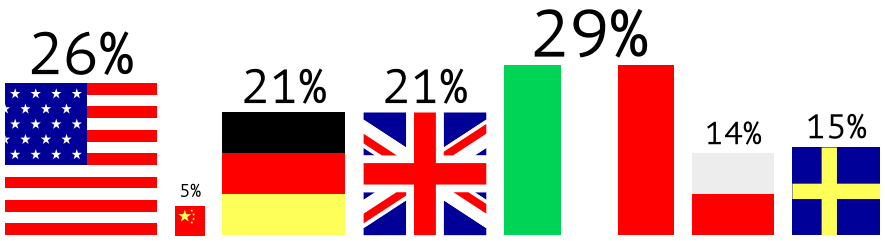


Figure 29: Share of dissatisfied public transport users per country
(China: n=53; USA: n=282; Germany: n=109; UK: n=117; Italy n=156; Poland: n=75; Sweden: n=80)

Public transport dissatisfaction due to lack of mobility and high prices can represent an opportunity for shared autonomous mobility

In order to offer a tailor-made service, it is important not only to know whether citizens are dissatisfied with public transport, but to know what the exact reasons for the discontent are. Our survey of dissatisfied local public transport users shows that the three largest pain points are due to insufficient mobility performance (frequency, punctuality, reliability) and price structure.

And why do you rate the public transport service at your place of residence as **less good**, or **not good at all**?
(Multiple answers possible)

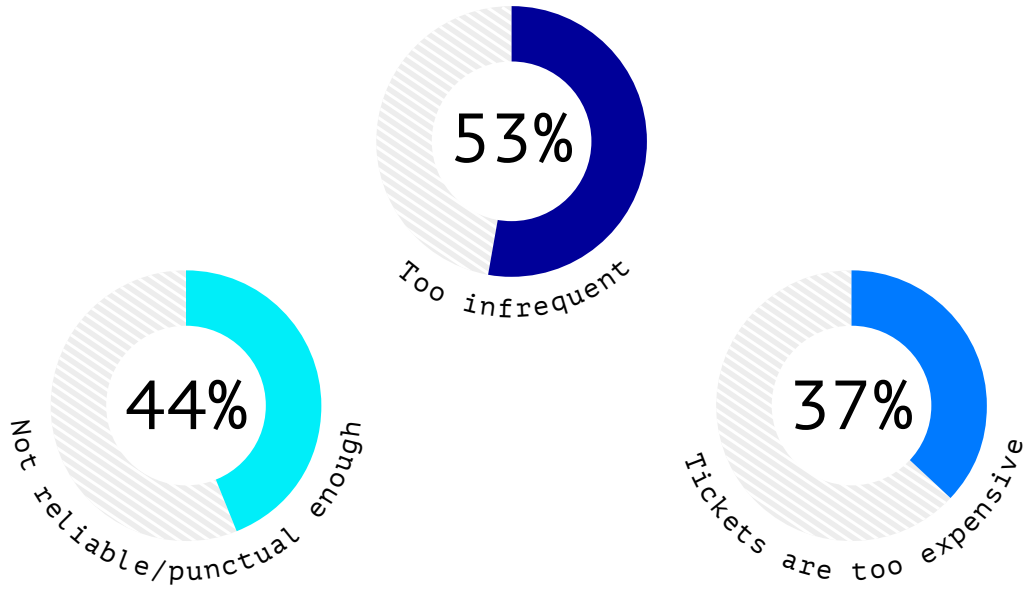


Figure 30: Top three reasons for dissatisfaction
(n=2,965; all those who rated public transport as less good/not good at all)

Autonomous mobility as an alternative and complement to public transport

As has already been noted, in addition to cities and municipalities, public transport companies in particular enjoy a high degree of confidence among the respondents regarding their suitability as operators of shared autonomous mobility. This is reflected in the analysis of the application purposes of corresponding concepts.

And for what general purpose could shared autonomous vehicles be **used particularly well**?

(Multiple answers possible)

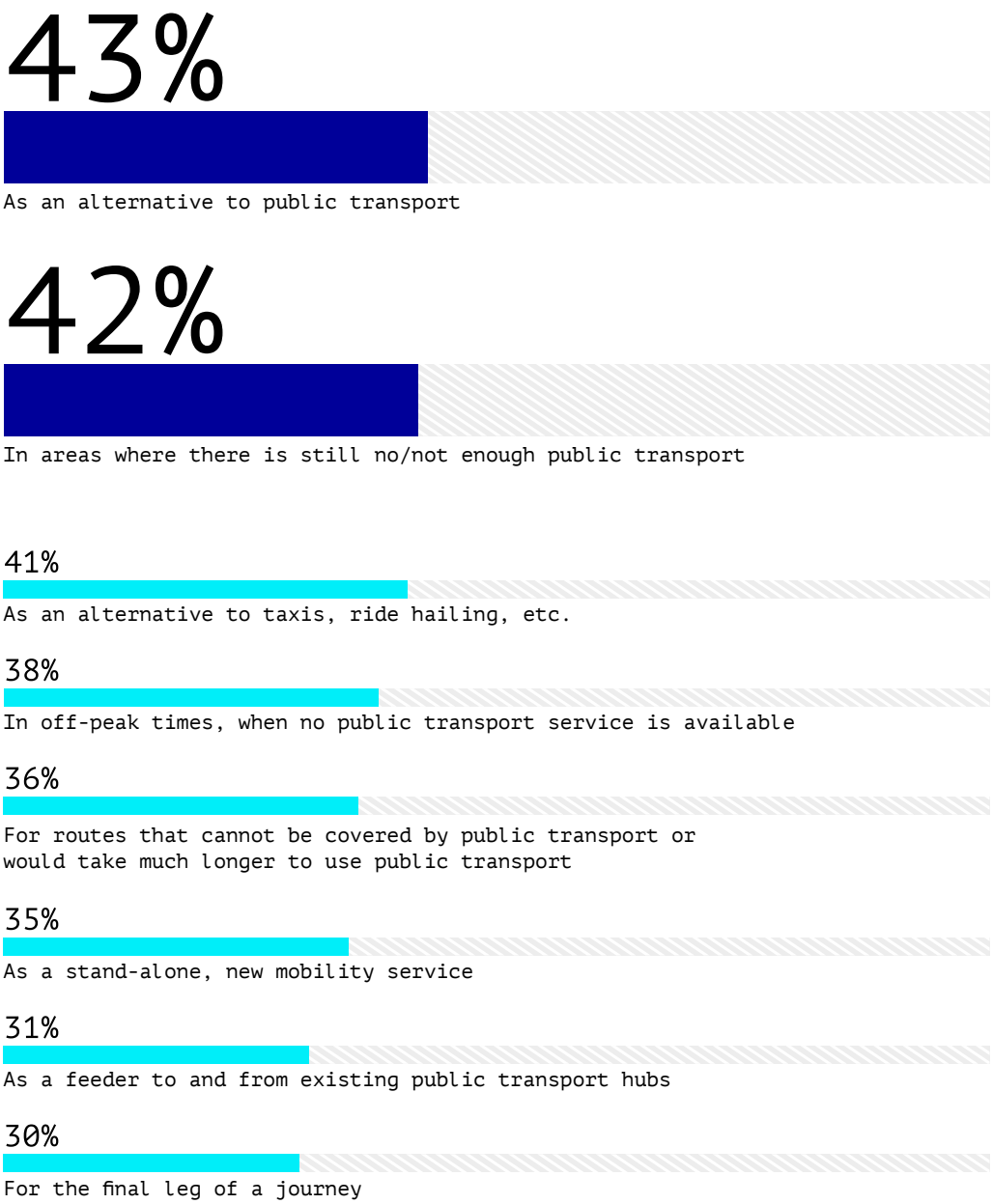


Figure 31: Purposes of use for shared autonomous vehicles
n=4,868

- It is clear that the use of shared autonomous mobility can be considered, in particular, as an alternative to public transport and in areas where there is no (sufficient) public transport available to date.

- When analyzing city types, it is noticeable that in urban regions, where transport and public transport infrastructure is better developed than in rural areas, the purposes differ considerably.
    - In urban areas, dissatisfaction or overload of public transport systems act as driving forces behind the desire for an alternative option through shared autonomous mobility. A possible scenario would be a reduction in the burden on conventional public transport through the integration of shared autonomous mobility.
    - In rural areas, public service through mobility warrants particular mention. Public transport systems and infrastructure are significantly less developed than in urban areas, which encourages the use of shared autonomous vehicles. Integration into an existing public transport system is unlikely.

Autonomous mobility as a second chance for the public transport system in the USA?

- For reliability of service, especially in rural areas, shared autonomous mobility is highly relevant. When it comes to the breakdown by market, the situation in the USA is a special case, so we will look at it in detail.

