Deutsche Bank
Research

Germany Monitor

The digital economy and structural transformation

# The digital car

## More revenue, more competition, more cooperation

July 3, 2017


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Editorial deadline of this report:
June 12, 2017

Original in German: June 19, 2017


The traditional automobile industry and companies that, in the past, had no involvement in the sector, are working hard to create software solutions, driver assistance systems and other technologies that will make networked, autonomous, traffic jam and accident-free driving possible. That means the digital car in its ideal form is no longer a utopian vision for the future, but is instead gradually taking shape.

However, the path to the digital car will be more of an evolution than a revolution. That is the result of factors on both the supply and demand side. They include the considerable development times in the industry and the longevity of its products, cars. Consumer preferences, which have been shaped over decades, are also unlikely to change overnight. It will take several decades for digital cars to make up a major proportion of cars on the road. That is unlikely to happen before 2040.

The technologies required for digital cars will have a positive effect on revenue growth in the automotive industry. Most of those technologies will be installed additionally in the digital cars. Companies that have not been active in the automobile industry in the past, or that have only played a peripheral role, will compete for the increased market volume. Meanwhile, the sector will become significantly more heterogeneous and complex. Cross-sector collaboration will change the industry significantly in the coming years. Despite that cooperation, competition in the expanded automobile industry will remain intense.

No company has an unassailable lead with regard to the digital car as a whole. Companies from the world of IT have more advanced knowledge than traditional automobile manufacturers with regard to some aspects of the digital car (such as the automobile data market, which will grow strongly in the future). However, the ability to command the entire automobile value chain in a mass market represents a significant barrier to entry to newcomers. Automobile production itself will continue to be relatively unaffected and will remain the domain of traditional automobile manufacturers in the future.

Social patterns of mobility are changing parallel to the emergence of the digital car. Innovative mobility services based on car and ride sharing are increasing their market share, particularly in large cities, where an increasing share of households will not own a car in the future. On the supply side, a wave of consolidation is expected in the coming years.

The digital car is not the solution for traffic problems in high-density cities, particularly those in emerging economies. Such cities primarily require good public transport systems to prevent gridlock. However, the digital car could make a contribution to improved traffic flow, compared to a business-as-usual scenario. That does not necessarily require a reduction in overall traffic volume, but rather the improved utilisation of vehicles.

## 1. Introduction: Digital structural transformation represents a challenge for the automobile industry

The digital car is gradually taking shape

The car, the most important means of transport in the 20th century, is undergoing a structural transformation driven by digitalisation. That process of digitalisation will change both the car as a product and the entire automobile value chain. The automobile industry and companies from other sectors are working hard to create software solutions, driver assistance systems and other technologies that will make networked, autonomous, traffic jam and accident-free driving possible, and progressively transform the car into a computer on wheels. That means the digital car is no longer a utopian vision for the future, but is instead gradually taking shape. Changing social patterns of mobility, which are driving trends such as the development of innovative mobility services based on car sharing and the intelligent networking of different means of transport, are also having an effect. Government regulations for climate and environmental protection, changing consumer preferences and the finite nature of oil resources are increasing focus on alternative drive technologies with lower $CO_2$ emissions and greater energy efficiency. Those trends will create significant challenges for the automobile industry:

— *Technical challenges:* The public has huge expectations with regard to the digital car. The companies involved will have to leverage extensive resources to (rapidly) fulfil those expectations.

— *Market structure and competition:* New market participants, above all from the IT and data processing industries, are changing the traditional structure of the automobile industry. They have increased the pressure in terms of innovation and positioning, and have significantly increased competition in the industry.

Government regulation is subject to conflicting priorities

— *Government regulation:* The technological developments around the digital car are a focus of government regulation, including in the areas of safety and data protection. Government regulation in this area is always subject to conflicting priorities: On the one hand it should allow technological development and fair competition, while on the other it should prevent undesirable developments (e.g. misuse of a dominant market position or the approval of immature technologies).

— *Social trends in mobility:* The changing consumption and use habits of many (not just) young urban customers, above all in industrialised countries, increasing interest in car sharing and the flexible use of various means of transport, raise questions about whether owning a car could become less attractive and the impact of new mobility concepts on the potential sales of manufacturers. From an economic perspective, and with regard to transportation, the effect of these trends on overall traffic volumes, particularly in cities, is relevant.

### Effects on the automobile industry

This report will consider the effects of the digitalisation of cars on the automobile industry. Among other things, we will consider how quickly, and in what stages, the development of the digital car could occur.

We will begin with an overview of current technology and the expectations of the public with regard to the new technologies. With those aims in mind, we will explain what the phrase digital car actually means to us (Chapter 2). We will analyse anticipated changes to the structure of the market and competition on the supply side from an economic perspective (Chapter 3). We will thereby compare the potential competitive advantages of new market participants, e.g.

from the IT and data processing industries, with the strengths of traditional automobile manufacturers. We will consider the position of the German providers in detail and explore the question whether, in the future, new market participants are more likely to become competitors of or partners to the traditional automobile industry.

In Chapter 4 we will consider the demand side: How quickly will the digital car become established with customers? What are the drivers and barriers, from a consumer perspective? On the one hand, we will consider the extent to which the car could become less important as personal property (particularly in Germany) and the effect of such changes on manufacturers' potential sales. On the other, we will consider the question of how driver assistance systems and alternative mobility concepts (taking the example of car sharing in Germany) are being received by customers and explore the potential of the car sharing market. Then we will consider the effect that new mobility solutions based on digital technologies could have on absolute (urban) traffic volumes (Chapter 5). Can the digital car fulfil high expectations in terms of traffic flow, safety, efficiency, convenience and, ideally, environmental sustainability? Or can (even) the digital car not save high-density urban centres from gridlock? We will outline four scenarios that explore these questions.

This report does not focus on technological aspects of the digital car or the digitalisation of the production process

Our report will not focus on the stages of technological development and challenges on the path to the digital car. We will also not explore the (clearly important) question of how digitalisation will change the production process in the automobile industry (keywords: Industry 4.0, internet of things, individual manufacturing in mass production). We will also largely ignore the question of how quickly and to what extent alternative drive technologies (e.g. e-mobility) will become established in the digital car, although it is generally clear that the proportion of electric vehicles will increase progressively over the coming years. (Comprehensive) Consideration of the three aspects listed above would exceed the scope of this report.

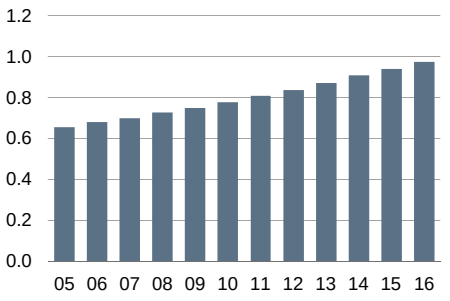
The idea of the digital car makes a utopia free of road accidents and traffic jams appear to be within reach. Without revealing the conclusions of our report in detail, we expect the path to the digital car to take the form of constant evolution, rather than a radical revolution.

## 2. Mobility today and tomorrow: The car is here to stay – but how?

### 2.1 A means of mass transportation in transformation

Constantly increasing number of cars on the road 1

Number of passenger cars worldwide, bn




Sources: OICA, internal estimates

Huge steps are being taken towards the digitalisation of the car. The technological progress towards the development of the digital car is attracting considerable media interest, and there is a broad spectrum of perspectives on the subject. Some market observers see the entire conventional automobile industry as an obsolete model – not least considering the ambitious research being conducted by technology companies, e.g. in Silicon Valley.

However, the fact is that the automobile is by far the most important means of transport in the key industrialised countries – and that has been the case since the mass motorisation of most industrialised nations following the Second World War. Emerging economies are increasingly following that pattern. Worldwide, and in Germany, the number of cars on the roads is increasing constantly. The automobile industry itself is an important employer in many countries and invests large sums in new and existing production locations, as well as research and development.

The passenger car has improved constantly in recent years. That is true with regard to very different criteria such as performance, safety, comfort, energy

Cars are very emotional products

efficiency, environmental sustainability and reliability. Vehicle design has also changed over time and still plays an important role for customers. And the image of an automobile brand continues to have a major influence on the purchasing decisions of drivers. The car was and remains an emotional product for many customers. Of course, the function of a car, to allow individual mobility, is the most important factor in its success. However, customers have changing requirements when it comes to cars. They increasingly want to be networked with other road users, family, friends and business partners. For a growing number of users it is important that the car can connect to the internet and that it offers interfaces, e.g. to their own mobile end-user devices (smartphones etc.). On the supply side, technical developments in the IT sector are also constantly driving those trends. That means the passenger car is undergoing an ongoing transformation. Along with sustainability in terms of the environment and climate, and vehicle efficiency, digitalisation is the defining megatrend in the automobile industry. But what do we actually mean when we use the phrase digital car?

## What is meant by a digital car?

Driver assistance systems are becoming more important

Today, and even more so in the future, the car has numerous additional functions that were not available in their current form just a few years ago – at least not in series-produced vehicles. So-called advanced driver assistance systems (ADAS) are carrying out an increasing number of tasks for the driver (during the journey).[1] They help the driver to steer, brake and park. Some assistance systems are even required by law. For example, since 2011 an EU directive has required that all newly registered cars have an electronic stability program (abbr.: ESP). It supports drivers with improved braking and steering in difficult driving situations (e.g. ice, rain or snow), and helps them stay in lane.

The digital car is fully networked and communicates with its environment

Such driver assistance systems are the first steps on a path that is expected to lead to automobiles that drive autonomously. To allow for such development, automobiles are being equipped with increasing amounts of software, sensors and radar and camera systems. Technologies that allow communication between vehicles or with traffic management systems and other static systems outside the vehicle (car-to-x communication) are also required. The details of the necessary technologies, and the resulting day-to-day benefits for drivers, have yet to be determined, but the digital transformation around the automobile will certainly be a major challenge for automobile manufacturers, suppliers and other companies that are active in this market. Those that successfully master these challenges will have new opportunities for growth.

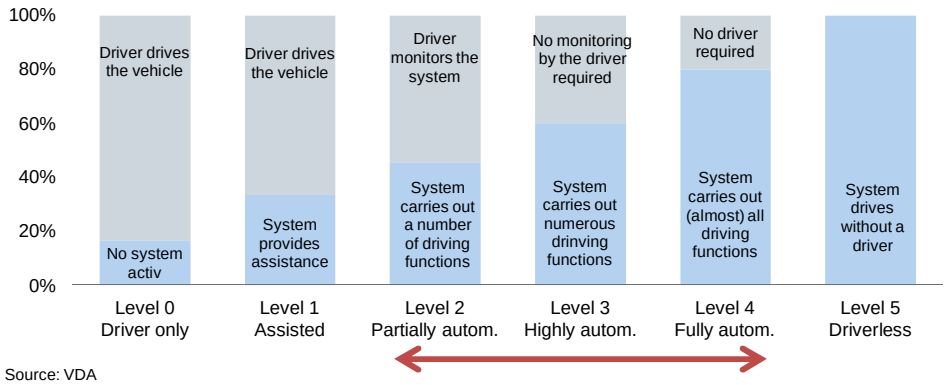
Driverless driving as the final level of automation

Therefore, the digital car of the future will be fully networked and capable of communicating with its environment. A classification system established by Federal Highway Research Institute's "legal consequences of an increase in vehicle automation" (Bundesanstalt für Straßenwesen (BASt), Rechtliche Folgen zunehmender Fahrautomatisierung) working group offers helpful orientation with regard to the levels of autonomous driving. It includes categories from "driver only" (level 0) to "partially, highly and fully automated" (levels 2 to 4) and fully "driverless driving" (level 5). While in the levels "assisted" (level 1) and "partially automated" (level 2) the driver is responsible for the range of driving tasks, in the levels "highly automated" (level 3) and "fully automated" (level 4), the system can automatically manage increasing numbers of driving situations. We will use those levels of development to orient ourselves in this overview of the current technology. Of course, they only serve as a rough guideline. In its final technological form, the digital car would have the highest level of automation,

[1] See also Deutsche Bank Markets Research (2016). Pricing the Car of Tomorrow – Part II". FITT-Report. London.

"driverless" (level 5), which assumes the full networking and communication of the vehicle with its environment.

