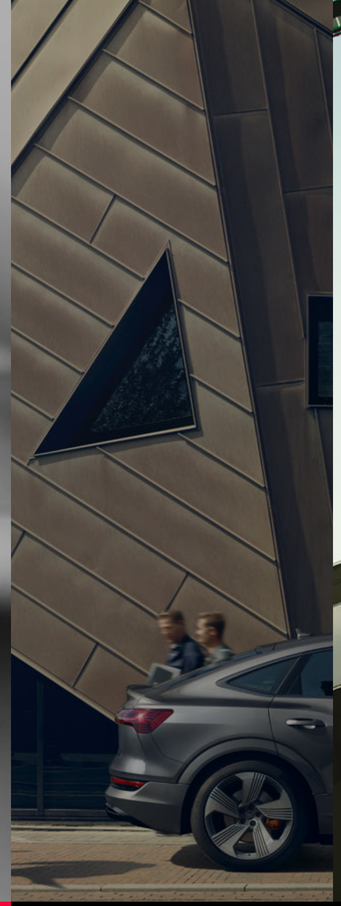

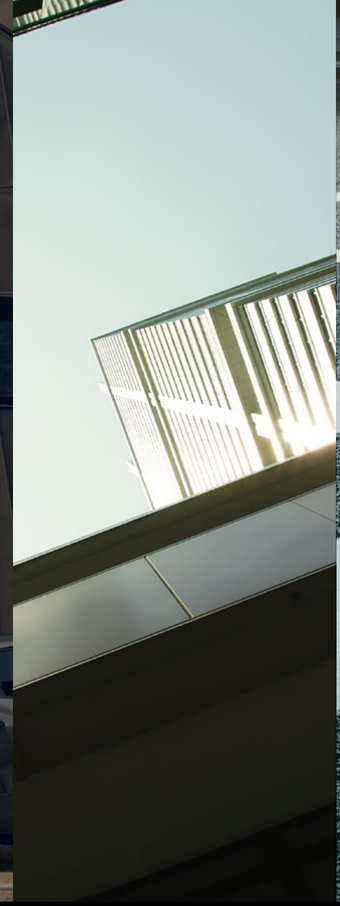

&Audi SocAlty Study

Autonomous Driving on the Road to Social Acceptance

&Audi SocAlty Study

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Foreword

Saskia Lexen
Project Manager, Initiative &Audi

The vision of autonomous driving fascinates us. It embodies a new type of mobility, where passengers are free to use the time they spend in the car to work or relax. The self-driving car is one of the single most tangible uses of artificial intelligence and an example of the opportunities, and challenges, new technologies have to offer.

Today, artificial intelligence is breaking new ground. But it cannot become an end in itself. Away from all the excitement, we need to consider new technologies through a critical lens. Only by engaging in such critical reflection will we able to strengthen people's trust in technology and empower them to embrace innovation. With the &Audi initiative, we want to be part of the conversation aiming to spotlight the opportunities technological progress can offer us. Driver assistance systems are already improving safety by helping us to drive with care and avoid risks. Long term, autonomous driving could reduce the number of accidents. After all, today nine out of ten collisions are the result of human error. In 50 years' time, people may well wonder why we ever got behind the wheel ourselves in the first place given this uncertainty. Equally, for many, the car is so much more than just a mode of transport. Many are not (yet) ready to give up the feeling of driving themselves, of literally taking the wheel in their hands. Indeed, beyond the technical maturity of autonomous driving systems, the social dimension is also key to achieving widespread acceptance. This study seeks to address society's questions on autonomous driving. Experts from academia, business, associations and politics draw on their respective expertise to shed light on these issues, with the focus of the conversation falling on law, ethics and data protection.

All things considered, the picture that emerges is of a mobility landscape that will look different in 2030 than it does now, but not the stuff of science fiction. We want to create realistic expectations of the possibilities, but also the limits, of technology in society and build up trust. In an era of intelligent and connected systems, we have unprecedented opportunities at our fingertips to tackle the core global challenges we face. As an automotive manufacturer, we see it as our responsibility to define digital technologies with ethical factors in mind and to use new technological opportunities responsibly. This way, we can achieve maximum efficiency without wasting time, space, energy or raw materials. Computers analyze our processes and suggest improvements, meaning we curb waste on a large and small scale alike, optimize routes and avoid empty runs and traffic jams. The bottom line is that we will only manage to protect the environment and climate, the major social challenge of our time, if we utilize new technologies. They are what will help us to keep our environment worth living in.

&Audi SocAlty Study

Executive Summary

The focus of the present study is on the core issues surrounding autonomous driving, both today and tomorrow. It considers where technology and society currently stand on the subject, what the near future of mobility with autonomous vehicles could look like and which issues and areas of activity are key steps on the road to an autonomous future.