- Due to historical developments, public transport in the USA can be described as being limited in scope and lacking in efficiency (Statista Research Department, 2022). One part of the problem is the settlement structure. Public transport is profitable when there is a high population density and usage density. In the USA, however, suburban sprawl dominates. Residents are therefore dependent on private cars due to the decreasing availability of public transport. Public transport has been reduced to a small network of buses and subways in urban areas. Sixty-one per cent of Americans say they never use public transport (Faris, 2015).

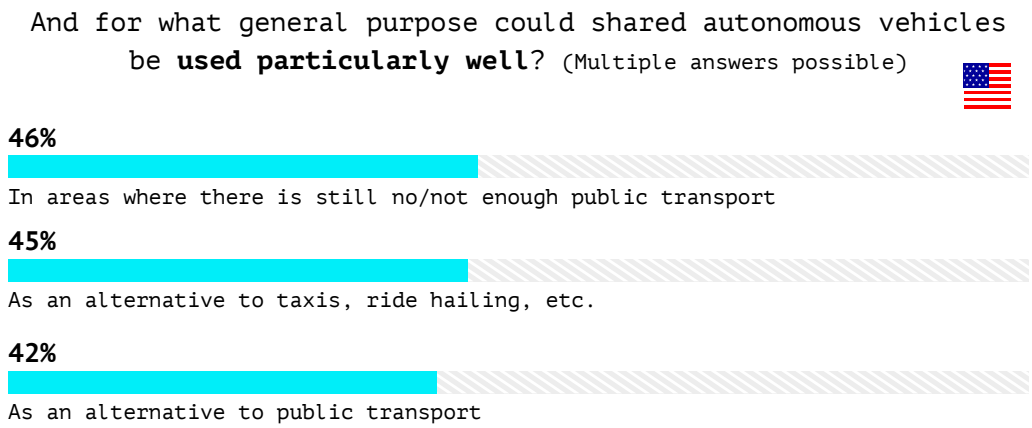


Figure 32: Top three purposes of use for shared autonomous vehicles in the USA
n=1,089 (USA)

- When looking at the American market in detail, it is striking that the most common purpose stated for shared autonomous vehicles is to close the public transport gap. Forty-six per cent of the Americans surveyed expressed a desire for autonomous mobility to be particularly beneficial in areas where there is no (sufficient) public transport available to date.

- This situation opens up a new "second chance" for the public transport system in the USA. The basis for this could in future be shared autonomous public transport vehicles.

Expert reflection:

- In general, we see a high level of agreement that autonomous mobility solutions should be integrated homogeneously into existing transport services.

- However, business model experts view this critically, as the actual economic potential and the resulting benefits are seen in free door-to-door services.

- However, integration into existing systems is seen as relevant in order to work with cities and municipalities. This is essential for identifying the business areas and the provision of the local legal framework.

- The need for large-capacity services is highlighted, especially at peak times. In particular, commuting traffic or the provision of last-mile shuttles at normal working hours is therefore considered critically.

- Integration is generally supported, but it is noted that companies typically operate in the private sector. Public transport must also strive for and facilitate integration.

Quote from ride-sharing provider (private sector): We are actually too expensive for regular journeys, so our services are seen rather as a situational supplement to existing services, meaning they cannot be available across the board in terms of location or time.

Quote from business model expert: When systems eventually become affordable and robust, transport systems can be completely rethought, not just in terms of a selectively available public transport connection.

8

Autonomous Mobility Concepts Reflected in International Market Regions

Based on the current state of research, five future-relevant concepts of shared autonomous mobility are presented below. First, the probability of use and possible uses of the respective concept are explained. Then the results of the survey are directly compared with findings and impressions of the experts and a forecast is given on the market potential within the respective markets under consideration.

VIP Shuttle

The VIP shuttle is a mobility offer that is particularly strongly oriented to the value promise of individual transport. Accordingly, the luxuriously equipped vehicles are designed for two to four people and can be used as an exclusive car-sharing solution. The idea of car sharing is subordinate in this concept. The difference is that, here, the focus is on privacy and comfort.

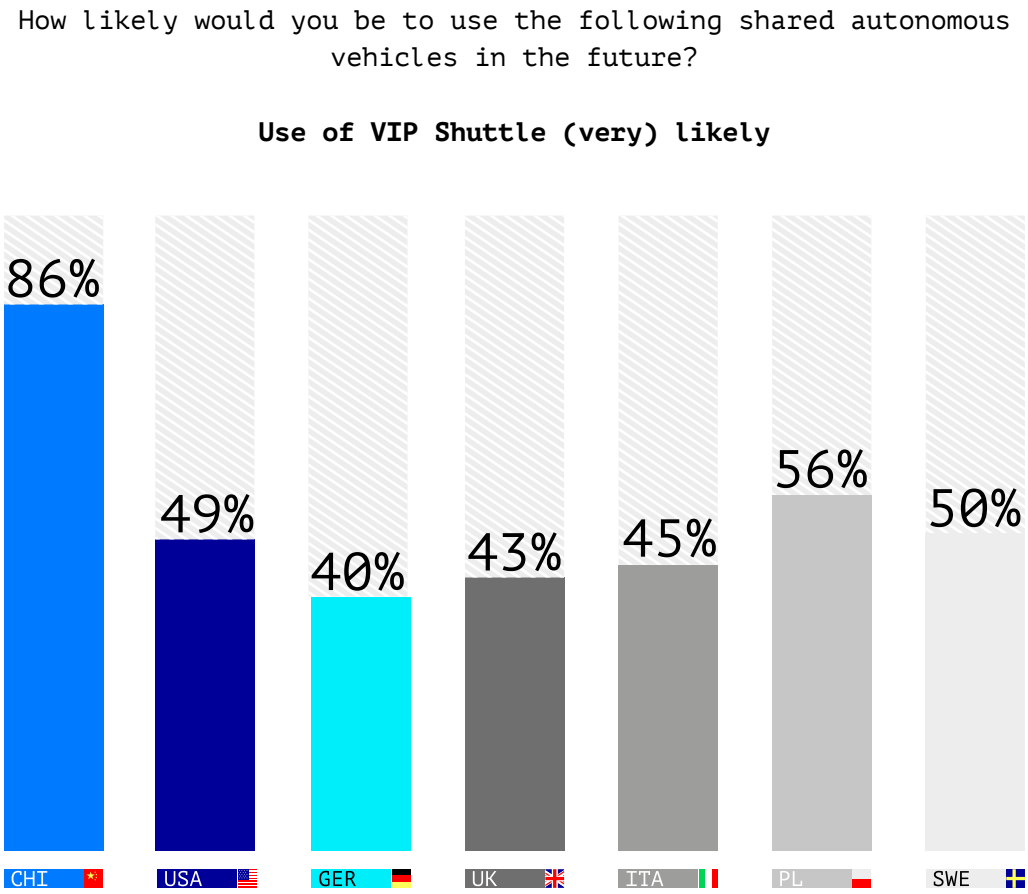


Figure 33: Probable use of autonomous vehicles as VIP Shuttles (China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

VIP shuttles as commuting service and entertainment in China

- China shows the highest usage intention for VIP shuttles in comparison to other countries.
- The older generation (55 years and older) in China is particularly in favor of the VIP shuttle concept. Transport to the workplace and to the train station/airport is the most common reason.
- The USA and China are more positive about VIP shuttle use, regardless of purpose, than they are in European countries.

Expert reflection:

- The sustainability of VIP shuttles is strongly questioned by the experts interviewed. However, it is expected that there will be a high demand from the side of automotive OEMs in particular.
- Free autonomous driving, especially in urban traffic, is regarded as technically very challenging, as external influences must be controlled at all times. This is not yet possible at the current level of technology available.
- As a point of criticism, it is clearly emphasized that VIP shuttles do not contribute to a reduction in traffic. It is therefore questionable whether they are an attractive solution in the face of increasing traffic and whether they can actually reduce the volume of passenger cars.

Relevant markets: China and the USA

The overall analysis shows that the use of VIP shuttles is more suitable in China and the USA than in the European countries. The limited sustainability potential, complex and tight European transport system, and a lack of willingness to set up special routes are regarded as crucial barriers in Europe. The desire for individual and comfortable mobility exists as an essential driver in China and the USA. In China, this is further reinforced by the high importance of privacy and vehicle size as a status symbol.