Levels of automated driving (levels of automation) 2




Source: VDA

## Huge technological challenges

Road traffic is a chaotic system with many uncertainties, but is rule based

We must overcome huge technological barriers on the path to the digital car, which we can only briefly outline here. Road traffic is characterised by millions of constantly changing and novel situations and uncertainties. They require split-second decisions, which, in extreme cases, can mean the difference between life and death.[2] All those decisions have a direct impact on other road users. Motorway journeys that don't involve oncoming traffic or (normally) pedestrians are an example of less complex traffic situations than road traffic in high-density cities with diverse road users. Automating a "chaotic" system of this type is highly complex.[3]

In the future, vehicles with different levels of automation will share the roads

Such plans are made more difficult by the fact that vehicles will have different technological capacities during a transitional phase of several decades. That means the influence of (error prone) humans on the system as a whole will change over time. For example, in 20 years fully automated cars could share the streets with cars driven completely manually by people. People and digital algorithms make decisions in very different ways. Harmonising very different technological standards to ensure high traffic safety is far from simple. The situation is further complicated by the fact that there will always be road users that are not digitally networked with vehicles (e.g. pedestrians, children, cyclists, animals, objects of various sorts on the road). Reporting on the subject of the digital car and autonomous driving can give the impression that these technological hurdles are easily overcome, which is not the case. Nevertheless, in the long term we expect the digital car in its ideal from to become possible and we believe road safety will improve as a result of increasing automation.

[2] For example, the question whether an automated car should make decisions in situations where an accident is unavoidable but the type of accident is undetermined has been discussed intensively. Should an algorithm primarily aim to protect a vehicle's occupants, even if that means the car hitting a pedestrian rather than a solid object? Along with moral aspects, such questions also relate to insurance.

[3] For example, rail traffic is easier to automate than road traffic becausee there are a lower number of vehicles and they must follow rails.

## 2.2 Numerous companies are driving technological development

While the vision of a digital car was already being artistically represented in the 1950s, a period characterised by high faith in progress, this vision of the future is now gradually becoming a technological reality.

**The legal framework for autonomous driving has been established in Germany**

With regard to the current level of automation, we are in the transition from partially to highly automated driving technology (levels 2 and 3). That means human drivers are still required and must monitor the vehicle at all times. That current state of technology is appropriate to the current legal requirements according to the 1968 Vienna Convention on Road Traffic. It requires that a vehicle is controlled by a driver at all times as long as it is in motion. In 2016, the German federal government agreed to an amendment to the convention. It fundamentally allows for the loosening of existing regulations, and thereby creates a legal framework for partially autonomous assistance systems. In the first half of 2017, the Bundestag and Bundesrat passed a law on autonomous driving (including highly automated driving). It generally allows for highly and fully automated cars. However, the driver must be prepared to take control of the vehicle at all times, including when the system requires it. That means they must be "ready to pay attention to the road". With regard to liability in case of an accident, among other things, it must be determined whether the car was in automatic mode and whether the driver reacted to the demands of the system quickly enough. Specifically, it may often be necessary to determine whether the owner's insurance company or the manufacturer is responsible for the damages incurred by parties to the accident.

**Vehicles with partially automated driving characteristics are already in series production**

Technological development is continuing: Assistance systems and vehicles with partially automated driving characteristics are currently in series production at almost all major vehicle manufacturers. They are equipped with systems such as cruise control, acceleration and braking assistance, parking assistance, hill driving and start assistance, emergency braking systems and automatic distance control. Along with the established automobile manufacturers from Europe, the USA, Japan and Korea, the new American automobile manufacturer Tesla offers vehicles that allow partially automated driving. The IT companies Google and Apple are also active in this area, although they have not (yet) brought any vehicles to market. The driving service provider Uber is an example of the application of these new technologies and vehicles, although the company does not have direct responsibility for development or production.

**Research has advanced**

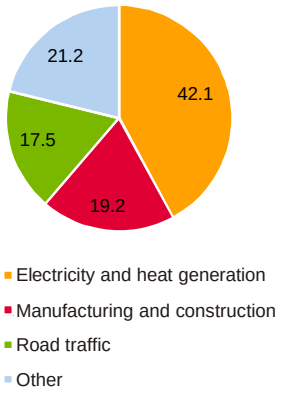
Current research is primarily focused on highly and fully automated driving technology. For example, Daimler is testing its highly automated research vehicle "015 Luxury in Motion" and the "Highway Pilot" assistance system for fully-automated commercial vehicles. Google, Apple and Uber have also been testing fully automated prototypes for some time. And other manufacturers including Toyota, PSA, BMW and Volkswagen are testing similar technologies in use. The American manufacturer Ford has announced that it wants to produce autonomous vehicles without steering wheels or pedals by 2021. At the most recent Paris Motor Show, Volkswagen presented its new electric car, which it plans to produce by 2020 and wants to make available in an autonomously driving version by 2025. The list of research activities carried out by automobile manufacturers and suppliers in this area is growing all the time, which is why we have only presented a selection here.

**Various companies are driving technological development**

These examples make it clear that technological progress is driven by both the major automobile manufacturers (and their traditional suppliers) and IT companies that, in the past, had no involvement in the sector. They are forcing established companies to take action. Here the conventional wisdom that competition invigorates business applies. It is plausible that without the initiatives of the "newcomers" traditional automobile manufacturers would have been less engaged with the field of autonomous driving.

Road traffic is a major source of emissions 3

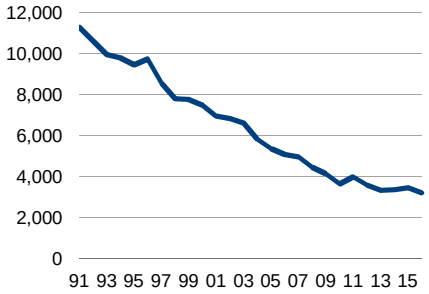
Share of different sectors in global $CO_2$ emissions, 2014, %




Source: IEA

Downward trend in the number of road traffic deaths in Germany 4

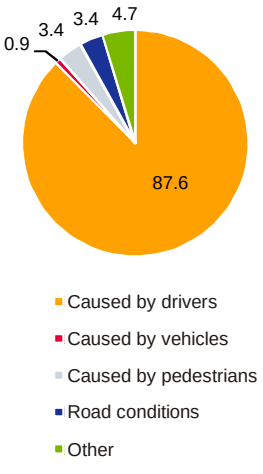
Number of road traffic deaths in Germany




Sources: DIW Verkehr in Zahlen, Federal Statistical Office

Most accidents are caused by drivers 5

Share of causes of road traffic accidents in Germany, 2015, %




Source: DIW Verkehr in Zahlen

## 2.3 The digital car is a source of great hopes and expectations

While suppliers are driving forward technologies relating to the digital car, the interest and expectations of the public are growing. Increasing congestion (above all in large cities and the emerging economies), pollution from exhaust emissions and the increased risk of accidents in many countries are negative developments resulting from current patterns of mobility. There is the hope, and the expectation, that these trends can be reversed by more intelligent mobility, among other things through the digital car.

— *Traffic volume and flow:* There are currently more than 1 billion motor vehicles on the world's roads (including commercial vehicles). It is estimated that the number of vehicles worldwide has increased by just less than 50% since 2005. The level of road traffic is also constantly increasing. Traffic jams are a fact of life in many cities and at major junctions. Intelligent driving technology could improve the flow of traffic and, ideally – in the minds of many market participants – reduce traffic volume, or at least slow the growth in traffic volume.

— *Effects on the climate and environment:* Road traffic accounts for just less than 18% of global $CO_2$ emissions. The digital car could be a factor in improved vehicle utilisation and/or reduced traffic volumes, e.g. by improving traffic flow, and contribute to developments that would help achieve the long-term goal of climate neutral road traffic. Of course, that would first require a transition to (affordable) renewable energy in the coming years. The potential contribution of the digital car alone is very limited as long as it is primarily powered by fossil fuels.

— *Road safety:* According to the World Health Organisation, approximately 1.25 million people worldwide die in traffic accidents each year, and that figure is rising slowly. While such deaths are decreasing in Germany, they still numbered more than 3,200 in 2016. According to the German Institute of Economic Research (Deutsches Institut für Wirtschaftsforschung – DIW), drivers caused nearly 88% of road traffic accidents involving personal injury in Germany. Increased safety and fewer road traffic accidents are, therefore, some of the most important expectations of the digital car.

— *Access to individual mobility:* The proportion of adults with driving licenses in Germany is very high; it recently totalled approximately 87% (in 2014). However, for cost reasons, not everybody has access to an automobile. The digital car could make individual mobility available to more groups in society. That clearly conflicts with the aim of reducing overall traffic volumes to a certain extent.

— *More comfort and available time:* Driver assistance systems already offer drivers a high level of comfort. The digital car could further increase that comfort in the future and allow the driver to work productively or relax during journeys.

In the following we will discuss the extent to which the digital car is likely to fulfil the expectations outlined here.

# 3. The supply side: The digital car is changing the market noticeably

The high pace of technological development on the path to the digital car is the result of a race between the companies involved. Competition between established automobile manufacturers and market participants from the IT industry that were not involved in the sector in the past is an important driver of that process. Reports in the media often give the impression that the traditional automobile industry is on the defensive. But are the market prospects of the

traditional automobile manufacturers really so bad? Before we consider the future of the industry as a whole, a short description of the automobile market from an economic perspective will be instructive. How exactly will the process of digitalisation change the market and competitive conditions?

## An overview of market and competitive structures in the automobile sector

The automobile value chain is very complex

The automotive sector as a whole includes a far greater number of participants than it initially appears: They include the automobile industry itself, which, according to official statistics is made up of automobile manufacturers, automotive suppliers and the comparatively small body, superstructure and trailer manufacturing segment. However, up and downstream sectors also play an important role. Companies from the electronics, metal, chemical, plastics and textile industries supply precursors to the automobile industry itself. Suppliers of automobile factory equipment, above all in the mechanical engineering sector, are also significant. And a variety of research institutions also make an important contribution. Downstream sectors include car dealers and garages. The automobile value chain is partially managed by specialised logistics companies. And, finally, there are a range of automobile-specific services (e.g. vehicle finance, insurance companies and experts, development contractors, inspection services).

Few automobile manufacturers, many suppliers

There are different numbers of companies in different segments. In the automobile industry itself there are relatively few, mostly large automobile manufacturers and a high number of suppliers. The latter includes everything from small and medium-sized companies to global groups. The large number of market participants is an indicator of intensive competition in the industry. The sector, and the car as a product, are subject to high levels of regulation, which primarily relates to the environment, climate protection and safety.

Automobile suppliers are essential to the ability of the industry as a whole to innovate. The range of products offered by suppliers is particularly diverse. And it is expected to become even more diverse in the future, because the digitalisation of the automobile will create demand for (even) more software, rather than hardware-based systems. That will tie up significant financial and personnel capacities at suppliers, and will create major challenges for the industry, which also has to constantly optimise production processes due to cost pressures. The need to make alternative drive technologies commercially viable requires further resources and puts the future of whole business areas in question. The shift from conventional combustion engines to battery-powered electric mobility will make a number of components (e.g. internal combustion engine, transmission and emission control) superfluous, although that will not happen overnight.

Boundaries between the automobile industry itself and related sectors are becoming unclear

Overall, the digitalisation of cars will increase the number of potential suppliers (particularly in the fields of electric technology, software, data processing and digital security). With regard to the market structure of the industry, that means the automobile sector will become even more complex, there will be more product segments and potential market participants and it will become increasingly difficult to clearly differentiate the automobile industry from related sectors.

The complexity of the automobile value chain creates barriers to market entry

Why are we describing these market structures? Considering the complexity of the automobile value chain as outlined here, the intensive competition in the industry and the high level of regulation, the industry may not initially seem attractive, or contestable, to new and lateral entrants. However, new market participants are pursuing the digitalisation of the automobile (and alternative drive technologies). That presents a number of challenges for automobile manufacturers and their suppliers, whether large and international or small and

medium-sized. From an economic perspective, we must therefore paint a differentiated picture by asking "Who will be able to make the transition into the various areas of the future automobile industry?"

## 3.1 New participants have entered the market

The new participants in the automobile sector include digital ecosystems

Google and Apple are two companies from other sectors that are making concerted efforts in the race towards a digital car. Considering their innovative power and financial strength, they have been seen as new competitors to the automobile industry since they announced their ambitions in this area. Google began testing its first prototype autonomous car in 2009 and is considered a pioneer in the field by many market observers. However, there is a far more diverse range of new market participants. That is why there is no simple answer to the question of how great the threat to the traditional automobile industry might be.