To this end, 19 international experts from the fields of law, ethics and data were interviewed and asked to give an understanding of their views. While local and professional differences did arise, on many points the results were unanimous. The consensus is that the time has come to move away from envisioning a future which bears little resemblance to reality and instead to work together on establishing a realistic vision of the near future. In order to do so, this study not only addresses the usual topics, such as the further development of key technologies and infrastructure, but also explores a new mindset in handling technological innovations. These experts showcase routes from their respective fields to discover more pragmatic solutions and promote greater collaboration and call for open and transparent communication with the public. As such, the study serves as a basis, food for thought if you like, for companies, policymakers, technology and mobility enthusiasts and other stakeholders invested in ensuring a safe, inclusive and environmentally friendly mobility transition.

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Methodology & Background

Methodology & Background

This study addresses the mobility of the future or, more precisely, the opportunities and challenges posed by autonomous driving. The intent behind the study is to make a contribution to the public debate surrounding current issues relating to autonomous driving and the responsible use of new technologies in mobility. After all, it only takes a brief look at the current discourse on autonomous driving to realize the vital role it plays in many social issues. Yet on the one hand, it seems that society in some countries is not yet ready for such a major technological advance and much of the debate seems driven by fear. On the other, real-life labs and testing facilities are bringing the technology closer and closer to the very heart of our society every day. Simultaneously, the international legal situation is currently undergoing rapid developments and varies from country to country. Equally, while sometimes seen as an obstacle to progress, issues of data protection are repeatedly raised for debate in the general discourse. Topics are discussed to much controversy and questions repeatedly raised for which there are, as yet, no clear answers. The present study addresses these questions and in doing so aims to answer open questions about the use of new technologies in mobility and their influence on people's lives.

Objective & Implementation

The purpose of the &Audi SocAIty study is to help secure a future wherein people and machines can operate reliably and in partnership with automated vehicles. The safe and legal use of this technology can and will foster long-term trust as well as widespread acceptance for intelligent and increasingly autonomous driving systems.

For the very first time, leading experts from the fields of mobility, innovation and society have come together to share their thoughts on ethical, technological and legal issues relating to autonomous driving and to present possible solutions. This study therefore proves an important catalyst for a sustainable societal debate on new technologies and their significance for the mobility of the future. As such, the &Audi SocAIty study has achieved a first in compiling the most pressing questions on and far-sighted solutions to autonomous driving.

Research Focus

It is the intention of this study to strike up a productive conversation on the social viability of autonomous driving. To this end, leading experts from around the world shared their thoughts on three focal points:

Law – Understanding the evolutionary interplay between legislation and progress: What are the biggest challenges and hurdles from a legal perspective and what are possible solutions to overcome such obstacles in an international context?

Ethics – Building a relationship of trust between society and software: What are possible answers to the moral dilemmas of autonomous driving and how can we alleviate fears and win trust in technology?

Data – Balancing performance and protection: What opportunities can connectivity and data collection offer autonomous driving and how can we overcome data protection obstacles?

Study Outline

The experts chosen to participate in the study are opinion leaders from academia, business and politics with a high level of expertise in the field of autonomous driving. Across a series of hour-long interviews, they were given an opportunity to draw a picture of the future of mobility in the year 2030 and to express their views and visions on the present and future of autonomous driving. The interviews were additionally enriched with hypotheses from public discourse and statements from the other experts.

*For the purposes of this study, the term **autonomous driving** broadly serves as a synonym for SAE (Society of Automotive Engineers) Levels 3–5 (see Fig. 1.3).*

Study Experts

This study saw leading experts from around the globe interviewed on the core issues in the field of autonomous driving across the areas of ethics, law and data.

Law

Richard Goebelt
Member of the Executive Board & Director – Automotive & Mobility, Association of Technical Inspection Agencies (VdTÜV)

Deborah Hersman
Former Chairman & Board Member,
U.S. National Transportation Safety Board
Ex-Waymo, Ex-Velodyne Lidar

Dr. jur. Uta Klawitter
Head of General Counsel Legal Services, Audi AG

Jessica Uguccioni
Automated Vehicles Review – Lead Lawyer,
Law Commission of England and Wales

Prof. Bryant Walker Smith, J.D., LL.M.
Associate Professor of Law and (by courtesy) Engineering, University of South Carolina
Co-Director – Project on Law and Mobility, University of Michigan Law School
Affiliate Scholar – Center for Internet and Society, Stanford Law School

Ethics

Pete Bigelow
Senior Reporter, Automotive News

Prof. Dr. Dr. Eric Hilgendorf
Lawyer, legal philosopher & former Member of the German Ethics Commission, Chair of the Department of Criminal Law/ Justice, Legal Theory, Inf. & Computer Science Law, University of Würzburg

Prof. Dr. Christoph Lütge
Chair of Business Ethics & Director of the “Institute for Ethics in AI”, Technical University of Munich

Sandy Munro
Automotive Engineer / Advisor / Speaker & YouTuber,
Munro & Associates, Inc.