Have another look at the offers that you want. Which vehicle concept is probably particularly suitable for this purpose?
(Multiple answers possible)

Suitability of VIP shuttle

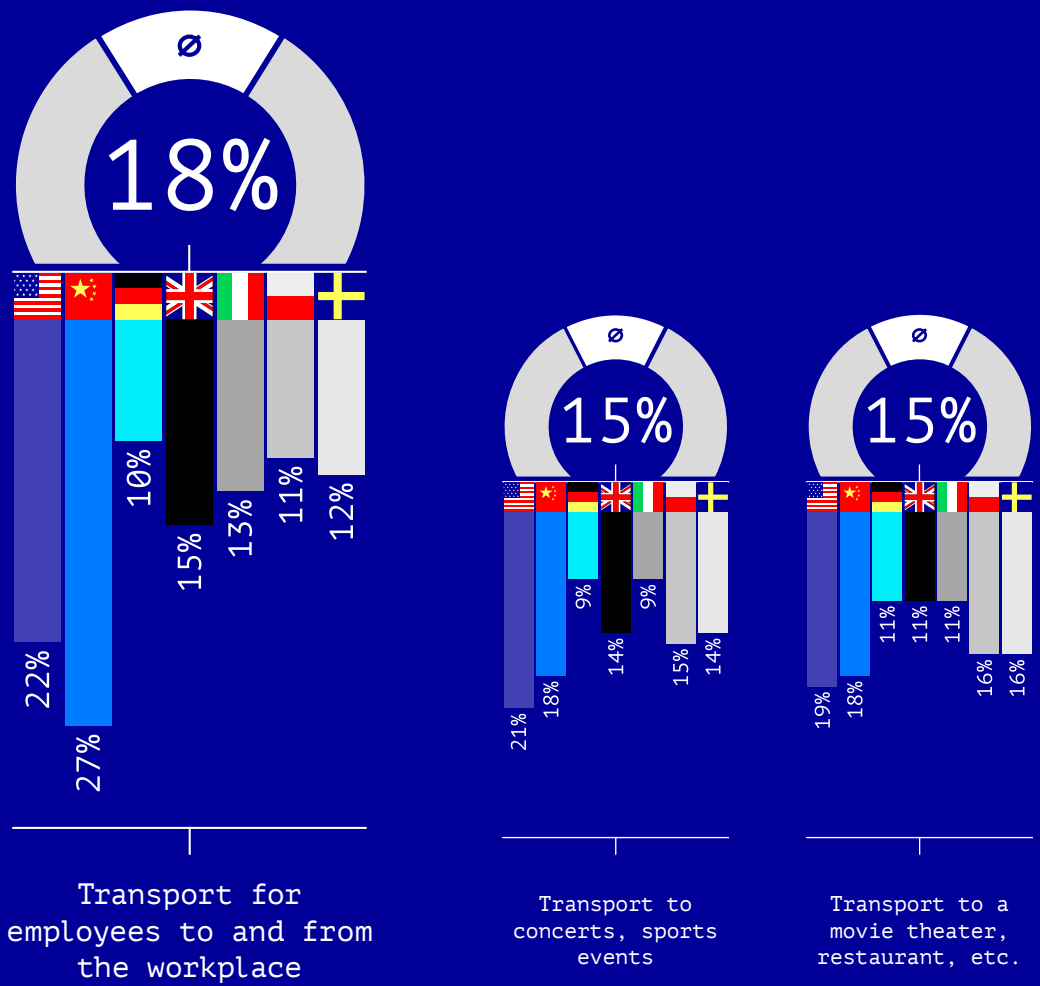
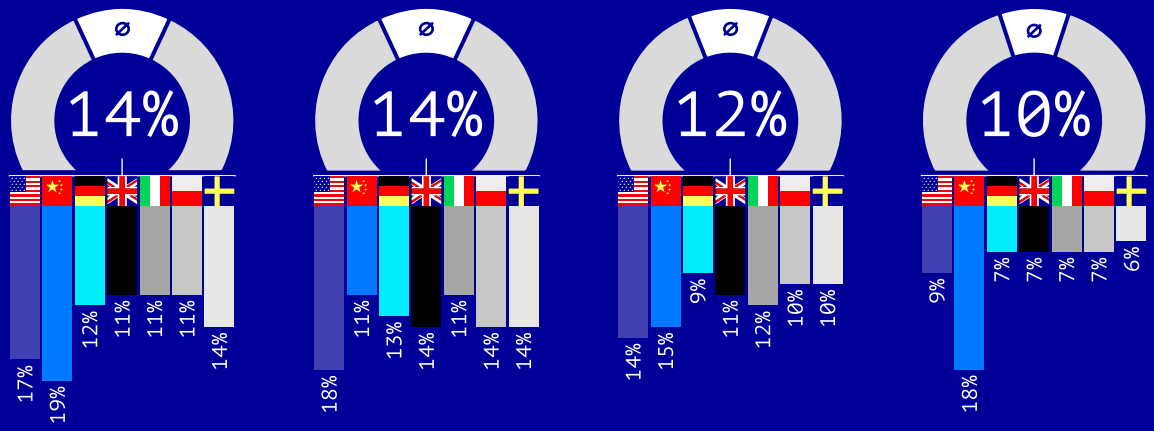


Figure 34: Suitability of VIP shuttle
n=4,868 (China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

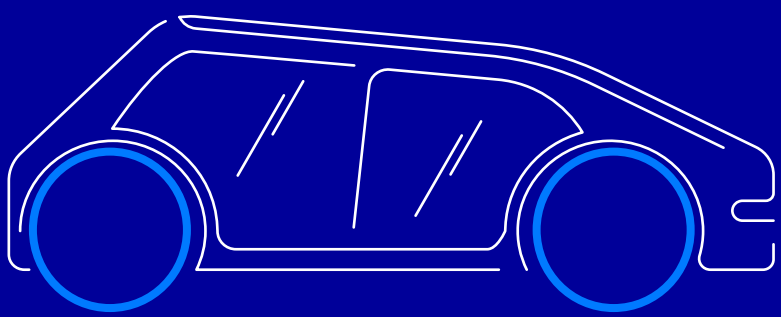


Transport to do errands, go shopping, etc.

Transport to and from the train station or airport

Travel within residential areas, downtown

Transport within company premises



Micro Vehicles

The micro vehicle segment includes compact vehicles that are to be used primarily in urban areas as a car-sharing concept. These are very small and agile vehicles designed for urban traffic. Their capacity of one to two seats is sufficient for the vast majority of inner-city journeys.

How likely would you be to use the following shared autonomous vehicles in the future?

Probable use of autonomous vehicles as micro vehicles

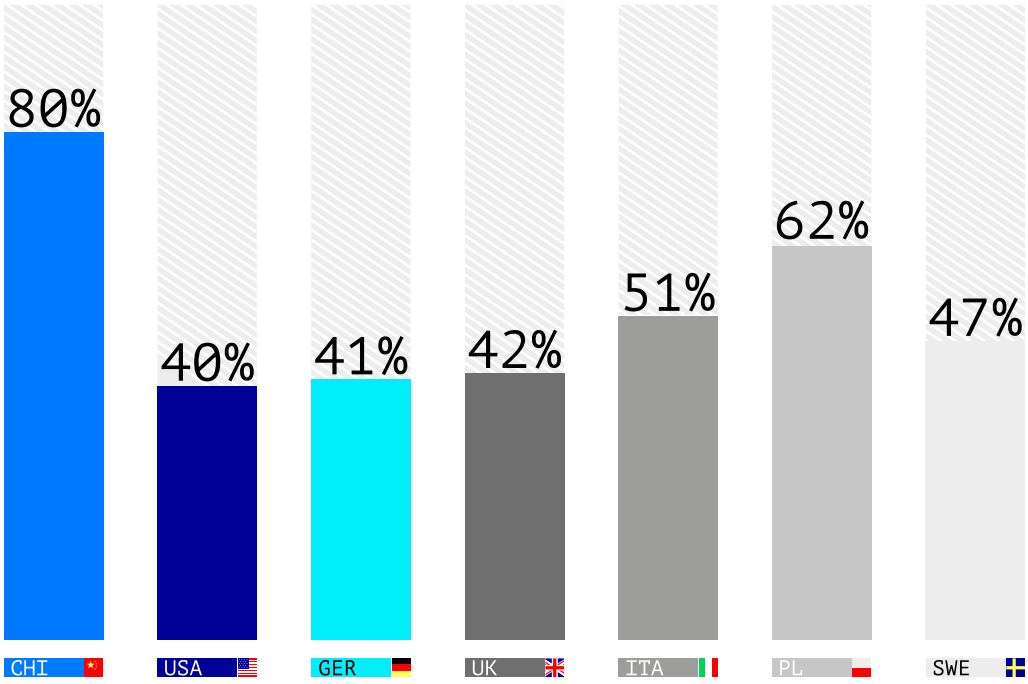


Figure 35: Probable use of autonomous vehicles as micro vehicles (China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

In an international comparison, the micro vehicle is universally desired for shorter private journeys when running errands and for entertainment purposes

- In all countries, the micro vehicle is chosen primarily for shorter journeys when running errands or for leisure trips to the movie theater or restaurant.
- In Poland, Sweden, and China, the concept tends to be preferred by the older population (45 years and older).