### Who are the new market participants and why are they interested in the automobile business (or not)?

To offer a better picture of the competitive situation in the automobile sector, we will use the following classification system in our presentation of potential competitors to the traditional automobile industry, their most recent activities and the orientation of their businesses:

i. New automobile manufacturers
ii. New suppliers
iii. Digital ecosystems
iv. Digital mobility service providers and car-sharing providers

#### *New automobile manufacturers*

Only a small number of car makers

The number of independent automobile manufacturers worldwide has almost constantly decreased over recent decades. Intense competition and the importance of economies of scale in purchasing, production and sales have contributed significantly to that process of consolidation. New providers of supra-regional importance are the absolute exception. And there are no (new) companies that are primarily driven by the digital car or autonomous driving. That means there is currently little direct competition in the core automobile production business. The closest thing to a competitor of this kind is the American company Tesla Motors, which was founded in 2003. The company is best known for using fully electric drives – currently with a focus on high-end automobiles. However, Tesla has also made significant progress in the field of autonomous driving. It is the first manufacturer to announce its intention to equip its cars with the hardware necessary for autonomous driving at a later time. The company has also announced plans for an online platform for the provision of mobility services. Tesla has thereby positioned itself in the fields of autonomous driving and mobility services. From a commercial perspective, for a variety of reasons, Tesla has predominantly operated at a loss and, in terms of the number of vehicles sold, remains a niche provider. However, its focus on electric cars, which it expects will make autonomous driving possible in the future, Tesla is currently the only (relatively) new competitor to the traditional automobile manufacturers in the core automobile production business.

Tesla is making progress in the field of autonomous driving

*New suppliers*

A comprehensive new spectrum of products is opening up for new and existing suppliers

Without the innovative power of the automotive suppliers, the digital car will struggle to find its way onto our roads. Numerous established companies are expected to expand their product ranges in this area. Meanwhile, new providers are entering the market. The group of potential suppliers is large and difficult to distinguish. On the one hand, broad-based IT and software groups including Google, Apple and the Chinese search engine Baidu are interested in expanding their business models to include the field of digital cars, while, on the other, highly specialised manufacturers of driver assistance systems such as the Israeli manufacturer Mobileye are active in the market. That is currently resulting in numerous new strategic partnerships and collaborations. The field of data security is also becoming increasingly relevant to the automobile industry, offering new companies, among others, access to the industry. For example, the Israeli start-up Argus Cyber Security is specialised in combating car hacking.

*Digital ecosystems*

Apple and Google are constantly expanding their offerings

In the eyes of the public, the so-called digital ecosystems offered by the IT and data-processing industries are often seen as the biggest competitors to the traditional automobile industry. The best known examples are certainly Google and Apple. While the search company Google started life as a software-based provider of online services, Apple initially built its reputation as a hardware manufacturer – the first company to make computers for home use. Both companies have significantly expanded their offerings over the years, to the extent that a broad range of products has become a hallmark of their businesses. Both Google and Apple have developed technologies that allow a smartphone equipped with one of their respective operating systems to be networked with a car's communication systems (Android Auto and Apple CarPlay).

In 2014, Apple's Project Titan attracted attention in the industry. According to media reports, the company hired numerous automobile industry specialists. That lends weight to ongoing speculation that the company is working on an autonomously driving, electrically driven "Apple Car". However, there has also been speculation in the press about the cancellation of the project. In spring 2017, Apple applied for permission to test autonomously driving vehicles in the USA.

Meanwhile, Google's autonomous tests have been making headlines for some time. Plans to spin the current research department off into a separate company, which were announced in October 2016, have become concrete. The new subsidiary is called "Waymo" and has been driving the development of autonomous driving technology since December 2016. Reports that Google is planning to enter the mobility services segment have also caused a stir.

Diverse investments

Both companies are generally interested in partnerships with automobile manufacturers and digital mobility services. For example, Google has invested in the mobility service provider Uber and is cooperating with the automobile manufacturer Fiat Chrysler, which provided the cars that were adapted for its tests. Apple owns a share in the Chinese mobility service provider Didi Chuxing and its collaboration with the Indian driving service Ola allows passengers carried by the Indian market leader to use Apple's music offering.

Automobile data is of great interest to digital ecosystems

The origins of Google and Apple make it clear that they are particularly interested in expanding and marketing the digital services they provide that could be useful to road traffic users and beyond. Their final aim is (also) to monetise the mountains of data made available or generated before, during or after a car journey. The greater the access of those companies to the current

and future data of individual drivers and their vehicles, the easier it will be for them to execute those plans. In the end, users will be able to exchange their personal data for the broadest possible range of tailored information about their car journey, and for the ability to better utilise their travel time for business and leisure, according to their individual preferences. That will raise questions about data ownership and security. Experience from other fields of digital business (e.g. social media) shows that many internet users are indifferent, generous, or at least unconcerned when it comes to the ownership of their data.

### *Digital mobility service providers and car-sharing providers*

Many new companies are offering digital mobility services

Digital mobility service providers, in the broadest sense, represent a large group of new market participants. A comparison of the product offerings, business models and markets of the best-known companies shows that such providers have very different areas of focus, and that the companies and their business models are undergoing rapid change. One thing they have in common is that they are predominantly relatively new companies. The best known is the American driving service provider Uber (established in 2009). The company is active in a large number of countries and provides drivers with rented or private cars via an app. Google and Toyota have invested in Uber. The company's autonomous tests using vehicles manufactured by Ford have been attracting attention since 2016. Its main direct competitor in the American market is Lyft (established in 2012). Its investors include General Motors.

The Israeli-American company Gett was founded in 2010 and is active in more than 100 cities worldwide. VW has been an investor in Gett since 2016. Unlike Uber (and Lyft), Gett works exclusively with licensed taxi drivers, thereby sidestepping the legal issues currently facing Uber, particularly in the European market. They relate to appropriate licensing (of the drivers used), which private drivers do not usually have. That creates numerous legal grey areas in Uber's business model when it comes to insurance (e.g. with regard to liability in the case of an accident) and is why, for example, courts in Germany have ruled that the company's services are illegal, and have suspended them in Germany for the time being. Questions relating to the status and pay of drivers under employment law are also causing public debate. It is currently unclear how the legal debates around private digital services will be resolved. It is likely that different countries will find different solutions.

Criticism of the business models of digital mobility service providers

The mobility service Didi Chuxing (established in 2012) is active in the Chinese market. Apple has invested in the company. The provider Grab-Taxi (established in 2012) is the market leader in Southeast Asia and cooperates with the start-up nuTonomy, which is testing autonomous taxi services in Singapore. The Indian market is served by the local provider Ola, which has also been cooperating with Apple since November 2016. That means the relatively new mobility service sector is characterised by a high level of dynamism. At the same time, the start-up scene faces allegations that its business model is largely based on poorly paid jobs (primarily in the form of pseudo self-employment) and irregular working hours. Such criticisms are familiar from other fields that rely on digital services (e.g. payment and working hours of package delivery service providers in the field of e-commerce or the couriers used by food delivery services). Nevertheless, as long as the regulatory barriers to market entry remain low, it is expected that new companies will try to enter the market for digital mobility services and that such services will move into additional cities and regions. However, because network effects and economies of scale are important factors with regard to user acceptance and the cost base, consolidation appears to be unavoidable. The situation is comparable to the market for long-distance buses in Germany where, following an initial

Consolidation is likely on the supply side

rapid increase in the number of providers there are now only a few large providers (who nonetheless rely on subcontractors).

Automobile manufacturers are active in the car sharing market

While the business models of the digital mobility service providers is almost exclusively based on the digital provision of driving services, car sharing providers instead focus on vehicle rentals. However, a look at the major car sharing providers shows that – at least in Germany – they are generally launched by automobile manufacturers (and car rental companies), so they do not represent completely new market participants. For example, Car2Go (established in 2012) is a service provided by Daimler in cooperation with the car rental company Europcar. The car sharing service DriveNow is offered by BMW in cooperation with the car rental company Sixt and is expanding in the American market under the name ReachNow. In any case, car rental companies have a natural affinity for the topic of car sharing. For example, the largest car sharing provider in the USA (Zipcar) is operated by the car rental company Avis.

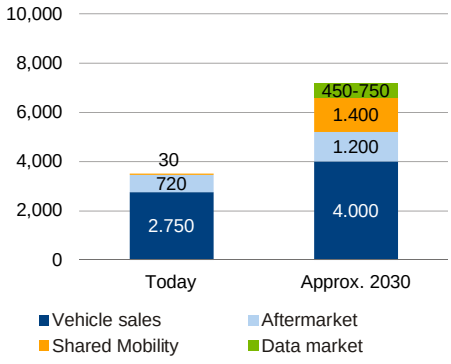
Car sharing etc. changes the use of the car as a product

We can conclude that companies specialised in the provision of driving services and car sharing providers are not in competition with the traditional automobile industry in the area of automobile production. Instead their market penetration is changing user behaviour and the demand for individual mobility from drivers. We will explore the effects changing demand on automobile manufacturers in Chapter 4.

## 3.2 Diverse competition for the traditional automobile industry – market opportunities for new market participants and for established companies

New markets are opening up around the digital car 6

Estimated annual sales by automobile industry segment, USD bn




Source: McKinsey

It is unclear how large the future market for digital cars will be. It is also unclear who will be able to open up new markets, how quickly and how profitably. However, current estimates give an approximate impression of the size of this market. According to a study conducted by McKinsey, global revenue in the automobile market (vehicle sales, aftermarket, shared mobility and the markets for data and digital services) could grow by 5% per year until 2030, to more than USD 7,000 bn – twice the size of the current market.[4] The new digital segments will disproportionately account for that growth. According to the study, the market share of data and digital services in 2030 (which is currently almost non-existent) could account for 6 to 10% of overall revenue. The market for shared mobility is also expected to see strong growth. While revenue in this area currently accounts for less than 1% (approx. USD 30 bn) of the market as a whole, it is estimated that its market share could increase to more than 20% (approx. USD 1,400 bn) by 2030. Such long-term forecasts should always be treated with caution and it is not possible to strictly separate those market segments. However, the size of the estimate cited indicates that the market for data and services relating to automobile traffic, and the field of shared mobility, offer huge potential. In which future markets will new participants position themselves? And how should their potential markets be assessed?

### Individual market segments are characterised by different levels of competition

Competition in the traditional core business of automobile production is unlikely to change significantly

Consideration of the new market participants shows that their competitive situation vis-à-vis the traditional automobile industry differs significantly between individual segments (automobile production, development of new technologies in the field of autonomous driving, mobility services, car sharing and digital data services):

*Automobile production:* Because hardly any of the new providers are specifically focusing their activities on automobile production, in our view the competitive

[4] See also McKinsey (2016). Monetizing car data. New service business opportunities to create new customer benefits.

situation in the traditional core business is unlikely to change significantly. Of course, Tesla has become an important competitor in individual markets, particularly for German manufacturers in the luxury automobile segment. That is primarily the case in car markets where electromobility attracts government subsidies.[5] The company has hugely increased the pressure on established providers to innovate in the fields of electromobility, partly by means of clever marketing. However, even if Tesla manages to achieve its ambitious plans for growth, and thereby achieves sustainable profits, the company would remain a comparatively small provider, by the standards of the global vehicle manufacturing industry, for a number of years.

Many factors make the entry of digital ecosystems into the automobile manufacturing market less likely

From today's perspective, we do not expect the digital ecosystems to extend their business models to include automobile production. A number of arguments support this view:

— The automobile industry is a strongly regulated market. Requirements relating to vehicles will continue to increase, e.g. in terms of ecological sustainability (climate protection) or safety. Why should companies that are currently engaged in far less regulated markets significantly increase their regulatory burden?

Relatively low returns in the automobile industry

— As a result of intense competition, the average returns in the automobile industry are lower than those that companies in the IT and data processing industries are used to and aim for. Involvement in automobile production itself could noticeably reduce their average returns.

— The established structures of the automobile value chain as a whole, as outlined above, represent a barrier to market entry, because producing automobiles would not be enough. In the short-to-medium term the digital ecosystems would only be able to offer a "complete package" through external growth – meaning acquisitions. Their financial strength means such external growth would be an option for the digital ecosystems. The question is whether other investments would generate higher returns.

— The average level of unionisation among employees of the actual automobile manufacturers is likely to be higher than among the traditional employees of the digital ecosystems.

Companies from the electrical engineering and IT and software industries will be able to profit from the trend towards digital cars

*Technologies around autonomous driving:* In the coming years, many companies will develop technologies that contribute to the digital car. The competition from market participants that previously had no involvement in the sector is likely to be far higher than in automobile production itself. Companies from the electrical engineering and IT and software industries are well positioned in this area. The primary market opportunities for new and established suppliers will presumably be in the areas of highly specialised software for driver assistance systems and the field of digital security technology. The revenue generated by these new technologies will increase the potential for growth in the automobile industry as a whole. By 2030, that additional annual revenue could well be in the triple-digit USD billion range. From today's perspective, it is difficult to say whether new or traditional providers will account for the majority of that revenue. However, the new market participants should be in a position to capture approximately half of the additional income.