Prof. Huei Peng
Professor of Mechanical Engineering & Director of Mcity,
University of Michigan

Dr. Ilja Radusch
Director – Smart Mobility, Fraunhofer Institute FOKUS
Head of the Daimler Center for Automotive IT-Innovations (DCAITI), Technical University of Berlin

Prof. Iyad Rahwan
Director, Max Planck Institute for Human Development
Honorary Professor, Technical University of Berlin

Hiltrud Werner
Member of the Board of Management responsible for Integrity and Legal Affairs, Volkswagen AG

Data

Sam Abuelsamid
Principal Research Analyst, Guidehouse
Columnist, Automotive Engineering Magazine

Dist. Prof. Genevieve Bell
Director of the School of Cybernetics & Florence Violet McKenzie Chair, The Australian National University
Senior Fellow – New Technology Group, Intel Corporation

Jake Fisher
Senior Director – Auto Testing, Consumer Reports

Dipl.-Ing. Torsten Gollewski
Executive Vice President – Autonomous Mobility Systems, ZF Group & CEO, Zukunft Ventures GmbH

Dr. Tobias Miethaner
Ministerial Director – “Digital Society” Directorate-General, German Federal Ministry of Transport & Digital Infrastructure (BMVI)

Alexander Pesch
Senior Director – ADAS / Automated Driving / ICV, Audi China

2

Foresight 2030

What will our transport and mobility landscape look like in 2030? This is the burning question for many experts, mobility users and companies alike. Will all cars be self-driving? Will passenger and delivery drones crowd our skies? What will this mean for our cities or for rural regions? Such questions surrounding potential future scenarios are currently at the heart of a highly controversial conversation – depending on your point of view, utopian or dystopian ideas set the tone of the debate.

Overall, the World of Mobility is Diversifying

Over the course of the interviews, all of our experts were asked about their vision of the year 2030, with a surprisingly unanimous result. The prevailing opinion was that the mobility landscape in 2030 will almost certainly be both more fragmented and more complex than it is today. According to the experts, this is primarily a result of the fact that we find ourselves in a transitional phase in which new mobility options are becoming increasingly established across all areas. This will, the experts believe, lead to a fragmentation of the market as a whole, at least temporarily. Nevertheless, the existing infrastructure will by and large prevail.

A preview of such fragmentation can already be glimpsed in some major cities, where a new last-mile concept pops up on the market almost every month – often to disappear just as quickly. Think of the manifold bike-sharing options or fleets of electric scooters. Moving forward, this new form of micro-mobility will only increase, especially in cities. For those very short distances still currently largely driven by car in particular, the advantages in terms of speed, finding a parking space, environmental footprint and costs clearly outweigh the disadvantages. According to the experts, however, managing to connect new mobility offers with those already established, and doing so in an economically and ecologically viable way, will become a key factor for user acceptance.

The experts are largely in agreement that, by 2030, autonomous mobility systems will have penetrated the everyday lives of people worldwide. Given the enormous influence large logistics companies exert over entire transport chains, it seems likely that freight and delivery traffic will take on a kind of pioneering role here. Nevertheless, there is an initial need for prototypes here, too, for a scalable market introduction and penetration. Various experts named specific use cases, including driver assistance systems for delivery traffic and trucks as well as fully automated systems in shipping or for delivery drones.

“It’s gonna be very messy.”

Jessica Uguccioni

Passenger Transport is in a State of Upheaval

Even more than in the transportation of goods, consumer demand and use habits will shape the passenger transport landscape. In addition to the issue of ecological sustainability, individual demands and personal convenience will play a decisive role here. The new principle is “fit-for-purpose mobility solutions”. This is about offering a particular solution for a particular situation or requirement with well-coordinated offers and services.

In all likelihood, a growing number of shared mobility and digitally connected mobility services will penetrate the market, especially in urban areas. A key factor in user acceptance will be the seamless integration of a range of mobility services for consumers. This means connecting individual transport with shared services and local and long-distance public transport in a way that entails as few disruptions and complications as possible for individual mobility participants.

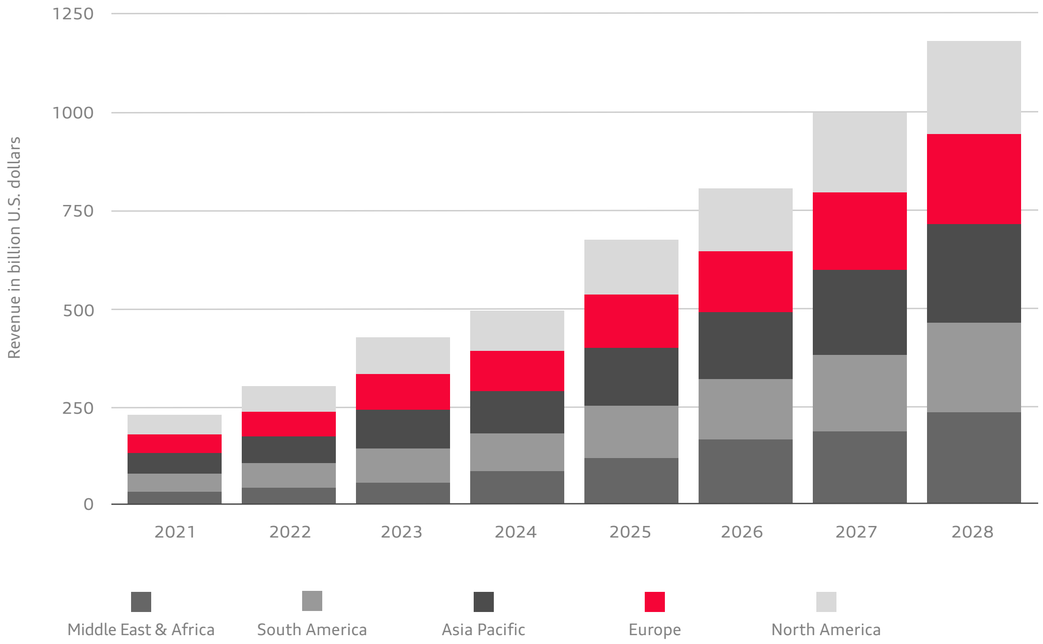
In addition, demand for a range of services will most likely be increasingly determined by the location of the mobility users. Rather than focusing on national differences, specific location factors will define the options for specific mobility solutions. After all, large cities have increasingly similar needs, both globally and nationally. Basic mobility requirements and needs in terms of mobility, flexibility and customer expectations hardly differ between New York, London and Shanghai, with similar patterns emerging in rural or suburban areas.