Expert reflection:

- The lack of a contribution to a reduction in traffic due to the low number of seats is seen as critical by the experts.
- Autonomous micro vehicles could even lead to more individual journeys or to empty journeys before and after the journey without an overall ride-sharing concept. The technical complexity in relation to the vehicle size is also critical. Being bound to special routes would in turn make larger vehicles and ride-sharing more attractive.
- In turn, it would be necessary to generate more revenue at higher costs, which would mean orienting them toward taxis. VIP shuttles seem to be more economical in this regard.
- The use of micro vehicles is expected at a later stage and as a supplement to future autonomous ride-sharing concepts as a way of offering individual rides on a situational basis.

Relevant market: USA

Small vehicles are expected to be seen in the USA in early applications. The strong orientation toward individual cars, the unattractive public transport system, and the settlement structures designed for car traffic with a lot of space can facilitate the use of micro vehicles. However, this contradicts the results of the user survey, which means that a closer analysis must be made of the extent to which the market suitability forecast by the experts actually results in an increasing acceptance of use. According to the experts, larger and more comfortable vehicles are in demand in China. The desire for privacy can act as leverage for ride-sharing services. The higher degree of privacy in smaller vehicles is reflected in the very dominant intention of the Chinese respondents to use shared, autonomously driven micro vehicles. For Europe, these vehicle concepts will be less relevant. They could be integrated into mobility-as-a-service offerings as complementary services at a later stage. In accordance with the desired purposes of journeys, this shows a high relevance for the European countries for running private errands and potential for everyday mobility.

Have another look at the offers that you want. Which vehicle concept is probably particularly suitable for this purpose?
(Multiple answers possible)

Suitability of micro vehicles

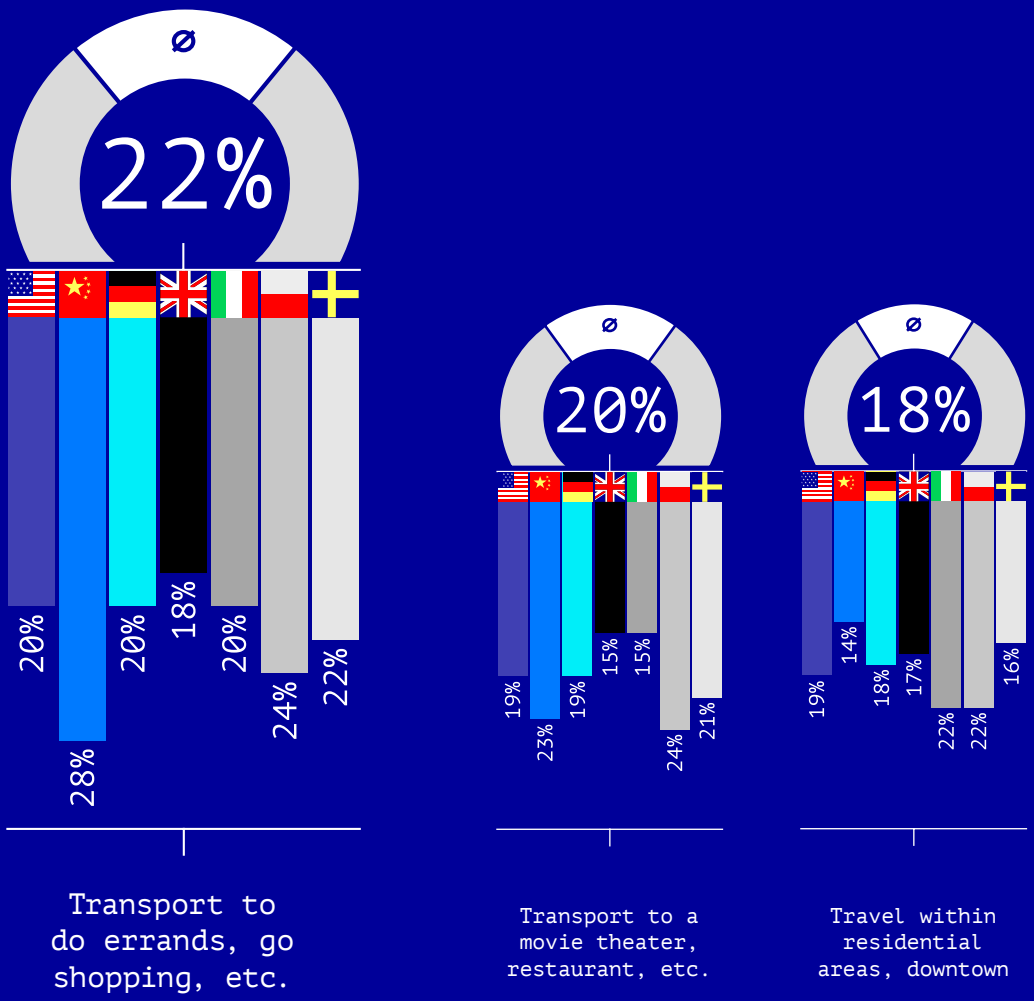
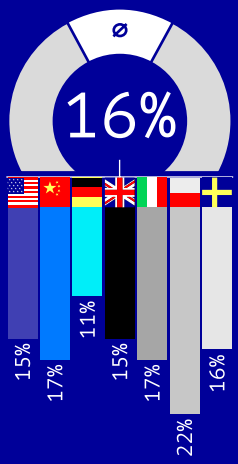
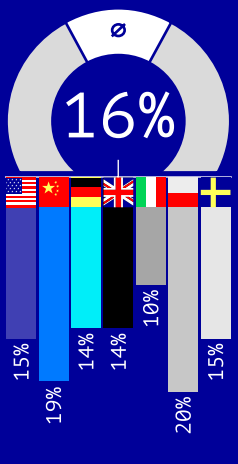


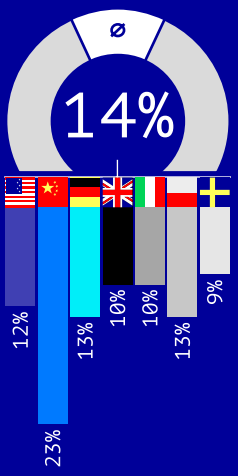
Figure 36: Suitability of micro vehicles
n=4,868 (China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)



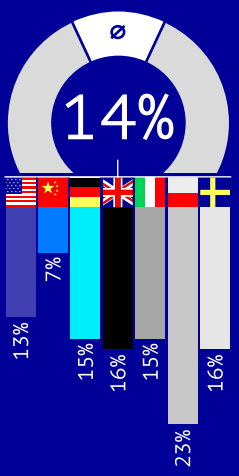
Transport for employees to and from the workplace



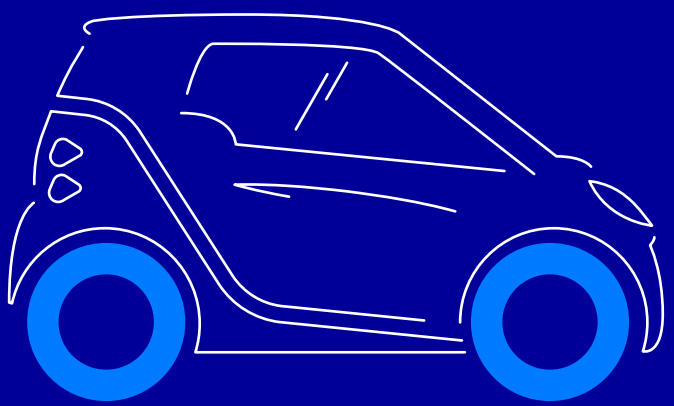
Transport to concerts, sports events



Transport within company premises



Transport to and from the train station or airport



Comfort Shuttle

The concept of the comfort shuttle is primarily intended to reduce traffic by means of regular journeys to and from the workplace or educational institution, for example by providing good connections to public transport, as is the case with today's park and ride systems. Comfort shuttles are mainly operated in a ride-sharing model, which bundles different travel requests. Accordingly, a comfortable interior and flexible booking times are required in order to actually replace the private car. The vehicles used tend to be large and particularly high with easy access and exit.

How likely would you be to use the following shared autonomous vehicles in the future?