Digital mobility services: new providers could achieve high market share

*Digital mobility services:* In the area of digital mobility services, new market participants have good chances of achieving an even higher share of future market volume. The digital mobility service providers (Uber and co.) are characterised, in particular, by their strong orientation towards the needs of consumers who may not necessarily be interested in owning a car. Their

[5] See also Heymann, Eric (2017). False start for electric cars – dilemma facing the automotive industry and the state. Deutsche Bank Research. Talking Point. Frankfurt am Main.

business model is built on software-based intermediary services, which are relatively easy to establish because, for example, they do not involve the cost of building manufacturing facilities. The best known intermediary services, Uber, Lyft, Gett and Didi Chuxing, have recently profited from a huge influx of capital. The mobility service providers also have strong market potential, although their ability to grow is strongly dependent on the regulatory environment and the current level of motorisation, among other factors. In countries with relatively relaxed regulation – such as China – the business models of the driving service providers could allow for significantly stronger growth than in Europe, where their position in terms of regulation remains unclear. However, the question whether mobility service providers will remain independent or (as the significant investment interest from various sides indicates) they will eventually be taken over by larger companies from the IT industry or major automobile manufacturers is yet to be answered.

The traditional automobile manufacturers and car rental companies could play a very important role in the area of car sharing. However, new companies with (regionally limited) car sharing offerings could also enter the market. As economies of scale will be an important factor for providers in terms of costs, and network effects will be important to customers in terms of user friendliness, there is likely to be a long-term tendency towards consolidation, at least at the respective national level.

The data market is likely to become the domain of the digital ecosystems – who does the data belong to?

*Digital mobility services and networking:* Data processing and IT companies such as Google, Apple and the Chinese search engine provider Baidu have particularly good prospects in the data-based fields relating to digital services and networking. The ability of digital ecosystems to monetise data relating to road traffic (e.g. via advertising or anonymised sale to third parties) will depend on the form and success of their cooperation with partners, above all from the automobile industry. Of course, questions about who actually owns the data generated and who will eventually receive the revenue resulting from its sale – the party that generates it or that is actually able to market it – are also relevant. Those questions will be answered differently by the various companies involved, drivers and finally by legislators, and the answers may differ from country to country.

Automobile manufacturers and internet companies will meet as equals ...

... and could collaborate to combine their strengths

Both the digital ecosystems and automobile manufacturers have very comprehensive, specific strengths and high levels of confidence in their abilities. Together with their financial strength, the great advantage of the digital ecosystems is in the marketing of large volumes of data, which is a key element of their business models. It is unlikely that the automobile manufacturers will be able to catch up in this area. Access to automobile data, and its marketing, will make the internet companies important players in the future automobile market. They should be able to gain a major share of the additional market growth in this segment. Among other things, their extensive experience and far broader customer base in this segment, compared to the automobile industry, make that likely. However, the established automobile manufacturers will not voluntarily concede this new area of business to the competition. They have close, often long-term relationships with their customers, which they will want to deepen. And, of course, the automobile manufacturers have a better understanding of the car as a product and the automobile value chain than their competitors from the IT world. The situation outlined above suggests that the digital ecosystems and automobile manufacturers will collaborate to combine their respective strengths. From a current perspective, that seems likelier than sustained confrontation.

## Automobile data market: on the path to a “zero euro car”?

There is no doubt that the market for digital vehicle data will grow rapidly. The potential revenue described above offers a rough guideline, although it is not easy to define the relevant market. Does it include revenue generated by a service station or restaurant that was advertised to the driver via digital media during their journey? Does the digital automobile data market include online purchases made by smartphone from a car?

The question of the future value of data generated by a vehicle is also difficult to answer. Some market observers go as far as saying that the value of that data over the lifetime of a car will exceed the cost of the new vehicle. The ultimate consequence of that view is that it would be possible to give cars to users at no cost, because the data that they and their vehicle will generate will be more valuable than the vehicle itself.

### In our view, the “zero euro car” is unlikely

It is currently impossible to predict technological developments in the automobile data market, the opportunities for monetisation and the commercial and regulatory conditions over the next 20 years. However, from today’s perspective the prospect of a “zero euro (or zero dollar) car” seems unlikely. Why? The fact that a large proportion of current driving is highly standardised, and is likely to remain so in the future (e.g. trips from home to work or shops) would suggest otherwise. And the distances involved in such journeys are often very low. That being the case, is the data generated really so valuable that it would justify the provision of a free car to the user? Are drivers – or in the case of (partially) autonomous cars, passengers – really so susceptible to advertising during such short, routine journeys?

### Low utilization of vehicle capacity makes the implementation of the “zero euro car” more difficult

Those facts are compounded by the fact that vehicles are primarily privately used and will remain unused for large parts of the day in the future. The average mileage of a car in Germany is approximately 14,000 kilometres a year, or less than 40 kilometres per day. Assuming an average speed of 50 kilometres per hour, that means the average car is not used 97% of the time, and is not producing any (mobile) data during this downtime. Even assuming that car sharing and similar services will hugely increase the average mileage and usage time per car, low utilisation is an impediment to the realisation of the “zero euro car”. It is interesting in this regard that private vehicle users are currently willing to pay high purchase prices for cars, despite their low utilisation. That shows that people are prepared to pay a very high price for the opportunity to use their own car at any time.

### Payment flows will need to change completely

A further barrier to the “zero euro car” is the fact that it would involve a complete change with regard to payment flows. At least that would be the case if the automobile industry is unable to independently monetarise the resulting data, or could only do so to a limited extent. Companies that are in a position to monetarise automobile data would have to purchase the cars from the manufacturers and, in the most extreme scenario, provide them to the user for free. We consider such developments over the course of the next 20 years to be very unlikely. Our scepticism is reinforced by the current situation: Today’s internet users – voluntarily or involuntarily – give away a large amount of personal data when they are online. In return they get free access to channels of communication such as social media, along with general or personally tailored information and many other digital services. However, the user does not receive any money and generally has to pay (directly or indirectly) for the end user device. The reason there is no “zero euro smartphone” or “zero euro PC” is that the personal information of the individual internet user is not of significant monetary value to them. However, it is possible that the authors of this report do not have the imagination to better evaluate the future potential of digital automobile data. Either way, the situation is sure to be exciting.

### 3.3 Interim conclusion: Automobile production will remain uncontested, new market for car data creates opportunities for digital ecosystems

The structure of competition will differ significantly between different areas of the automobile industry

Overall, we believe that automobile production itself will continue to be relatively unassailable and will remain the domain of traditional automobile manufacturers. It is unclear whether further new companies like Tesla will try to enter the automobile production business, or, for example, Chinese providers that currently serve the domestic market will enter other markets by focusing on autonomous driving etc. The example of Tesla shows that, in the short-to-medium term, establishing a commercially viable business model in the core business of the automobile industry is far from easy. In our view, digital ecosystems will not expand their business models to include (large series) automobile production. Instead we think their focus will be on equipping digital cars with soft- and hardware, and on the growing automobile data market. Here they have a clear advantage over traditional automobile manufacturers, which could allow them to capture a significant proportion of the additional income generated by this data-driven segment. They will also have a particular focus on technologies that will make autonomous driving possible in the future. New suppliers will increase competition in the market for digital automobile technology. With regard to digital mobility services (transport services, car sharing etc.) both existing and new providers have equally good chances. However, economies of scale and network effects make significant consolidation likely in the future. Overall, boundaries in the automobile sector as a whole will become less defined.

Many factors suggest there will be evolutionary development towards a digital car

It is fundamentally worth considering the temporal dimensions of the structural transformation. If you believe media reports about the digital car, you might get the impression that the industry faces an outright revolution, both in terms of technology and the timescale for its implementation. However, many factors suggest that the path to the digital car will be evolutionary rather than revolutionary, in terms of the time required. They include the longevity of cars, the traditional patterns of driver behaviour and regulatory hurdles. Despite rapid technological development, which presents challenges for all the companies involved, the technical issues on the path to autonomous, accident and traffic-jam free vehicles remain considerable. We will consider those aspects later in this report.

#### Automobile industry: no sign of shock-induced paralysis – increased cooperation

Automobile manufacturers are expanding their product ranges

The established automobile manufacturers are reacting to increased innovative and competitive pressure. They are investing in technologies around the digital car and autonomous driving and will work towards developing fully-automated vehicles mature enough for series production in the coming years. Legislators are likely to adapt regulations to the technology, although safety will be a particular area of future focus. Automobile manufacturers are likely to remain active in the field of digital mobility services. The car sharing offerings of Car2Go and DriveNow mentioned above are examples. They will be joined by additional digital services such as taxi booking (e.g. the myTaxi-App from Daimler), online booking of parking spaces (ParkNow) or charging station booking for electric cars (ChargeNow). Drivers will have access to increasing quantities of real-time (digital) information about their route, shopping opportunities, restaurants, petrol stations, hotels etc. and automobile manufacturers will increasingly provide personal contacts who will carry out specific services for the customer during their journey (e.g. restaurant or hotel reservations).

Cross-sector collaborations become more important

The path to the digital car will be shaped by a large number of cross-sector collaborations, investments and takeovers. That trend is likely to continue in the future. The German automobile manufacturers appear to be very open to

collaborations, as demonstrated by the following examples: In 2015, Audi, BMW and Daimler together took over the online map service HERE. The 5G Automotive Association was established in autumn 2016. It involves collaboration between the three German automobile manufacturers named above and Ericsson, Huawei, Intel, Nokia and Qualcomm to develop networked vehicles. That alliance can clearly be interpreted as a response to the activities of the digital ecosystems. There are also collaborations and takeovers in the automotive supply segment and among digital mobility service providers. Overall, there are almost daily reports of (cross-sector) collaborations with a focus on the digital car. The examples given here and in other parts of the report are just a small selection of the activities currently taking place.

### The automobile industry will maintain its traditional strengths

German manufacturers have strong research skills

The strengths of the traditional automobile manufacturers will remain important on the path to the digital car. They include established long-term business relationships with other companies in the automobile value chain and mastery of that value chain, from research and development to sales and after-sales service. One indicator that underlines the innovative strength of the (German) automobile industry is the number of patents granted in the field of autonomous driving. A total of 57% (since 2010) of patents granted worldwide in this area were awarded to German manufacturers and suppliers.[6] Their international focus gives them a certain level of protection against economic ups and downs, and German companies have made huge progress in this regard in recent decades. In terms of brand awareness and image, many automobile manufacturers have nothing to fear from the new competition from the IT industry, although there are, of course, customer groups that identify more strongly with brands from the IT world.

For drivers, changes on the supply side in the automobile sector are generally good news. An increasing number of companies in this market are competing to improve existing automobile offerings and add digital services. That competition will contribute to innovation and lower prices. In the next chapter we will explore whether those offerings will find fertile ground for future growth.

## 4. The demand side: what do users actually want?

It is almost impossible to do anything against the customer's will.

We have seen that many companies from a range of different industries are working on developing the digital car. Put in simple terms: the supply side is endeavouring to create additional demand. But, provided the government does not intervene and alternatives continue to exist, not a single digital car will make its way onto the roads against the will of users. In the following chapter, we would like to evaluate to which extent the preferences of (potential) users and social mobility trends could advance the development of the digital car by focussing on the following questions: how do users feel about the digital car? Which specific properties do they value and which technologies are they sceptical about? To which extent will car clubs and alternative mobility concepts diminish the importance of owning a car? What impact will changing mobility preferences have on the automotive industry and how are companies positioned in this regard?

### 4.1 The digital car will provide additional benefits – but what kind of benefits?

In its ideal form, the digital car will create tangible added value for drivers – or, rather: occupants. For example, they could utilise the time they spend in the car

[6] See also Bardt, Hubertus (2016). Autonomes Fahren. Eine Herausforderung für die deutsche Autoindustrie. Institut der deutschen Wirtschaft. IW-Trends 2/2016. Cologne.

flexibly if the car was driving itself automatically; customised information will make everyday life easier. These benefits or the extent to which individual users will perceive their value will depend on factors such as users' individual preferences, the purpose and length of car journeys, vehicles' technical capabilities at different points in time and therefore users' level of freedom. So, it is not easy to answer the question of how appealing digital cars will actually be for users.