“I think that there will be more options in the future. It will be more fractured than it is today. And obviously there is more variety of modes available that are kind of just coming to the fore.”

Pete Bigelow

Global shared mobility market size forecast from 2021 to 2028, by region (in billion U.S. dollars)

Statista estimates; Data Bridge Market Research, Statista 2021



"We need to move people but not cars."

Torsten Gollewski

"So of course, today is the baseline in big cities such as London, Paris, or Manhattan, San Francisco. It's very possible that part of the areas there, you can not drive your individual owned vehicles in there. You have to take the shared service."

Huei Peng

Individual Transport is Still a Gamechanger

Does it then follow that the sharp rise in Mobility as a Service (MaaS) offerings means that individual transport and the automotive will lose massively in importance? No. Here, too, the experts are mostly in agreement: individual transport will continue to dominate the mobility landscape. In less urban regions in particular, but also in suburban areas and cities, having access to one's own vehicle, whether purchased, leased or made available in some other way, will continue to offer an additional level of flexibility and comfort in the near future.
Those who can will still be able to enjoy regular travel in their "own" car in 2030 and beyond. In addition, the automotive will continue to be of symbolic relevance for individuality, freedom and status.

“Owning a car will still be a status symbol.”

Genevieve Bell

Responsibility Still Primarily in the Hands of the Driver

So, what will vehicles look like in the near future and, above all, who will be driving them? Will they be completely autonomous, or will humans still be mostly in charge? What impact will this have on people and society? The majority of the experts are in agreement on one thing: autonomous driving will change our mobility landscape gradually, meaning the great “autonomous revolution” has yet to happen.

At first, it seems highly likely that there will be a strong penetration of (partially) automated systems in driver assistance systems in private transport by 2030. Functions such as highway or traffic jam assist, which currently predominantly feature in luxury vehicle classes, will by then be widespread. In future, it seems highly improbable that there will be any cars without driver assistance systems. One reason for this will probably be regulatory requirements.

Nonetheless, humans will in all likelihood remain in the driving seat in the majority of vehicles making up the individual traffic of tomorrow, above all outside of urban centers. The reason behind this is that the autonomous driving technology in private transport will not yet be fully scalable by 2030, meaning few vehicles will be able to offer Level 4 or 5 of autonomous driving.

This primarily stems from the fact that artificial intelligence will not yet be capable of fully and comprehensively mapping interdependencies and the complexities of reality. As such, the dream of “relaxed driving”, where humans have only to lean back and relax, will, in 2030, still be a vision for the future. Responsibility will remain firmly in the hands of the human being.

Society of Automotive Engineers (SAE – J3016 Standard)
Automation Levels

(cf. NHTSA, 2021)

No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation
Zero autonomy – the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like accelaration and steering, but the driver must remain engaged with the driving task and monitor the enviroment at all times.	Driver is a necessity, but is not required to monitor the enviroment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

“This isn’t a case of revolution, but rather evolution. Step by step in a direction that’s already becoming clear.”

Eric Hilgendorf

Specific Areas Will Be Fully Automated

While it remains unlikely that Level 4 or 5 autonomous driving will be implemented across the board in passenger transport, most of the experts were convinced that Automated Driving Systems (ADS) will by no means be a rarity on our roads. It seems highly probable that we will see autonomous shuttle services in urban areas, even if limited to fixed routes in clearly defined areas.

One possible form these shuttles could take is carpooling systems that can be called up via an app to supplement public transport at low speeds and on specific routes. Known as automated people movers, such services are intended for between 6 and 10 passengers, or up to a maximum of 20 people. The experts rated these systems as particularly attractive, as implementation costs are relatively low compared to rail-based transportation, such as trams or other alternatives. For users, these shuttles offer greater flexibility and comfort than existing public transport, while at the same time promising lower costs than taxis or other individual transportation services.