Probable use of autonomous vehicles as comfort shuttle

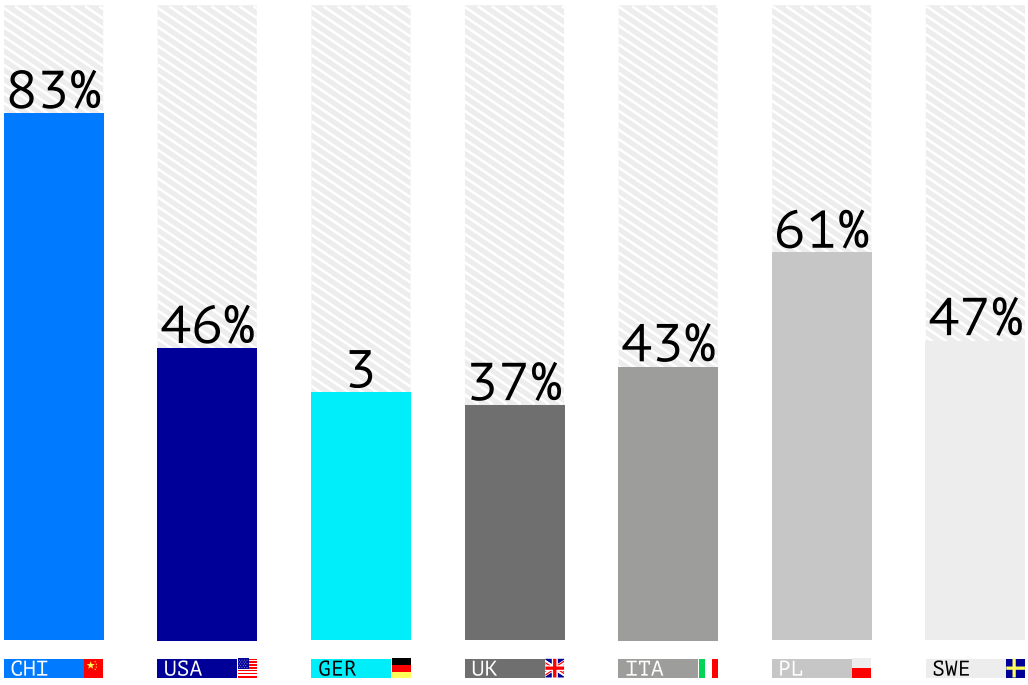


Figure 37: Probable use of autonomous vehicles as comfort shuttle (China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

The comfort shuttle is suitable as a drop-off service in Europe and the USA, whereas in china it is preferred for factory mobility. It is universally desired for longer distances

- In the country comparison, there is a particularly high interest in use in the Chinese and Polish markets. The UK and German markets are much more moderate.
- For all countries, the comfort shuttle is preferred for longer transport routes.
- In Poland and the USA, it is also considered an interesting possibility for transportation to sporting events/concerts as well as within residential areas.
- The concept is prioritized primarily by the rural population for private purposes (except in Germany and the UK).

Expert reflection:

- Comfort shuttles are expected to be an early form of shared autonomous mobility and seen as fundamentally attractive.
- The concept enables the direct establishment of new business models in combination with insights from current ride-sharing usage behavior.
- Suppliers of pilot projects based on passenger cars are also pursuing the implementation of ride sharing for the future.
- Comfort shuttles are seen as a mobility concept to complement public transport.

Relevant markets: Europe, China, and the USA

The comfort shuttle is expected to be of early importance in all three markets, with Europe somewhat lagging behind in its implementation due to the complexity of the traffic situation. Ride-sharing will be a strong driver for Europe as well as the USA. In China, on the other hand, it is important to observe how the respective services can be positioned between the individual VIP shuttles and large-capacity vehicles – but very early use as a factory mobility solution is conceivable. The Chinese sample shows the greatest potential for comfort shuttles in the comparison. In addition to the high salaries of drivers, the regulation of the mobility market has a positive effect on the spread of the technology in Europe, particularly in Germany. This prevents cheaper ride-hailing services and enables more attractive conditions for autonomous comfort shuttles than in other markets with stronger competition through ride-hailing services.

Have another look at the offers that you want. Which vehicle concept is probably particularly suitable for this purpose?
(Multiple answers possible)

Suitability of the comfort shuttle

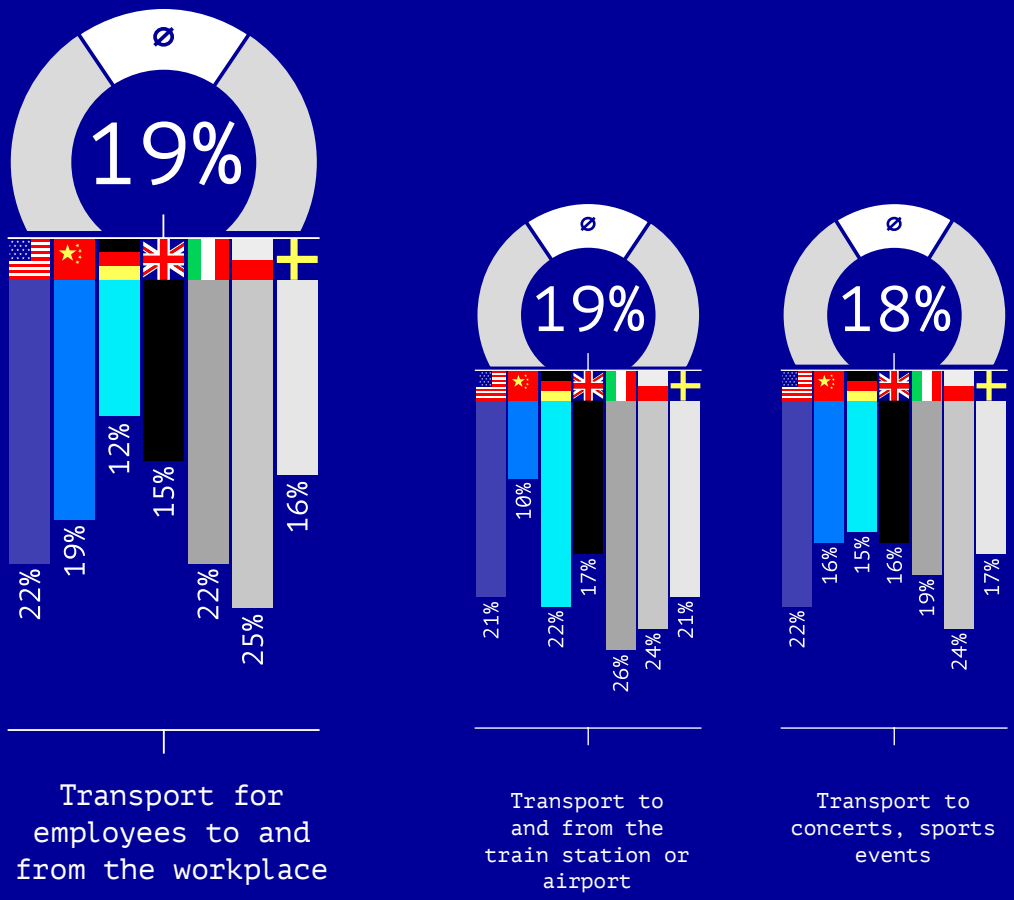
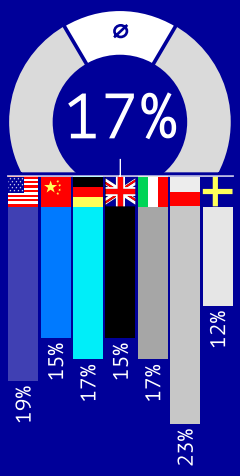
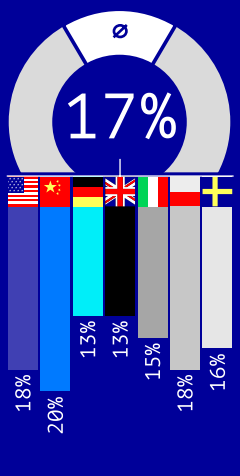


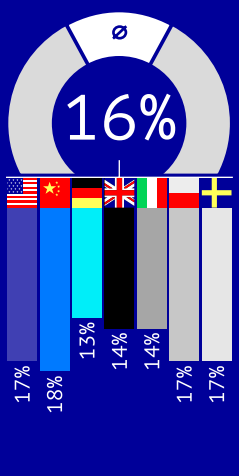
Figure 38: Suitability of the comfort shuttle
n=4,868 (China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)



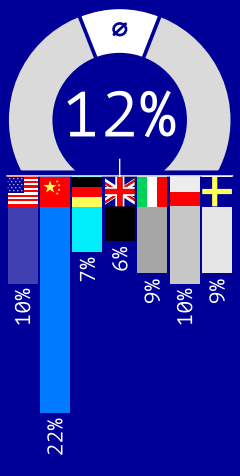
Travel within residential areas, downtown



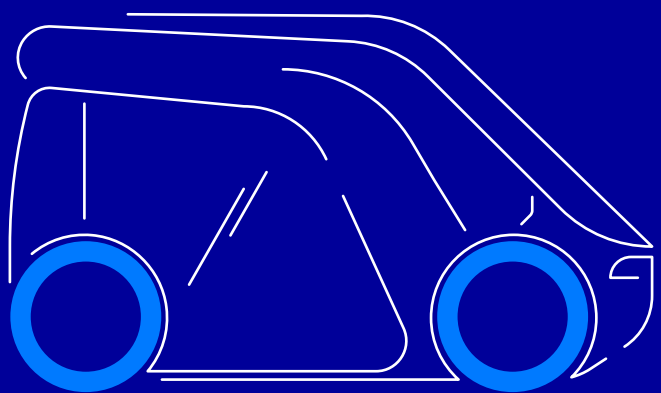
Transport to do errands, go shopping, etc.