Surveys have produced a range of very different results

This first prediction closely corresponds with the very different results produced by surveys about digital cars and autonomous driving that have been published and reported on in the last few months and years. For example, one of the results of a survey carried out by McKinsey was that 81% of all German car buyers would switch to an autonomous car if they could still take control of the vehicle at any time,[7] while a Deloitte study has claimed that about half of those surveyed could imagine taking advantage of the benefits of autonomous driving, although 90% still said that they would want to be able to take control of the vehicle at any time. According to this survey, young urban populations are particularly open to the topic of "autonomous driving", while older rural populations are the most sceptical.[8] The results of an ADAC survey from the end of 2016 were more reserved, stating that one third of those surveyed (ADAC members) would consider using an autonomous vehicle, whereas it would not even be an option for 35% of respondents.[9] Other surveys have confirmed this mixed picture.

When will autonomous driving become the norm? There are wildly conflicting opinions

There are many different answers to the question of when autonomous cars will become commonplace. A Forsa survey carried out on behalf of DEKRA in autumn 2015 revealed that 8% of those surveyed in Germany expected autonomous cars to have asserted themselves within the next 10 years; another 26% believed that this would take 10 to 20 years. 32% of respondents thought that it would take more than 20 years, whereas 31% were of the opinion that completely autonomous cars would never be the norm. The same survey was also carried out in other countries. US citizens demonstrated the most optimism. Here, 33% of those surveyed believed that there would be a technological breakthrough within the next 10 years, while 29% were of the opinion that it would take another 10 to 20 years.[10]

Drivers would relinquish control in "stop-and-go" traffic and in traffic jams

Recent surveys have also differed in terms of the situations in which drivers would be most likely to use autonomous driving technology or in which it would be used first. One example of this is a survey carried out in summer 2015 and published on the online platform Statista. In response to the question of which situations they would generally be prepared to relinquish control of their vehicles, 63% of respondents answered with "when parking" and 45% of those surveyed said "in traffic jams and on the motorway" (multiple answers were possible). Only 7% could imagine handing over driving activity for the entire journey, and for 27% it was not even an option to relinquish control to the car. According to the aforementioned Deloitte survey, traffic jams and stop-and-go traffic were the driving situations in which those surveyed were most likely to be willing to pay for autonomous driving technologies.

[7] Cf. McKinsey (2016). Fahrdaten werden zum Milliardengeschäft (Driving data is becoming a billion-euro business). Press release. Düsseldorf.
[8] Deloitte (2016). Autonomes Fahren in Deutschland – wie Kunden überzeugt werden (Autonomous driving in Germany – how customers are being won over.)
[9] Cf. ADAC (2016). Mitglieder rechnen mit autonomen Autos (Members expect autonomous cars).
[10] Dekra Automobil GmbH (2016). Leben retten durch technische Sicherheit (Saving lives with technical safety). In: Verkehrssicherheitsreport 2016 – Personenverkehr (Traffic safety report 2016 – passenger transport). Stuttgart.

## A lack of empirical data for digital cars

Reports on accidents in autonomous cars influence sentiment

How can we explain the very different results in the surveys cited and other surveys? Firstly, survey results should always be viewed with a certain level of caution. Statements made in surveys about planned behaviour often deviate from actual behaviour. Specifically, one explanation for differences in these assessments is that there is (almost no) empirical data about the possibilities that digital cars would provide occupants. Because respondents have not yet experienced autonomous driving themselves for example, sceptical attitudes like these are understandable. This explains why only a few of those surveyed would be prepared to completely relinquish control of their cars. It shows that users still do not trust this relatively new technology. Reports about automated test cars getting involved in accidents also have a short-term impact on surveys like these. What is interesting about this set of circumstances is that the added value of digital (autonomous driving) technologies for drivers will actually remain very limited as long as drivers are required to assume control of the vehicle at any time and/or are still liable in the event of an accident. At any rate, the potential benefits of autonomous driving – more time for things other than steering the vehicle, convenience, ideally more safety – will then only be realised to a limited extent. In fact, there would have to be a lot more willingness to completely relinquish control, as only then would drivers be able to take advantage of the spare time now available to them. This is probably a question of trust, which will build with time.

As a group, drivers are anything but homogeneous

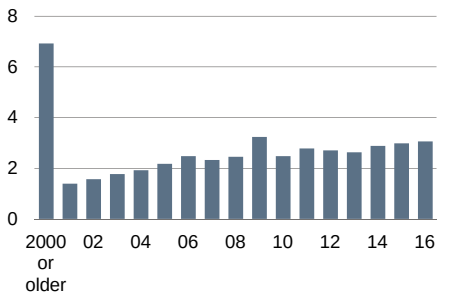
These survey results also show that, as a group, drivers are anything but homogeneous. For some of them, driving itself is linked to emotions and feelings of joy – at least in part – which means that these drivers (still) do not have any pronounced interest in being chauffeured around, wanting to steer their cars themselves instead. This is why the message that driving is fun is often the focus of car advertising. On the other hand, other drivers would be more inclined to switch to autopilot today rather than tomorrow if it allowed them to use the time they spend in the car differently.

Users will have increasingly positive experiences with the technology

Over the course of the next few years, drivers will have increasingly positive experiences with the opportunities provided by partially autonomous driving. Each model generation will make its own improvements. This will build users' trust step by step – but only if the technologies function seamlessly and purchase prices for automotive customers do not increase dramatically. If regulatory issues (e.g., insurance factors and questions of liability, data privacy) are clarified at the same time that technical advances are being made, attitudes towards autonomous driving will improve. However, this process will take many years, if nothing else due to the long life cycles of vehicles. Most cars that are manufactured and developed today can only provide limited possibilities in terms of "autonomous driving". However, many of these vehicles will still be on the roads in the 2030s unless they are prohibited by legislators (which is very unlikely from a present-day perspective). For example, at the beginning of 2017, more than one third of existing passenger cars in Germany (almost 16 million cars) had been registered in 2005 or earlier. Here, we once again see that the digital car in its ideal form will not come to dominate vehicles actually in use until we have reached the end of an evolutionary development – by which we mean a matter of decades.

Many old cars on the roads 7

Share of cars in DE by year of first registration, Jan. 2017, m




Source: German Federal Motor Transport Authority

## There is a general willingness to pay

The cost of new technologies is likely to drop over the course of time due to economies of scale

If nothing else, the costs associated with additional technologies will be crucial to the success or failure of digital cars and whether they are accepted by users. In general, we must differentiate here between one-off costs on top of the purchase price and ongoing costs, for example, for using digital assistance

systems. In terms of one-off costs, the issue of electromobility has shown that average car users do not accept purchase prices for electric cars that are (too) high. We can expect that many of the technologies that will make the digital car possible will first be used in cars in the automotive upper class, where relative price mark-ups are quite low and encounter a higher willingness to pay. Economies of scale and advances in manufacturing productivity will lower costs over time, meaning that, by and by, it will also be possible for digital cars to be manufactured in the volume segment. Patterns like these, i.e., the diffusion of new technologies "from top to bottom", have been frequently observed in the automotive industry in the last few decades (e.g., in safety technologies). The cost of technologies that are primarily based on software are likely to drop especially quickly, making them ready for use by the mass market. The production costs for electric equipment are also likely to fall rapidly, as indicated by the continued drop in the prices of consumer electronics. According to our predictions, another reason that these price increases will remain manageable for average end customers is that vehicles will be equipped with digital technologies (hardware and software) step by step in each model generation, which means that there will not be a sudden excess of them. Additional costs are likely to run into the three to four-figure range, depending on the vehicle's class and technological features. In the volume segment in particular, this would mean significantly lower price mark-ups than those currently being charged for cars with alternative drive systems (electric cars or plug-in hybrids).

Price mark-ups are likely to be manageable for most end customers

Surveys have shown that there is a general willingness to pay for digital assistance services. According to a survey of potential new car buyers in China and Germany carried out by Berylls Strategy Advisors and mm customer strategy in 2016, an overwhelming majority (80% of those surveyed in Germany and 97% in China) said they were generally prepared to pay for digital assistance systems. But this mainly applied to services that affect the vehicle directly (safety, navigation, repairs and maintenance). There was much less willingness to pay for services that did not affect the vehicle directly and could also be used on the driver's smartphone, for example. Those surveyed in Germany still quantified their willingness to pay for digital assistance services at 400 euros (as a one-off payment) in the first three years.[11] The Deloitte survey mentioned above showed that respondents had a clear preference for making one-off payments when purchasing a car. They tended to reject the idea of ongoing, use-based payments or time-based subscriptions.

Willingness to pay, especially for services that are directly related to the vehicle

A survey carried out by the German Road Safety Council in 2016 illustrates that the reasons that car buyers do not purchase new assistance systems have less to do with costs as they do with their (still) lower level of recognition or the fact that the car models that they prefer do not have such technologies.[12] Both of these aspects are very likely to improve in the coming years.

## Autonomous driving in the future: government enforcement or voluntary basis

A higher level of road traffic safety is often cited as a positive argument in favour of digital cars and autonomous driving. There are a number of interesting issues within this context that still receive little discussion: will legislators force car users to use autonomous cars – as soon as the technological preconditions are in place – in order to put an end to the human "source of error"? Will this eliminate the individual elements of private car use, for example, factors like desired speed and general driving behaviour? Will autonomous driving go hand

Are the drivers of the future prepared to relinquish their freedoms on the road?

[11] Cf. Berylls Strategy Advisors (2016). Endkunden-Studie zum vernetzten Fahrzeug (End customer study on connected vehicles). Press release. Munich.

[12] Cf. German Road Safety Council (2016). Fahrerassistenzsysteme: geringe Verbreitung trotz hoher Akzeptanz (Driver assistance systems: low distribution in spite of high acceptance). Press release. Bonn.

in hand with a general speed limit? In light of the fact that most today's car users want to be able to intervene in the driving process at any time, would they accept enforcements like these? Trying to answer these questions would be speculating. However, it is clear that a general obligation such as this, which would be a kind of disenfranchisement, would be met with considerable resistance on the part of drivers, even if it only pertained to selected routes or certain driving situations. Moreover, it would have a considerable impact on the purchasing decisions of car users and, ultimately, on vehicle features, as it would eliminate the "fun factor" during actual driving. We will come back to this in chapter 4.3.

## 4.2 Is the "shared car" gaining in significance? Or: what users like about their own cars and what it costs them

In the previous chapter we looked at the additional benefits that technological advances towards the digital car could provide drivers. In the following, we will be asking if it is currently becoming less important for drivers to own their own car or if it will be less important in the future, to the benefit of car clubs (also often referred to as car sharing services) and alternative mobility services. The following data shows that this question is not that easy to answer:

— For years, what has been referred to as "motorised private transport" (MPT) has by far been the most important mode of transport in German passenger traffic, comprising a very constant share of approx. 80% of total transport volume. MPT also has a similarly constant share of a similar size in the EU and the USA. Although we must consider that MPT also includes taxi and rental car traffic, their share in total MPT is probably quite small.

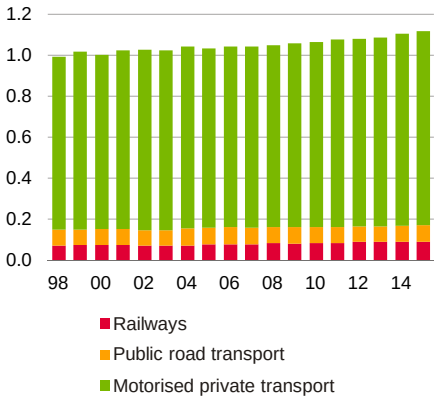
— The following number also demonstrates the significance that users attach to their cars as "everyday" commodities: according to the German Federal Statistical Office, about 77% of all German households own a car. This value has also remained relatively consistent for many years.

— In 2014, the share of adults holding a driver's licence in Germany was 87%. In 2005 it was 84%. This increase can be attributed to a higher share of female driver licence holders. According to these statistics, there is no trace of "car fatigue". At the same time, according to many media reports, the number of young people in Germany (and in other industrialised countries) that do not sit a driving test once they have reached the required age is increasing. According to the German Federal Motor Transport Authority, in 2013, a good 12% fewer general driver's licenses (for all age groups) were issued for cars in Germany than in 2004 (no new data has been published since 2013). In the same period, the number of people aged 20 and under also dropped by around 12%, meaning that demographic developments are an important explanatory variable for this trend. It is also debatable whether the young people in question will go without a driver's licence "forever" or if they will just get one later on. There is not yet any conclusive answer to this question.