Another likely use case we will see more and more of on our city roads in 2030 is ‘robo-taxis’. In certain regions, these could replace conventional taxis, with the majority of experts envisaging such use cases in large cities across Europe, North America and China. Expert opinion differed substantially, however, when it came to market penetration. Some believe larger fleets will already be on the market by 2030, while others do not see this happening until later. Above all, this will depend on breakthroughs in technological developments, such as comprehensive 5G networks, cloud edge computing or quantum computing.

“You will see certain areas like city centers, universities, large campuses, retirement communities etc. where you’re going to have autonomous driving Level 4–5. But I think, that we are going to see a lot of geofencing in those environments.”

Deborah Hersman

“One kilometer of rail in the city costs around 10 million euros. A kilometer of shuttle on the road costs around 20,000.”

Torsten Gollewski

An Era of (Partially) Autonomous Mixed Traffic

By 2030, mobility will already entail a new type of mixed traffic with both autonomous and human-driven vehicles on the road. The extent to which this mixed traffic will actually be a widespread reality largely depends on whether and how well autonomous systems are able to react to irrational human behavior in their current form.

Many of the experts interviewed agreed it is quite conceivable that there will also be areas, including for individual passenger transport, where only Level 4 or 5 vehicles will be allowed to drive. The Operational Design Domain (ODD) will play a key role here. This domain sets out the requirements or conditions under which an autonomous driving system can function safely and reliably. The better and more clearly factors such as infrastructure, environment, weather influences and road conditions can be defined and predicted, the higher the level of automation can be.

It is a fairly safe assumption that the cars of the future will have different driving modes that are activated or offered depending on the location at hand. That is to say, the area in which a vehicle is traveling could determine whether a particular level of automation is possible or even mandatory (cf. Fig. page 16). In rural areas, for example, with less developed infrastructure and less predictable road conditions, Levels 1 and 2 will continue to be the standard. Conversely, when the same vehicle joins the highway or enters an urban area, Levels 3–5 could be automatically activated or a higher level of automation suggested. Geofencing, the technology to delineate these different zones, already exists and is even being used in other areas.

“Infrastructure plays a vital role. Just think of the grid street plans and long highways in the US. From a manufacturer’s point of view, it’s much easier to find solutions there than in the winding old-town streets of European cities.”

Tobias Miethaner

“I believe we could see extensive global robo-taxi operations in cities by around 2035–2040 if we hedge on 1 critical error per 1 billion kilometers. With strong technological progress every four years, we could even see this not long after 2030.”

Torsten Gollewski

ODD (Operational Design Domain)

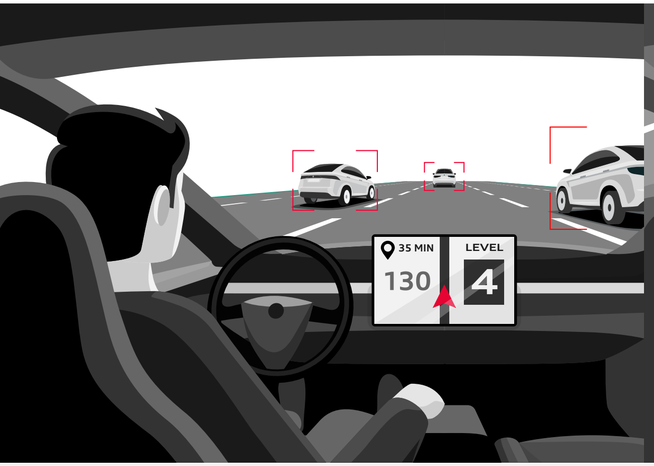
Describes the specific operational domain(s) in which an automated function or system is designed to operate properly, including but not limited to road types, speed range, environmental conditions (weather, day/night, etc.) and other domain limitations. (cf. Berman, 2019)

Geofencing

Geofencing refers to the technological ability to define and mark a specific geographical zone, with GPS used to locate which zone a vehicle is in. The features and rules that have been set for a zone then determine which driving modes can be activated in a vehicle. in theory, it is also possible to completely block access to certain zones. (cf. Quartix, n.d.)

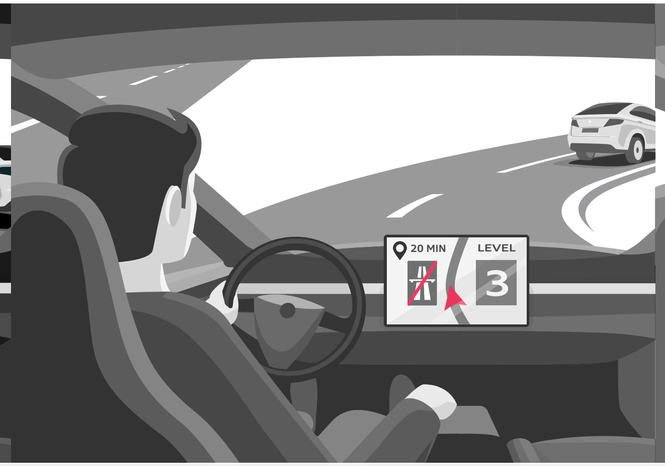
Exemplary scenarios of environment-dependent driving modes with limited ODD*