Transport to a movie theater, restaurant, etc.



Transport within company premises



People Movers

People movers are based on autonomously driven minibuses. They are intended for public use as an integral part of a long-distance and line-based public transport system. The focus is on dedicated, mostly traffic-restricted areas (e.g. historic city centers or pedestrian zones) and their connections to the public transport network. The vehicles used can accommodate between 10 and 25 passengers and are characterized by a very functional and purpose-oriented interior – without special comfort functions or design elements.

How likely would you be to use the following shared autonomous vehicles in the future?

Probable use of autonomous vehicles as people movers

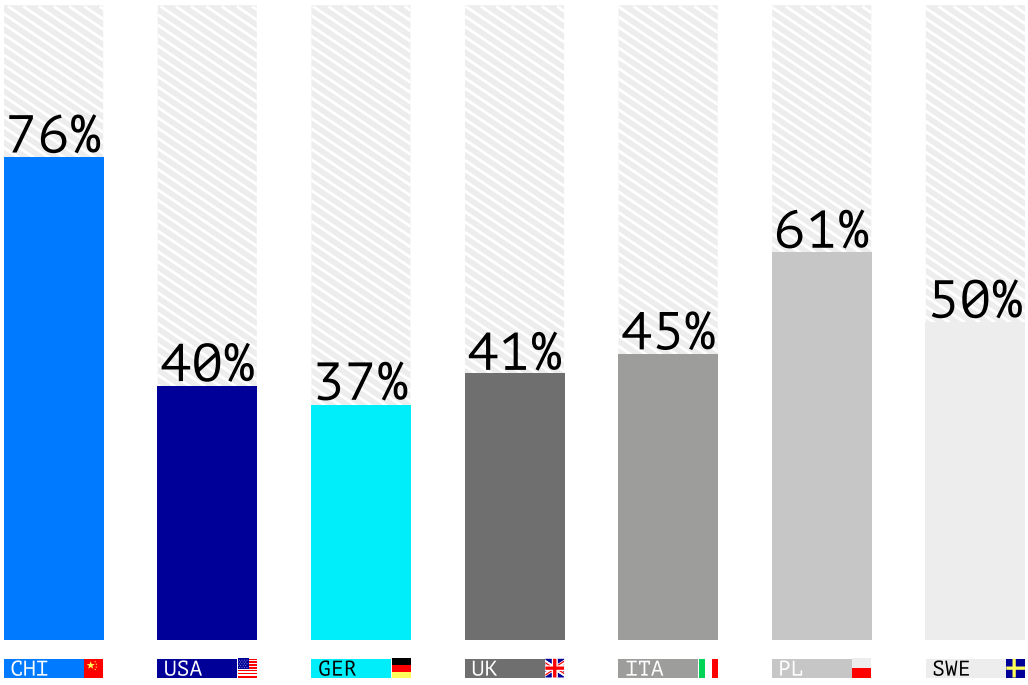


Figure 39: Probable use of autonomous vehicles as people movers (China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

The people mover is seen as a relevant concept in Europe and the USA in particular. It is especially suitable for commuting or as a drop-off service for transport hubs

- For all countries, the people mover seems to represent a suitable concept for functional commuting journeys, such as to work or to the airport/station.
- The Chinese sample envisages the fewest possible uses for the people mover across all purposes.
- European public transport users across all countries (except Germany) tend to see a higher potential in using them for commuting purposes.

Expert reflection:

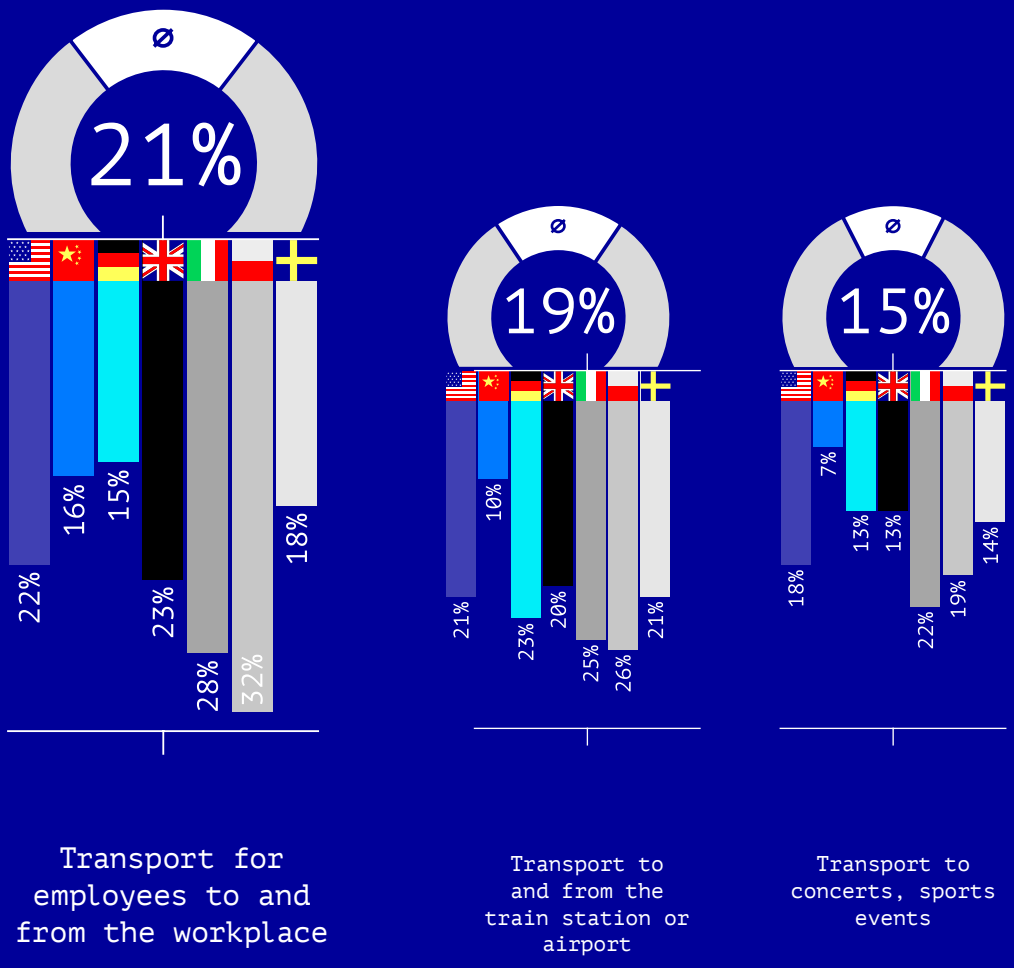
- People movers are expected to be the first form of autonomous mobility on dedicated routes.
- Their usage potential is seen primarily in the expansion of the public transport network and is expected to come with fixed stops as well as in part with timetable operation.
- Business models can be realized primarily through complete integration into local public transport if the technical costs do not become too high.
- As the size of the vehicle increases, the cost advantage over conventional minibuses with human drivers becomes noticeable.
- On the other hand, vehicles with too little capacity cannot complement public transport in a meaningful way (e.g., capacity bottlenecks in transfer situations from a packed subway train at peak times).

Relevant markets: Europe and USA

Shared autonomous large-capacity vehicles are promoted and accepted in Europe in particular. They will increasingly be used in Europe on defined routes and in specific areas of operation, for example on well-structured roads with directed traffic. This includes city highways as well as in traffic-restricted urban areas with additional V2X support. Usage in separate lanes will generally only be possible if these can be considered early in the planning of city districts or in the basic restructuring of traffic infrastructure. In China, corresponding services will have to be compared with the generally well-developed public transport system and will probably be used where gaps exist in this system. In principle, Chinese users are more inclined to use smaller, more individual vehicle concepts, which means that people movers offer less potential for the Chinese market. Vehicles with passenger volumes of 10 to 20 seats are widely accepted in the USA. There is the possibility of quickly setting up new public transport structures on the basis of these vehicles. However, it is not clear who would be considered the provider of the services and how their business model would work. The deliberate construction and proactive promotion of such mobility systems by cities and municipalities is seen as a less likely scenario within the American market. In Europe and China, on the other hand, this is a key factor in the proliferation of people movers.