— However, a long-term comparison shows that young people in Germany are becoming less important as car buyers.[13] In 1999, 9.6% of all new car registrations by private owners were for people under the age of 30, whereas, in 2016, this figure was just 6.9%. There are a number of reasons for this development: On a banal level, it is due to the aforementioned lower birth rate. Moreover, the trend towards increasing costs for car ownership affects a higher number of students (with limited financial means). Note must also be made of the fact that people are starting families later and

Car the most important mode of transport 8

Traffic volume by mode of transport in Germany, passenger kilometres, tr

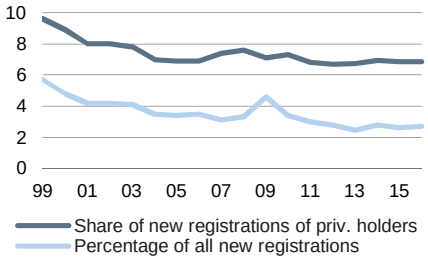



Source: DIW Verkehr in Zahlen

High percentage of population has a driver's licence

Young car buyers are no longer losing in significance 9

Share of under 30s in new passenger car registrations in Germany, %



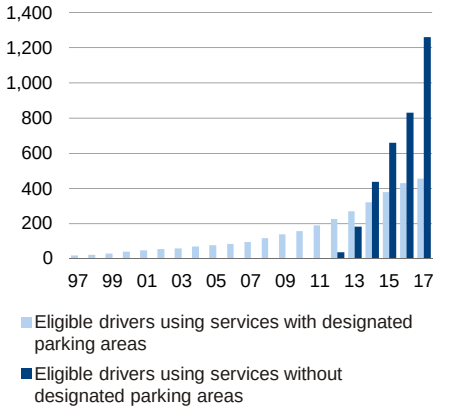

* All holders whose ages are known (i.e. excluding car registrations by legal persons)

Source: German Federal Motor Transport Authority

[13] Cf. Heymann, Eric (2013). Young people in Germany buying fewer cars. Deutsche Bank Research. Talking Point. Frankfurt am Main.

Car clubs: Services without designated parking areas gaining ground 10

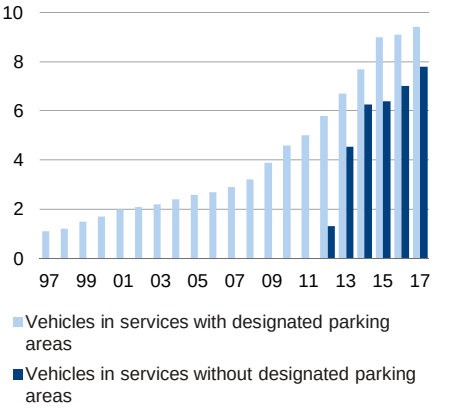
Eligible drivers using car-club services in Germany, '000




Source: Bundesverband CarSharing e.V.

Number of car-club vehicles continuosly increasing 11

Vehicles in car-club services in Germany, '000




Source: Bundesverband CarSharing e.V.

later, which makes it easier to get by without a car. The increasing urban population is another factor, as public transport services are more extensive in cities than in the countryside. However, it is striking that the diminishing importance of young people as new car buyers in Germany has now been stagnating for a number of years, remaining at the low level mentioned previously.

— Some of the trends mentioned are responsible for the increasing prevalence and popularity of car-club (car sharing) services in Germany and in other countries. According to the German association CarSharing e.V., at the beginning of 2017, more than 1.7 million eligible drivers were registered for car clubs. This was an increase of 36% compared with 2016. A total of about 150 providers were recently active in the market. The number of vehicles in car clubs ran to a good 17,000 at the start of 2017. Car-club services without designated parking areas have been able to enjoy especially wide-spread popularity in the last few years. While there were still no services without designated parking areas in Germany at the beginning of the current decade, recently, around 73% of all eligible drivers were registered with such a car-club provider. In spite of the strong growth in the German car-club market, the low number of vehicles being used shows that car clubs are only a niche market when compared with total MPT. At the beginning of 2017, there were about 45.8 million cars on German roads. According to estimates made by Berylls, car clubs only meet 0.05% of mobility needs in Germany.[14]

The aforementioned figures underline the importance of cars for everyday mobility. What makes cars so valuable in the eyes of users? A survey of car owners mentioned in the 2016 DAT report sheds light on this issue: 80% of those surveyed (it was possible to name up to three factors) valued the unique mobility and freedom that having their own car afforded them. The second most important reason provided by 64% of those surveyed was that they were dependent on owning their own car. This was followed by the factors time saving (48%) and increased convenience compared with public transport (41%) in third and fourth place. In contrast, cost factors played a subordinate role. Only 20% of those surveyed said that the reason that they owned a car was that the cost-benefit ratio was better than in public transport.[15]

## High willingness to pay for mobile freedom, flexibility and convenience

The car is, indeed, an important cost factor for private households. The ADAC has estimated that the cost for owning a VW Golf, depending on its features and degree of motorisation, ran to about EUR 600 per month. This estimate was calculated on the basis of all of the costs associated with using a car (loss in value, fixed costs, operating costs, maintenance and repairs) plus mileage of 15,000 kilometres per year. From a purely economic perspective, private car ownership cannot be worthwhile for many car owners, above all due to both the high loss in value and a low level of “capacity utilisation” (i.e., long periods of downtime). But drivers are obviously prepared to accept these costs in exchange for individual mobile freedom, flexibility and convenience, as said survey confirms.

Most car owners do not see car clubs as an alternative to owning their own cars

In order to motivate today’s average driver to go without owning his or her car and to instead switch to an alternative (digital) mobility service and/or car-club service, the latter would have to convince users that it is, above all, flexible and convenient. This is no easy task, as another survey in the aforementioned 2016

[14] Cf. Berylls Strategy Advisors (2015). Car sharing – der große Durchbruch steht noch bevor (Car clubs – the great breakthrough is yet to be seen). Press release. Munich.
[15] Cf. Deutsche Automobil Treuhand GmbH (2016). 2016 DAT Report. Ostfildern.

DAT Report has indicated. According to this report, 88% of respondents do not see car clubs as an alternative to owning their own car. They named the effort required (be it actual or imagined) to find a car at the time requested as the main reason for dismissing car-club services. This was followed by the statement that there were no car clubs on offer near the respondents. Furthermore, those surveyed said that they did not want to share a car with others and that car clubs are not flexible enough. Interestingly, only a small proportion of those surveyed (12%) said that the cost-benefit ratio was not good enough in car-club services.

### Long-term mobility habits a great hurdle for car clubs & co.

It is difficult to convince car owners of the benefits of using alternatives

It is not entirely surprising that car owners have a great affinity for owning their own cars. This must be taken into account when interpreting the survey results from the DAT report, as the survey only interviewed car owners. There probably would have been less scepticism towards car clubs if the survey had also interviewed people that did not own their own cars.[16] In general, however, surveys indicate that it is more difficult to convince people who have been used to having round-the-clock access to their own cars for years or decades of the benefits of alternative mobility concepts than it is to convince people who have never owned their own car (status quo bias). This means that long-standing mobility habits coupled with a high degree of motorisation pose a hurdle for car clubs & co. Surveys indicate that these habits are more relevant for car users than cost arguments.

In future, it will be easier to access digital mobility services

Ultimately, car clubs are just one of the many ways to share the use of a car. Classic forms (e.g., taxi operations, car rental) are being supplemented by new services (car sharing and transport services). Digital technologies are making it possible for customers to use these services more easily and to combine them with other modes of transport such as public transport, which, ultimately, is also a form of shared mobility. In terms of flexibility and convenience, there are increasingly fewer disadvantages compared with car ownership.

### Who is most likely to consider car clubs as an option?

Studies on the topic of car clubs[17] as well as empirical data show that car clubs are predominantly used for inner-city routes, for major shopping trips, weekend excursions and short holidays. The study cited, carried out by the Institute for Mobility Research, indicates that services without designated parking areas are frequently used for inner-city journeys, whereas services with designated parking areas are used for transporting items or short holidays, therefore usually making the routes covered longer.

Young, urban populations are most likely to use car clubs

Ultimately, car clubs have so far been targeted towards younger, urban populations that do not usually own their own cars. They are an interesting option for people who usually get around using public transport, by bike or on foot, but who also require a car sometimes. Although actual user profiles are much more heterogeneous, in the next few years, the demand for car-club services is likely to grow, especially in cities. Population growth in urban centres throughout the world is being accompanied by an increase in the market potential for car clubs & co. Digital technologies are likely to reduce one-off costs charged for registering with a car-club provider as well as fixed annual costs. As a result, the number of registered users is likely to grow more quickly than the number of available vehicles, which was already the case in the last few years in Germany.

[16] This can also be explained by the ownership bias, i.e., people thinking that a product is more valuable when they actually own it.

[17] See, for example, Institut für Mobilitätsforschung (2016). Carsharing 2025 – Nische oder Mainstream? (Car clubs 2025 – niche or mainstream?) Dresden, Vienna.

According to Berylls, only about 6% of registered users use car clubs intensively.

Car clubs & co. are having a rough ride in rural areas

The more rural a region is, the more dependent private households are on having a car on a day-to-day basis, which is ultimately why so many of them own their own car. Together with lower population density in the countryside, this makes it harder for car-club providers to establish economically viable business models outside of larger cities.

This also applies to transport services in general. Although it is conceivable that car clubs could be organised privately in rural regions (neighbours share a car), we believe that there is little potential here, although private car-club models such as these this would likely be economically lucrative for the private households involved. The convenience factor is likely to be the main factor that will prevent them from becoming widespread.

## Do digital mobility services eliminate the need for car ownership?

Market potential for car clubs is increasing, but will initially remain a niche

We expect that, over the course of the next few years, digital technologies will make mobility services like car clubs more appealing to many customers. This will make it more convenient to access and use services like these (e.g., booking and invoicing processes, locating vehicles and parking spaces, customised supplementary information). Moreover, the cost-benefit ratio for customers will also improve. With more and more people moving into the cities and urban areas, the number of people who want to and are able to go without owning a car, either temporarily or permanently, and who use car clubs, rental cars or transport services if they need to, is increasing. However, we think that it is very unlikely that (digitally based) mobility services will quickly or extensively replace private car ownership. There are several reasons for this:

— *Cost:* there is no general answer to the question of whether it is more affordable to own a car than it is to use alternative mobility services. It depends on individual mobility needs. Car clubs & co. are certainly no guarantee for continuously affordable mobility.

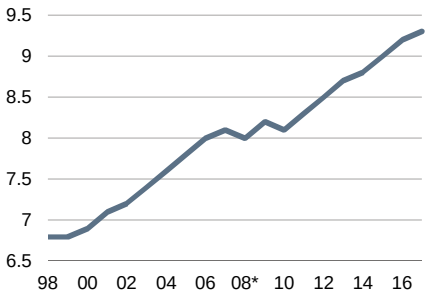
— *Convenience:* when it comes to convenience, nothing is likely to beat having constant access to one's own car in the future either. The same can be said for flexibility, independence etc. The surveys mentioned have shown that private households are very willing to pay for these benefits.

— *Fixed consumption patterns and long car life cycles:* the average driver has been used to owning his or her own car for years or even decades. It is unlikely that it will be easy to break these fixed consumption habits, especially considering that the average age of new private car buyers in Germany is 53, which means that these people are not (yet) members of the "digital native" generation. The previously mentioned long life cycles of cars will also delay the switch from car ownership to mobility services. The average car age in Germany was 9.3 years at the beginning of 2017. Most private households are at least unlikely to sell their vehicle if they are not forced to. Added to this is the emotional connection that many drivers feel with their cars. Traditional consumption patterns could also explain why it is only slowly that alternative drive technologies such as electromobility are obtaining noteworthy market shares, even though there are subsidies for electric cars in many automotive markets.

— *The peak load problem:* In terms of supply, there are also reasons why digital mobility services, car clubs & co. will only be able to replace private car ownership to a limited extent. This has to do with the unequal distribution of traffic flows over the course of the day, week and year. For example, during a working day, peak load times are usually the morning and

Cars on Germany's roads are ageing 12

Average age of cars on German roads, years




* The decrease in 2008 can be attributed to a change in the statistical assessment basis

Source: German Federal Motor Transport Authority

Car-club providers are not likely to base their capacities on peak load times

evening hours, i.e., the times at which many road users are out and about (especially journeying to or from work or educational institutions). At these times, there is a corresponding number of vehicles being used that (today) will hardly be moved for the rest of the day, i.e., at low-load times. Peak and low-load times are characteristic for most modes of transport. In spite of the increasing flexibility of working hours, these differences are likely to remain a fixture in the long term. Time-based price differences (high prices during peak-load times, lower prices during low-load times) will probably only have a limited levelling effect. It is unlikely that car-club providers will base their vehicle capacities on peak-load times. Capacity utilisation at low-load times would be too low, which is why it would not be very profitable to operate a service this way. Moreover, orienting their services towards peak-load times could limit the number of parking spaces available in public spaces, as at least some privately used vehicles are parked on private properties. The more providers are active in each relevant market, the larger the problem of non-utilised capacity will be at low-load times. Moreover, in the long-term, autonomous cars would increase the number of services that are privately owned but then booked by third parties for journeys when the actual owner does not need the car. This would put additional pressure on capacity utilisation for commercial car-club providers. As we have already explained, private car owners are (still) willing to pay to barely utilise their own cars (i.e., high fixed costs), although it is seldom economically viable. In contrast, the commercial providers of mobility services have to be able to generate profits, which makes vehicle capacity utilisation an essential factor in their success.