*c.f. Fig. p.13



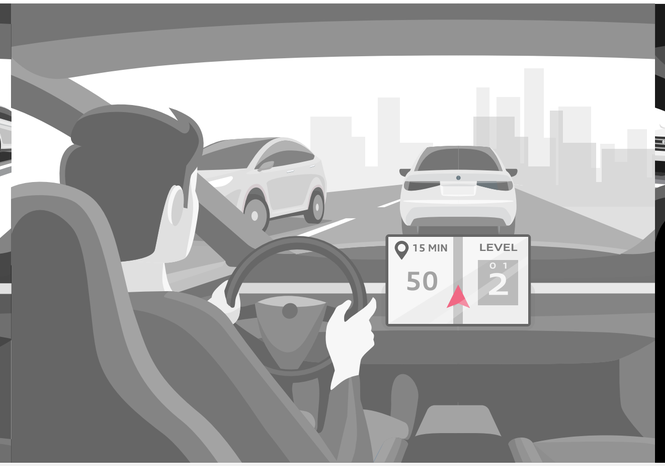
Situation 1 Highway pilot –
is performing all driving functions

Automation Level 4



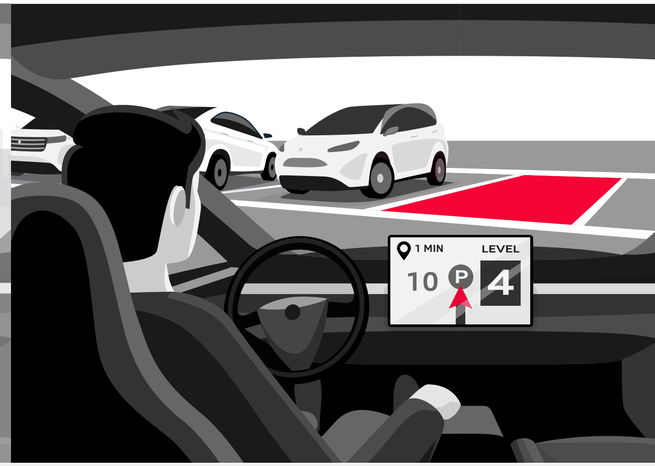
Situation 2 Automated driving system –
is performing certain driving functions

Automation Level 3



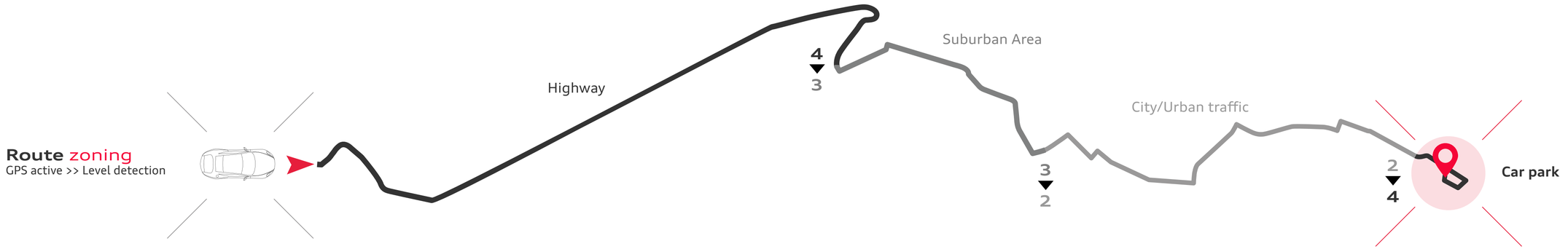
Situation 3 Driver assistance system –
supports the driver

Automation Level 2



Situation 4 Automated valet parking –
is performing the parking process

Automation Level 4



How Drivers Are Viewed Will Gradually Change

What the impact of these developments will be on the role and self-image of mobility participants in future proved a controversial topic among the experts. In zones or environments where Levels 1–2 are the norm, people will continue to actively drive the vehicle. At the same time, the role of the driver will increasingly become that of the passenger, thanks to a wide selection of mobility services. As a result, drivers are likely to take on a far more diverse range of roles than they do today, depending on the situation at hand. It follows that a new way of driving will emerge in Level 3–4 autonomous vehicles – a mix of active driving and driving with automated driving system in specific situations or areas will then become the new normal.

It is an interesting exercise to imagine how our behavior and habits will also change as a result. Will the car become a third living space of sorts? A second home or office? That is to say, will we sit relaxed in the car and work, read or chat before we arrive relaxed at our final destination? Not by 2030, say the experts. Switching between different zones and driving modes will continue to demand our attention in 2030, thus continuing to involve a certain degree of effort. The major opportunity, at least in the near future, lies therefore in making driving safer, more reliable and faster, as traffic volumes likely increase.