Have another look at the offers that you want. Which vehicle concept is probably particularly suitable for this purpose?
(Multiple answers possible)

Suitability of people movers

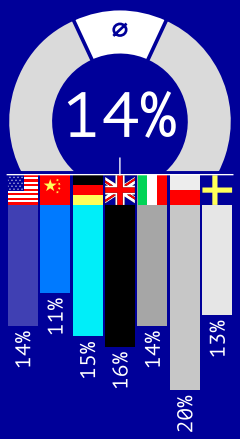


Transport for employees to and from the workplace

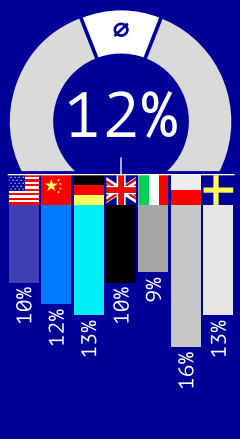
Transport to and from the train station or airport

Transport to concerts, sports events

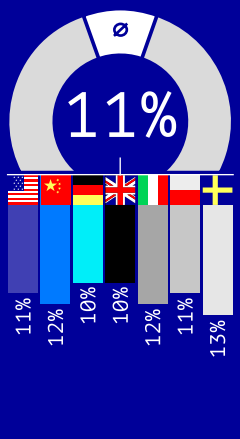
Figure 40: Suitability of people movers
n=4,868 (China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)



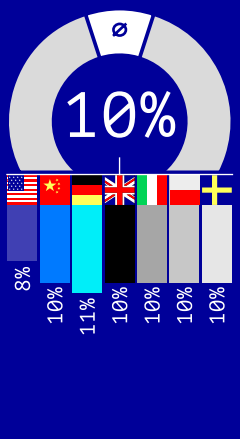
Travel within residential areas, downtown



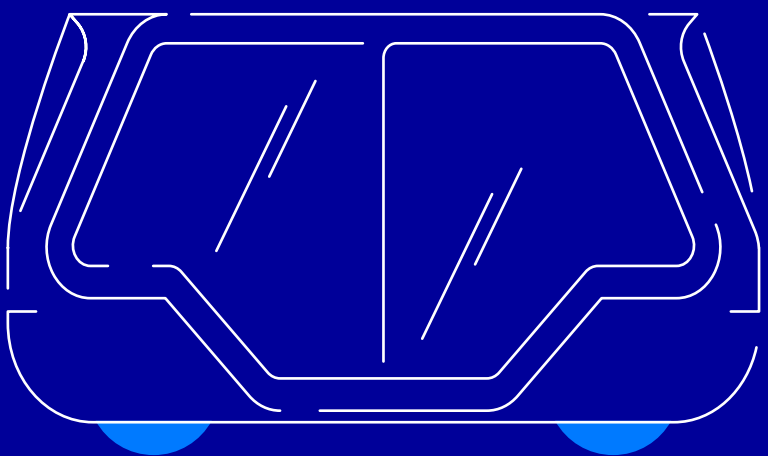
Transport to do errands, go shopping, etc.



Transport within company premises



Transport to a movie theater, restaurant, etc.



Distribution Logistics

For distribution logistics, our survey focuses on the end customer perspective. An autonomous transport solution is considered that takes over the delivery service from a supplier or an interim warehouse and delivers directly to the end customer. The vehicles used may be of different sizes, from variable vans to larger special vehicles for individual deliveries. Accordingly, they operate in mixed traffic on public roads or even on the sidewalk if they are authorized to do so. We also reflect logistics B2B solutions such as highway trucks or platooning in the context of expert interviews.

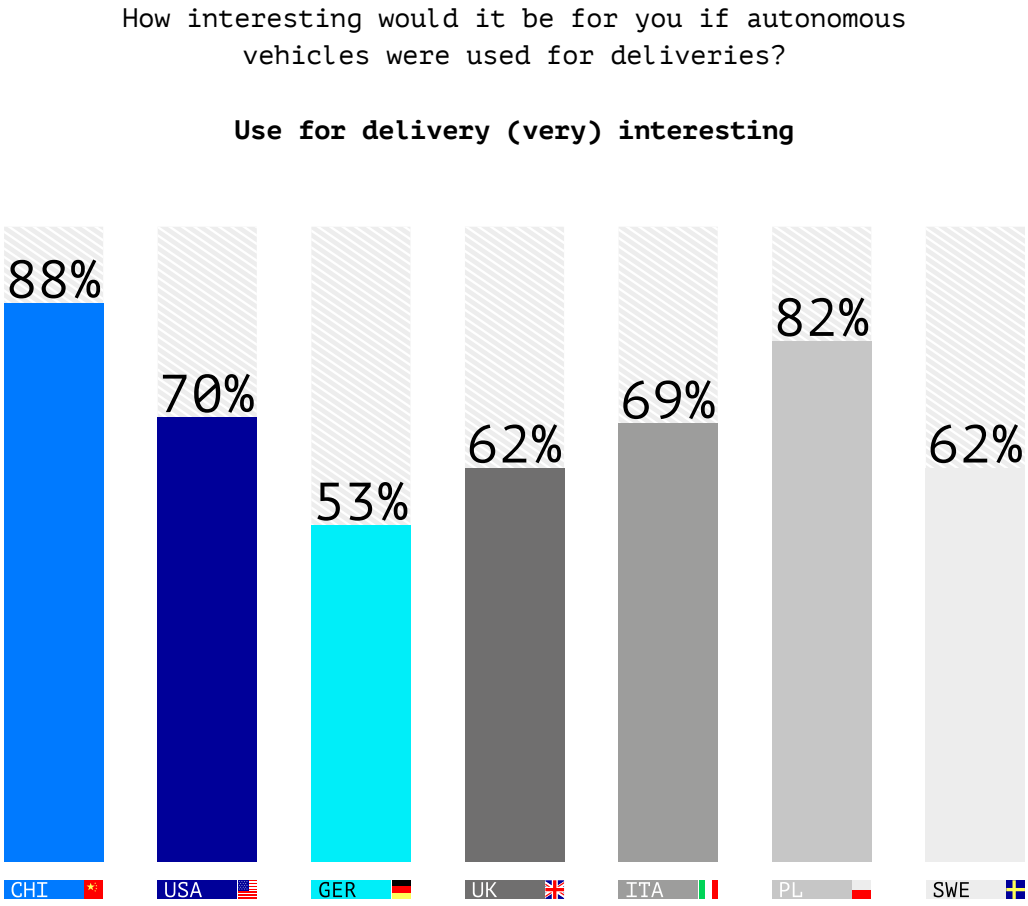
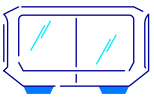


Figure 41: Use for delivery (very) interesting
(China: n=1,090; USA: n=1,089; Germany: n=512; UK: n=548; Italy n=545; Poland: n=539; Sweden: n=545)

Delivery robots are a relevant concept in the USA and China in particular. Their use is particularly promising in populous urban environments

- China, Poland, and the USA show the highest interest in autonomous delivery robots in comparison to other countries. Interest is lowest in Germany.
- A higher interest is particularly evident among the younger generation (18–34 years). With increasing age, the interest in delivery robots decreases .
- Across all countries, interest is greater if there is already a subscription with a goods service provider (e.g., Amazon Prime).
- People living in populous urban regions consider the concept to be much more interesting than the rural population.

Goods transport in combination with passenger transport: economically sensible, but viewed critically by customers



But it is not only autonomous delivery robots that will play a role in the future. Autonomous vehicles used for transporting passengers can be used efficiently for transporting goods, for example, at off-peak times where demand is low or to avoid empty journeys. In this regard, we have shown the results of the respondents who regularly commute and are therefore relevant for this scenario.

- For all countries, there is a very low willingness to combine passenger and goods transport.
- In China, a slightly higher willingness is shown if the goods are stored in a separate luggage compartment.
- In Germany, a large proportion of people are in favor of exclusive passenger transport. Combinations of passenger and goods transport are rejected.
- The duration of the journey seems to have hardly any influence on the evaluation.

How do you imagine the concept of a shared autonomous vehicle for this purpose: Goods transport?

(Deviations of 100% due to “Not specified”)