### Alternative mobility services are becoming a billion-euro market

The aforementioned reasons show that the model of private car ownership and use (including company cars etc.) is unlikely to be abandoned in the medium to long term. Flexibility and convenience are probably the most decisive benefits, especially for people who require a car frequently or regularly. Nevertheless, alternative mobility services such as car clubs (car sharing) and transport services will gain in importance in Germany and elsewhere in the next few years. The primary target group will be the young urban population. And, at the end of the day, this is where a billion-euro market is developing. This is illustrated by a simple rough estimate: let us imagine that the share of alternative (car-based) mobility services will increase in the next 10 to 15 years to 5% of (today's) total mileage for the cars currently on Germany's roads (2015: 635 billion kilometres). This would make the market share 100 times larger than it is today. Let us then imagine that users pay 30 cents for every kilometre travelled. In a (not so unrealistic) scenario like this, sales for mobility services would amount to almost EUR 10 bn per year in Germany alone (without fixed user fees etc.).

### Car clubs: a business case with prospects for car manufacturers?

Car clubs & co.: a market share of 5% of total MPT will be possible within the next 10 to 15 years

The great market potential of car clubs & co. is one essential reason for the automotive industry's involvement in this area. While American car manufacturers have so far mainly been investing in new mobility services, the founding of in-house car-club services is a very German phenomenon. Overall, the forms of alternative car use services are increasing. Alongside services that have been around in Germany for a while (e.g., teilAuto (1992), stadtmobil (1999), Cambio (2000), Flinkster (2001)), car manufacturers are also active with their own car-club services. Included in this group are BMW with its car-club service DriveNow (2011), Daimler with car2go (2012) and the PSA Group with Free2Move (2017). In addition to this, car manufacturers have been observed

Some car manufacturers are taking a spin in the car-club market

making domestic and international investments in alternative mobility services. The VW Group is cooperating with the Israeli mobility service Gett (similar to General Motors and Ford) and is, going by its own statements, putting its trust in an IT-based on-demand service (including car sharing) with its subsidiary MOIA, founded at the end of 2016.

Car clubs also have a marketing effect for car manufacturers

Although very few business figures have been released for many of the car-club services that are being run by car manufacturers, it is an open secret that, overall, this business area is not yet profitable for manufacturers. So far, they have been accepting these losses, as many manufacturers in the market for mobility services have a foot in the door and want to gain first-hand experience of any structural changes to the way their products are being used. Moreover, car-club fleets provide a marketing effect that cannot be ignored. According to one study, a good quarter of car-club users became new customers of the brand in question, although only about one tenth of car-club users planned to get rid of their own car. It remains to be seen whether and how quickly providers will be able to establish car-club services that are economically viable in the long term. We have already explained that a consolidation of the car-club market is probable in the medium to long term (economies of scale and network effects).

## Interim conclusion: users are sceptically open towards the digital car

New technologies have to provide real added value

The sum of all drivers is a heterogeneous group. Average users are just as curious about and open to the digital car as they are sceptical. Due to their basic lack of experience with these new technologies, attitudes like these are understandable. Advancing technological progress will increasingly build users' trust and make them more accepting. To this end, the technologies also have to provide real added value, not just gimmicks. The topic of safety is of the highest priority. In terms of demand, the path towards manufacturing a completely autonomous car for the mass market will be evolutionary and not revolutionary.

We also think it likely that car ownership will continue as the status quo for the majority of drivers in the years to come due to the reasons we have already stated, although car clubs, car sharing and other mobility services are currently gaining significance in urban centres. Within the next 10 to 15 years, these services' share of total MPT in Germany could increase to 5%. This market share will differ from country to country and will depend on factors such as the regulations in place.

Functionality takes centre stage in car clubs

We have spent very little time discussing the topics of data access and data security. The digital car will make the "transparent driver" a technological possibility. The degree to which drivers will accept this is yet to be seen. Average smartphone and internet users are quite careless with their data. Will users behave similarly on the road? The data accumulated during one car journey is of little value to the actual user. However, by aggregating the data of many road users, this data will be valuable above all to digital ecosystems, as their monetisation strategies are based on gaining access to this data. It will also be valuable to car manufacturers (gaining information about driving behaviour, maintenance and traffic information by aggregating the data from all of the vehicles of one provider). Insurance providers are also interested in this data, as digital cars will make it much easier for them to reconstruct accidents (using the car's "black box"). Not least, the state will also have an interest in the accumulated data, which will be valuable for traffic control, but also for prosecuting crimes. The battle for data is likely to be an exciting one. It is debatable whether individual car users will insist upon safeguarding their data or if they will even be able to assert this demand.

Data security and data privacy remain controversial issues

### 4.3 Fewer cars and reduced premium segment due to car clubs and autonomous driving

The demand for cars and car-based mobility will change in the next few years – evolutionarily and at different paces in regional terms, but for good. The significance of car clubs, flexible car sharing services and other services of this kind is increasing. This will have an impact on both the absolute number of cars sold and their features.

Autonomous cars could reduce the number of cars on the road, but mileage per vehicle is increasing

— More people will go without owning their own car if they are able to gain access to better possibilities for alternative (car-based) mobility services. In the future, one autonomous car could replace several conventional vehicles. In conditions that are otherwise the same, sales potential could decrease in the affected car markets. Our colleagues at Deutsche Bank Markets Research have, for example, calculated that the number of cars on the road in the USA would decrease by about 7% if 15% of private households would switch from owning two conventional cars to owning just one autonomous car. This is bad news for the automotive industry at first sight. Nevertheless, a strong increase in absolute annual mileage could overcompensate for the impact outlined here. Because a car's life span depends heavily on its mileage cars that have above average utilisation and mileage are likely to be replaced more quickly. Another additional stimulus could result from autonomous driving technology also making it possible for people to use a car who do not have a driver's licence or who have a physical disability, for example. Even more vehicles could then be sold in sum.[18]

Technological advances and car users' mobility preferences are important influencing factors

Privately used autonomous cars: interiors more important than motorisation

— For German car manufacturers, which focus on vehicles in the automotive upper class and the premium segment, the question of how the expectations customers have of their cars will change if they use car clubs (car sharing) more frequently or if autonomous driving becomes commonplace is of particular importance. For car clubs, functionality is generally more of a focus than it is when customers own their own cars, as the car is a very emotional product for many users. It is very likely that customers would have lower expectations of the cars in a car-club fleet in terms of their features, motorisation etc. than they would have for a vehicle that they are able to configure themselves and then use for a number of years. For this reason, the average car-club car is likely to have less extensive features than a privately used vehicle. As a result, there will be fewer opportunities for car manufacturers to generate additional earnings by providing especially high-quality features or motorisation. There will also be a shift in customer preferences when it comes to autonomous cars in private ownership. If you are no longer steering or operating the gas pedal yourself, car motorisation loses significance in favour of high-quality features in the interior of the car. "The joy of driving" will then relate less to engine performance or acceleration than it will to providing the highest possible levels of convenience. Engine manufacturing, car manufacturers' core competence and an important yield earner, will therefore lose significance in the long term. This will be all the more the case if electric drive technologies manage to oust combustion engines by and by. On average, customer willingness to pay for premium features beneath the bonnet is likely to decrease in the case of autonomous cars; this would certainly be the case if autonomous driving became obligatory. Ultimately, such a development is likely to be more of a risk for car manufacturers than dropping sales numbers due to an increase in car clubs & co.

[18] Cf. Deutsche Bank Markets Research (2016). Pricing the Car of Tomorrow – Part II. FITT Report. London. This report presents more academic studies that provide statements about the degree to which automated vehicles could lead to a lower number of cars overall. However, these statements are not unanimous when it comes to the temporal framework, i.e., by when these developments are likely to take effect.

Companies could also adapt

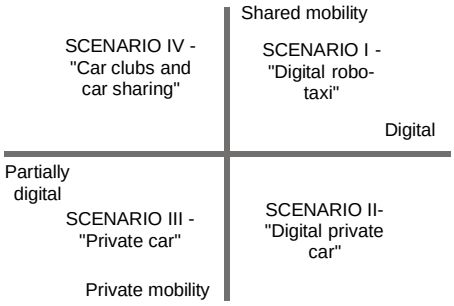
The aforementioned developments will take many years, which is why all of the companies involved will have the basic opportunity to adapt to meet these changing customer preferences (even though not all of them will succeed). For actual car manufacturers, it is also important that there is still a lot of backlog demand in terms of mobility and a strong desire for car ownership in many countries. The global demand for cars will grow in the coming years. The premium segment will also play an important role in the future. In particular, customers who are able to afford expensive cars will only want to use car clubs or share their vehicle with others to a limited extent. Overall, social mobility preferences (like the supposed turn away from car ownership) are likely to change only very slowly – more quickly in cities than in the countryside. Car manufacturers might manage to play an important role in the market for alternative mobility services in the long term.

## 5. The digital car: a solution for high-density cities?

One of the essential expectations of the digital car is that it will improve the flow of traffic in high-density urban centres. In the following, we will outline how digital automobility could change urban traffic volumes and traffic flows in 15 to 25 years in four scenarios. We will describe the scenarios from a 2035 perspective. In our opinion, the question that we deal with in these scenarios (how the digital car will influence urban traffic developments) is dependent on two essential influencing factors: firstly, the degree of technical progress made in the digital car itself and, secondly, the relevance of demand, i.e., users' mobility preferences. We have set out two different manifestations of these two influencing factors: the technical advances made in terms of the digital car could progress quickly and comprehensively or slowly and inadequately (digital mobility versus partial digital mobility). So, in its ideal form, the digital car could either quickly become a technical reality, or developments towards the digital car will take place less seamlessly, meaning that road traffic will still be dominated by partially autonomous driving for many years. Users' mobility preferences, on the other hand, could either change for the most part in favour of alternative mobility services based on car clubs and car sharing, or persevere in the dominant model of individual car mobility with a high rate of ownership (shared versus private mobility).

Schematic overview of the four scenarios 13

X axis: degree of technological development
Y axis: users' mobility preferences




Source: Deutsche Bank Research

Depending on the manifestation, four scenarios result from these two factors (see schematic presentation), although it is not easy to quantify these individual manifestations. Moreover, we must take into account that the broader framework will have a considerable impact on traffic developments (not just) in cities, as well as on the appeal of different modes of transport. This includes, factors like fuel and energy prices, national traffic regulations (e.g., in the form of restrictions on or preferential treatment for different modes of transport) and the relative costs of alternative modes of transport and settlement structure (further densification in the inner cities or a renaissance and expansion of the suburbs). Moreover, socio-demographic developments will also play a role: how is the average number of people per household developing? Is immigration continuing? How quickly is society ageing? When are people starting families? In addition to this, upheavals in the working world (e.g., the significance of working from home), changes in shopping possibilities (e-commerce versus stationary retail), the performance of IT infrastructures (e.g., in order to deal with the amount of data that will be accrued by the digital car), the significance of company cars for car users, and insurance questions will also be relevant. We cannot address these frameworks in detail here, which means that the scenarios described in the following can each only rudimentarily describe one possible future and are intended to provide food for thought.