The Race Between Systems & the Role of Companies

To follow the discourse in the media would be to think that a race of sorts exists, a struggle for global technological supremacy in the development and implementation of autonomous driving. The US versus Europe and China, Tesla versus the German carmakers: such narratives abound. In actual fact, the reality in 2030 is likely to show more of a global division of roles between states, cities, systems and companies. The large and innovative companies driving development ultimately see the world as a global playing field, both in terms of markets, but also in choice of location and investments. Local legal frameworks play a decisive role here, as do a willingness to invest, existing and planned infrastructure as well as culture and acceptance in society.

“From being a driver – to being a passenger with duties (user-in-charge).”

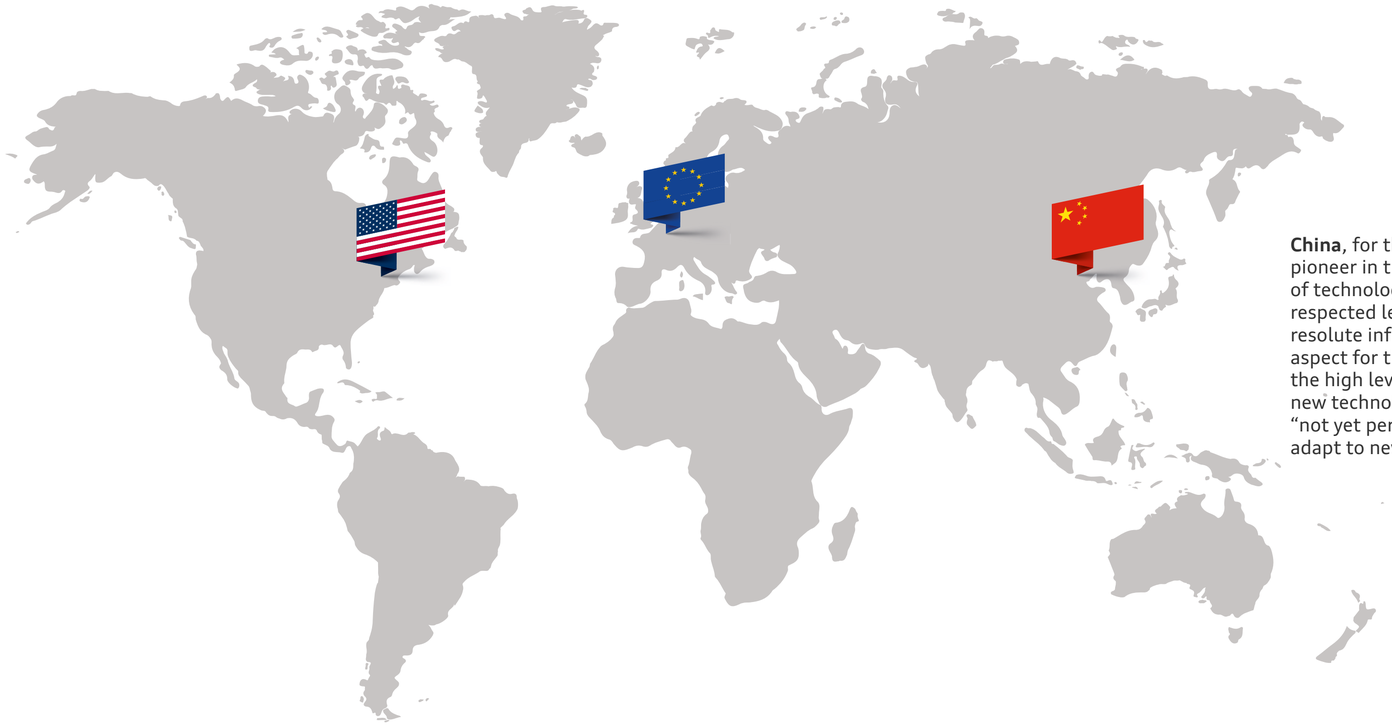
Jessica Uguccioni

“I’m very sceptical of rankings, and i’m very sceptical of speaking about technologies in national terms. Because as you know the reality is much messier. We have transnational companies.”

Bryant Walker Smith

The **USA** is seen by the majority of experts as the enabling and promoting force behind technology. While new technologies are not always primarily developed here, they are nevertheless brought onto the streets with the help of capital and knowledge. Another decisive factor is the USA's progressive and opportunity-focused self-image with regard to the development and introduction of new technologies, which creates favorable conditions for the implementation of autonomous driving.

Germany and **Europe** will presumably also play a key role – primarily as a location for vehicle technology innovation and series production but also as a sales market. That is why European consumer law and data protection regulations are shaping the global environment and product standards for the industry as whole. According to the experts, European decision-makers and players from business, research and politics tend to act more conservatively and are more regulatory-minded, as opposed to the more "hands-on" approaches in the US or China. This could, however, change in future if large companies place a greater emphasis on innovation.



China, for the majority of experts, is regarded as the pioneer in the scaling and widespread penetration of technology. Here, having the appropriate and respected legislation in place is crucial, as is a resolute infrastructural expansion. Another key aspect for the penetration of technology in China is the high levels of social and societal appreciation for new technologies. There is a great openness to new "not yet perfect" technologies, and people quickly adapt to new innovations.