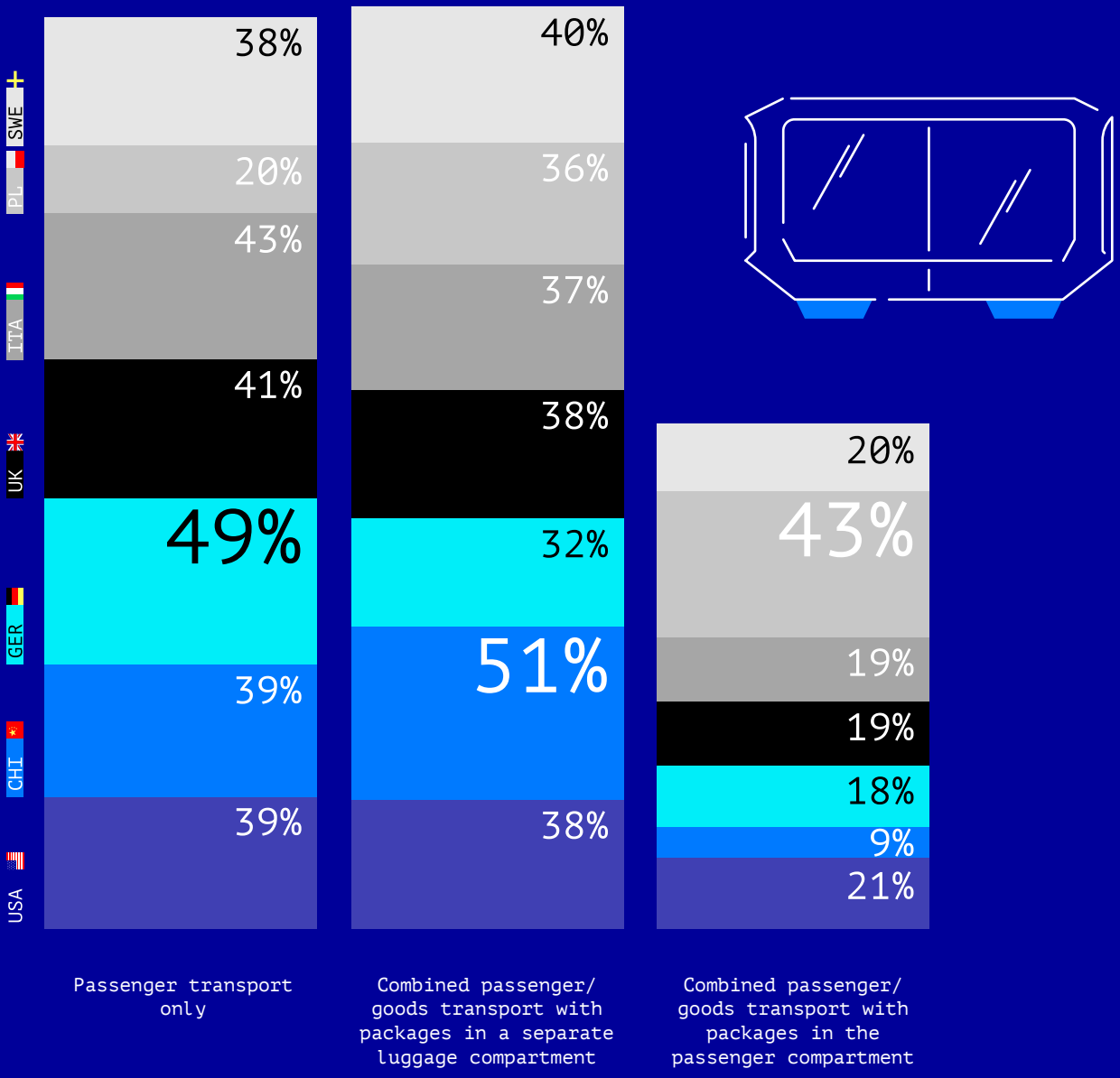


Figure 42: Concept for goods transport

Scenario 1: Commute to work up to 30 minutes: n=1,799 (USA: n=335; China: n=503; Germany: n=167; UK: n=167; Italy n=210; Poland n=222; Sweden n=195)

Scenario 2: Commute to work over 30 minutes: n=1796 (USA: n=344; China: n=543; Germany: n=158; UK: n=165; Italy n=198; Poland: n=216; Sweden: n=172)

No willingness to pay for sustainable delivery

Would you be willing to pay an extra charge for this contract/for delivery of online orders if the deliveries were particularly environmentally friendly?

Figure 43: Willingness to pay for sustainable delivery
n=4,868

- The willingness of potential customers to pay more for sustainable autonomous logistics concepts for online orders clearly shows that the majority of customers are not willing to pay more for environmentally friendly delivery, or are willing to pay only a small surcharge (5 per cent surcharge).
- China is the only market in the comparison that would consider paying more: Just under a third of the Chinese population would pay a 15 per cent surcharge.
- Germany shows the lowest overall willingness to pay more: Fifty per cent of respondents reject such a measure.
- People who order goods or food more frequently online show a higher willingness to pay a surcharge for sustainable delivery across countries. This goes for all countries.

Expert reflection and addition:

- Autonomous highway trucks are seen as early use cases of autonomous mobility, especially for the American market. The heterogeneous legal framework in the different states is still considered problematic. Homogenization is absolutely essential to implementing interstate routes.

- Robustness against bad weather conditions is regarded as a major challenge, especially by the technically experienced experts, which is particularly relevant in terms of logistics applications that must operate reliably.

- Small delivery robots for the last mile are considered to be particularly relevant for China. However, they have to overcome the competition of cost-effective bicycle couriers. In some cases, they are expected to demand significantly higher salaries in the future, which would change the competitive situation.

- In general, a critical view is taken of the extent to which attractive business models could be established for deliveries that are individual and often free of charge, considering the technical costs of delivery robots. An early spread of the technology is therefore not expected.

- Ride-sharing providers are generally open to mixed concepts combining passenger and goods transport, but are skeptical about the extent to which this makes economic sense and the extent to which the corresponding business and operator models can be achieved at attractive terms.

- Expectation gap: The experts predict cost advantages through the combination of passenger and goods transport with shared autonomous mobility, whereas users are extremely critical of such dual use.

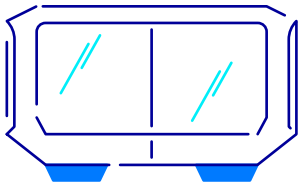
- In principle, no positive environmental or social sustainability effects are envisaged with regard to autonomous logistics solutions – these could only materialize if a completely new, fully networked, and automated logistics sector is created in which systemic efficiency optimizations can be made.

“The biggest leverage is the entire automation of the supply chains, from the first to the last mile, which is why different vehicle sizes and intelligent networking are required”

Christian Rosen, Head of MaaS TaaS Services at VW Commercial Vehicles

Relevant market: USA

Autonomous trucks will soon spread in the USA and operate within the framework of different business models and technical concepts. In addition to the complex but complete gate-2-gate services, cheaper options will also be offered as a hub-2-hub service, whereby human drivers will drive the vehicles on the first and last stretches of the journey as far as the highway. Motivators for use in the USA are the high costs and low availability of drivers, the poorly developed rail network, the low speed difference between trucks and passenger cars, as well as the favorable, stable weather conditions in the southern USA, where prominent goods transit routes run between the east and west coast, and the simplicity of driving on the roads (few towns, often wide visibility, straight roads). There is currently only a small demand in China. However, this could change in the future with increasing costs for drivers. It must be ensured that the driving functions and, by extension, the service availability are also guaranteed during the rainy season. Up to now, extreme weather conditions have been a major technical barrier to the operation of automated distribution logistics. In Europe, densely built-up areas with winding roads and many intersections and towns, as well as the different general conditions of the countries, are considered a major challenge. In addition, many European countries, particularly in a central location as a traffic hub, are characterized by strongly changing weather conditions (rain, snow, fog), which still pose problems for autonomous vehicles.

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2
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Further Information

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Study Design

A standardized, international online survey (CAWI) provided insights into the specific requirements of potential users as well as the use potential within various markets in Europe, China, and the USA. The results were supplemented and validated by qualitative expert interviews in order to reflect viable business models as well as feasibility and sustainability.

Quantitative online survey of potential users

The survey was conducted within the relevant future markets of Europe, China, and the USA with panels that were representative of the population. The European market is diverse as an object of investigation and has therefore been divided into Germany, Italy, Poland, Sweden, and the UK. The selection ensures that a large part of Europe is geographically represented and that different ecosystems, technological standards, and settlement structures are represented. Accordingly, a representative ratio based on gender, age, and place of residence was used for the individual samples. Participants were recruited via the online access panel of the provider dynata, coordinated by Motor Presse Stuttgart, and took place between July 7 and July 18, 2022. The survey period is 11 days. The total sample size is n = 4,868 valid cases, where the US sample contains n = 1,089 subjects, China n = 1,090, and Europe n = 2,689. The European sample is divided into Germany n = 512, Italy n = 539, Poland n = 545, Sweden n = 545, and UK n = 548. Participants are at least 18 years old.

Qualitative expert interviews

Autonomous mobility has opened up the market for new stakeholders from outside the sector and offers plenty of scope for new partnerships and profitable alliances. It is therefore necessary for the international experts interviewed to represent different stakeholders who play a role in the implementation of shared autonomous mobility. The experts were selected via the network of MHP Management- und IT-Beratung GmbH as well as the Fraunhofer Institute for Industrial Engineering IAO. In total, 15 guideline-based expert interviews were conducted in September 2022. In addition, ten open interviews were conducted to reflect the findings of the user survey and to take account of the current state of technology. Furthermore, in July 2022, the state of the art of automated vehicles was discussed at a network meeting of the "FutureCar" innovation network organized by the Fraunhofer Institute for Industrial Engineering IAO, and a workshop was held to assess the market launch of autonomous mobility services. The expert opinions were reported anonymously and, when direct quotations were given, only their respective industry was mentioned. If the experts agreed to being named publicly, they are assigned by name to the quotations.

General note: Selection of certain attributes and rounding may in some cases cause the totals in the graphs to not always add up to 100%.

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