### Scenario I: the “digital robo-taxi”

Scenario I: significantly fewer cars per household in the cities

In scenario I (digital shared mobility), large parts of the urban population (more than 60% of private households) go without owning their own car in 2035. Instead, they use digital mobility services such as car clubs and car sharing and, of course, public transport or their bikes on a day-to-day basis. In comparison: Today, there is approx. 0.66 cars per private household in the three German city states; outside of the city states, this figure is 1.14 cars per household. Digital mobility services are affordable, flexible and easy to reach in 2035. After a wave of provider consolidation, only a handful of companies are active in Germany in this sector. This allows for economies of scale. In many cities with more than approx. 100,000 inhabitants, customers can use services from the same companies; there is a low access threshold for mobility services. However, in the countryside, services like these remain the exception. In spite of the high absolute user numbers, there is barely any peak-load problem, as public transport remains the most important mainstay for commuter traffic – also due to state subsidies. Moreover, working hours have become more flexible, especially in cities. In this scenario, viewed absolutely, there are fewer cars out and about on urban roads, but their average capacity utilisation has increased significantly. Rapid technical advances have made efficient traffic management and a relatively seamless flow of traffic possible. In many big cities, completely autonomous cars from commercial providers are already part of the everyday streetscape (robo-taxis). Private individuals provide their autonomous cars to third parties for car-sharing services, which are made possible by efficient invoicing systems and the equivalent insurance products. Autonomous cars are also used by people who do not have a driver’s licence (including children and teenagers) or people who have a physical disability. The vehicles of commercial providers have functional features; the focus is on their transport function alone. In terms of their design, autonomous cars have little in common with today's vehicle generation. Technical advances have significantly reduced the incidence of accidents in cities. The losers in these developments include classic taxi operations, which are being used significantly less by private individuals. For holiday trips or other out-of-the-ordinary purposes, “carless” private households can rent vehicles from a range of different providers that meet their individual needs. Although this incurs very high one-off costs, it is still lucrative for users, as they do not bear any fixed costs for their own vehicle for the rest of the year.

### Scenario II: the “private digital car”

Scenario II: private households can go without having a second or third car thanks to autonomous cars

In the second scenario (private digital mobility), technical advances develop so quickly that, by 2035, digital cars are rapidly obtaining market shares and making driverless, convenient, safe driving possible with their numerous functions. However, a larger proportion of customers than in scenario I still want to own their own vehicles; unbeatable flexibility is the main reason for this. Restrained demand makes it more difficult for commercial providers to disseminate financially appealing car-club or car-sharing services that are also economically viable in the long term. Although there are services like this providing autonomous driving in some big cities with more than 250,000 inhabitants and therefore sufficiently high customer potential, they have not yet been able to establish themselves in most smaller cities. Thanks to the digital car, in 2035, more households, above all families, can go without owning a second or third car. This means that automated vehicles can take owners to work, children to school, to practice or to their friends’ houses at different times, or carry out the shopping at specialist retailers. Automated vehicles are predominantly shared within one family unit, but with friends and neighbours as well in some cases. Suitable insurance options make this possible. Vehicle features are generally more targeted towards convenience than in the first

scenario. The premium segment is still significant due to car ownership. By 2035, the absolute number of cars in cities has dropped compared with the current situation, but almost half of private households still own their own car. The following principle applies: the bigger the city, the lower the ownership rate. Thanks to relatively even car capacity utilisation, traffic flows in cities have also improved in the second scenario. Without an efficient, customer-friendly public transport network, however, this will not be possible.

### Scenario III: the private car

Scenario III: lacking economies of scale make it difficult to operate digital mobility services in a way that is economically viable

In scenario III (private partially digital mobility), technical advances are significantly more sluggish. Although the digital car has been available on the market for some time now in its ideal form, autonomous driving is still predominantly limited to motorways and some federal roads, where traffic flows are easier to steer digitally. In city traffic, autonomous driving does not yet play any significant role and is instead limited to some cities and individual routes. This significantly limits its benefits for users. This slow development is also due to legislators exercising caution due to a number of accidents caused by autonomous cars. At the same time, the majority of users still prefer owning their own car in this scenario. In terms of flexibility, but also from a financial viewpoint, for many customers, digital mobility services are not an appealing alternative to owning their own car – this also has to do with the fact that the technology is not yet sophisticated enough. Due to a lack of economies of scale in terms of operating vehicle fleets, user fees are rather high. In the early years, business models like this were frequently cross-subsidized by providers. However, many companies took leave of these economically unviable strategies in subsequent years. In this scenario, the number of cars per household began dropping in the cities in the mid-2020s, but less so than in the first two scenarios. Crucial for lower car density have been factors such as higher costs for maintaining vehicles due to regulations (city tolls and regional driving prohibitions in specific cities and for specific vehicle types). Policy makers used both the environment and frequent urban traffic jams to justify the regulatory burden on MPT. In contrast, regulators favour vehicles with lower pollutant and $CO_2$ emissions (electric cars). In cities with very dense populations, the issue of charging infrastructure (for electric cars) has not yet been sufficiently resolved. In this scenario, private car ownership is even more of a status symbol for wealthy households than it is today. Most households that own a car in spite of the higher regulatory and fiscal burdens place particular value on their vehicle's features. By 2035, volume manufacturers in the automotive industry have lost market shares to companies in the premium segment. Outside of cities, car use is still the standard model. The level of motorisation here remains high.

### Scenario IV: classic car clubs and car sharing

Scenario IV: classic car clubs, especially in cities with more than 500,000 inhabitants, are very successful

In scenario IV (partial digital shared mobility), the digital car has not yet established itself in the mass market. As in scenario III, autonomous driving predominantly takes place on motorways and federal roads. However, because the fixed and variable costs of private car ownership have increased significantly by 2035, more private households decide against owning their own car in favour of alternative mobility services. There has been a massive consolidation process on the supply side, so that only a few providers are still active on the market. Services like this in cities with more than 500,000 inhabitants have been particularly successful due to the fact that it is easier to achieve economies of scale here, as there is a higher level of vehicle utilisation, which keeps customer fees relatively low. Services without designated parking areas dominate, in spite of the greater logistic challenges they pose for companies (parking space availability, refuelling or recharging electric car batteries, cleaning, maintenance

etc.). Customers can easily locate and book the cars they want using a smartphone and then return them to any location after their journey. However, users are usually the ones sitting at the steering wheel. In smaller cities, the range of car-club and car-sharing services on offer is significantly smaller. The companies in question have learned which conditions (population, settlement structure, importance of public transport, commuter habits etc.) are required to operate economically viable services. They have consistently pulled back from markets where these conditions do not exist. Outside of big cities, private sharing models (e.g., amongst neighbours) have gained in significance. Car rental, car retailers and car manufacturers are collaborating with new players in the urban car-club and car-sharing segment. They are also providing flexible solutions for (urban) households that would like to rent cars for longer periods of time (holiday trips), longer routes and/or special occasions. Customers have become used to initially higher variable costs for services like these and know that these costs are still economically reasonable compared with owning a car. In the outlined scenario, the inner city traffic flow has improved, there are less cars on the roads. Car functionality has gained in importance, while users' emotional connection to their car has become less important. This is reflected in both reduced motorisation and by "conservative" interiors. This development has posed challenges for German manufacturers in the premium segment, although many affluent households that own their own cars still appreciate it when their cars have convenient features.

## The car is not the solution for inner-city traffic problems

The digital car could lead to a drop in motorisation levels in cities

These four scenarios can and are intended to only outline the basic characteristics of a possible future. But there are some identifiable patterns. For example, in every scenario, the individual level of motorisation in cities decreases in the long term, not only but also because of the digital car. This is true first and foremost for cities in industrialised countries where car density is already very high. In many developing and emerging countries, backlog demand coupled with higher incomes is initially likely to provide for increased individual motorisation also in cities.

Functioning public transport is important for preventing a traffic collapse

It is also apparent that the car, neither in its "digital" nor in its "conventional" form, will be able to solve traffic problems in urban centres. Comparatively speaking, an automated, well-utilised car requires a lot of space per passenger – space that is simply not available, especially in fast-growing metropolises in developing and emerging countries with high population densities. These cities require well-functioning public transport systems if they are to prevent a traffic collapse from taking place. However, they are not designed to accommodate a high proportion of MPT, as many examples of the earth's large metropolitan areas are already showing today. Finally, massive, cost-intensive investments in public transport infrastructure and suitable vehicles are required. The digital car can only mitigate traffic problems compared with a business-as-usual case. The increase in the number of electric cars and lower-emission vehicles with combustion engines will reduce local emissions of pollutants.

A long transition phase very likely

In all of these scenarios, there are still many vehicles on the streets in 2035 that are far removed from the digital car in its ideal form in terms of their technology. This includes older vehicles that were registered in the 2020s and young cars whose features only enable partially autonomous driving for example. Car markets will probably (still) be in a transition phase in 20 years' time (which will also apply to drive technologies). In light of dominant, frequently "black and white" perspectives on the future of the car, it makes sense to think about the many different grey areas that are likely to shape the industry in the future. It is also clear that there will be regional differences in the market penetration of

digital cars. These differences will likely be apparent both between countries and within individual countries.

## 6. Conclusion and outlook

In light of technological, economic, political, social and other uncertainties, predicting all of the developments that will shape the future of the digital car is like gazing into a crystal ball. Looking into the future is made more difficult by a lack of (quantitative) history on this topic for the most part. However, in our opinion, it is possible to make a number of reliable statements about the digital car.

At a number of points within this report, we have addressed the idea that the journey towards the digital car will be more like an evolution than a revolution. That is due to factors on both the supply and demand side. They include long development periods in the industry and the long life cycle of the car as a product. Other reasons for this are consumer preferences that have been growing for decades and will only change very slowly. The sum of all car drivers is very heterogeneous.

Overall, we believe that the digital car will become technologically possible in its ideal form and will also become part of the everyday streetscape, even in complex traffic situations like city traffic. Autonomous driving is not a utopia. However, it will take several decades for the digital car to make up a significant proportion of the number of cars on the roads; this will not become a reality before 2040. The precondition for there being a high proportion of automated vehicles on the roads will also be car users' willingness to relinquish some of the freedoms in road traffic that are a self-evident part of driving today. Some car users will voluntarily relinquish such freedoms. Others will have to be forced to by state regulations. Political discussions in this regard are likely to be controversial. The digital car is likely to help reduce the number of accidents in road traffic; the human "element of uncertainty" will lose significance. Moreover, more automation will (ceteris paribus) improve the flow of traffic.

The technologies required for digital cars will have a positive effect on revenue growth in the automotive industry. Most technologies (software and hardware) will have to be installed additionally in digital cars; they will not necessarily replace other parts. This is a considerable difference to alternative drive technologies in the automotive industry. For example, battery electric vehicles no longer require many of the parts and components of a vehicle with an internal combustion engine.

This means that the digital car will increase revenues in the automotive industry. Companies that were not active in the automotive industry in the past or that only played a peripheral role will compete for the increased market volume. The supply structure will become more heterogeneous than it is today. Cross-sector collaboration is already on the agenda and will continue to significantly change the industry in the coming years. Collaborations like these will be the best way to pool the strengths of the individual players. In spite of increased collaboration, competition in the "extended" automotive industry will remain intense.

The German automotive industry in particular will be frequently forced to hear the accusation that it has slept through important developments on the path to the digital car. Accusations like these have been and can also still be heard in discussions of other issues, such as electromobility. But the generalisations they make are simply false. Of course, some companies, for example from the IT world, have more advanced knowledge about some aspects of the digital car (e.g., the growing automotive data market) compared to the (German) automotive industry. However, no company has an unassailable lead with regard to the digital car as a whole. Moreover, in this report, we have shown that

being in command of the entire automotive value chain in a mass market is a significant entry barrier for newcomers. If nothing else, evolutionary developments towards the digital car will provide all companies with the fundamental opportunity to adapt to technological, social and regulatory trends. Of course, this will not be possible for some companies, which is nothing more than a process of natural selection.

Discussions about the digital car, autonomous driving, car clubs, car sharing, other digital mobility services and new competitors in the automotive industry are a little reminiscent of the euphoric predictions that were made about electromobility a little less than ten years ago. Some market observers are now once more suggesting that not a stone will be left standing in the industry in the short term (i.e., in the next five years). We cannot help but believe that opinions receive a wider audience the more extreme they are. In our opinion, more caution is advisable: of course, the digitalisation of the car (alongside the development of alternative drive technologies, and improving vehicles' energy efficiency and climate footprints) is an essential mega trend in the industry. It is posing great challenges to companies both technologically and financially, while changing the car as a product and its use are leading to completely new competitive constellations. However, overall, the car market is less prone to short-term (technological) revolutions than the market for short-lived electronic consumer goods, for example. No company can afford to sit back and wait and see what happens. But in light of their capacity for innovation and adaptability, and their control of the entire automotive value added chain, it would not be surprising if many of the car manufacturers and suppliers that are active today (not just in Germany) were still having a decisive impact on technological trends relating to the digital car in 15 to 25 years' time.

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Printed by: HST Offsetdruck Schadt & Tetzlaff GbR, Dieburg

**ISSN : 2511-8552**