"The US often takes on the role of incubator; it breaks new ground early on. In China, on the other hand, new technology is often quickly rolled out and scaled across the board."

Uta Klawitter

"Fundamentally, Germany is well positioned. We're still right out in front. In terms of regulation, we're even in pole position."

Eric Hilgendorf

3

SocAIty Impact Radar

In light of a possible future scenario for mobility in 2030 and beyond, the question arises as to which conditions must be met for a society in which autonomous driving is widely accepted and anchored to become a reality. In this context, what are the key issues with implications for society as a whole, and how are they interrelated? Many of the experts interviewed believe there is a need to identify, understand and resolve the main obstacles relating to the tension between humans (society) and machines (technology). As such, this study classifies the primary issues addressed that fall under the umbrella of tension – issues which are located along an unspecified time axis toward a future in which autonomous driving is socially established.

SocAIty

A term coined from amalgamating the words Society and AI (Artificial Intelligence)

(Social) impact

Social impact describes the phenomenon whereby the behavioral changes of a multitude of individuals bring about a change in society as a whole.

Radar

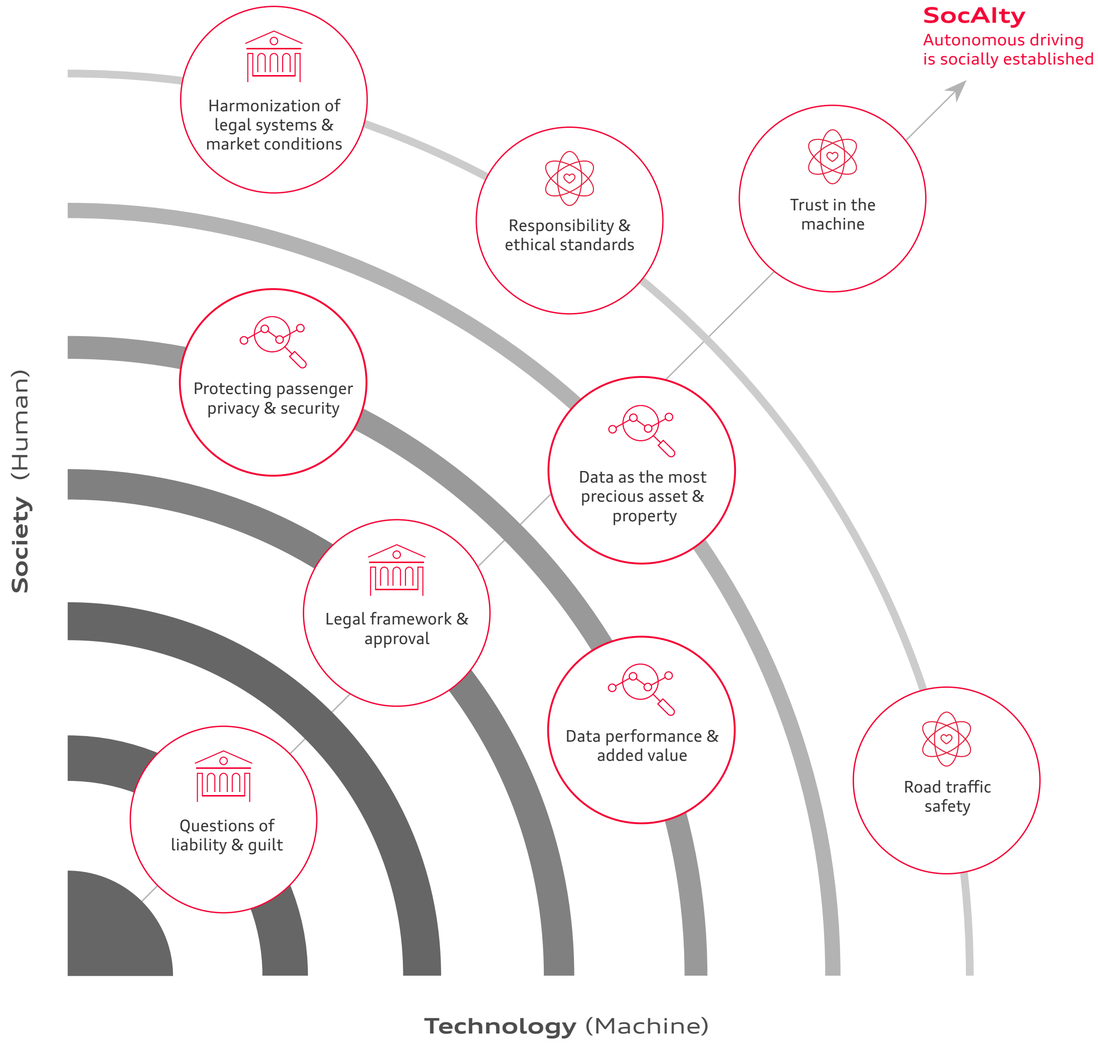
A technology, or in this case a representation, used to predictively locate and track objects, or in our case, relevant subject areas.

The SocAIty Impact Radar highlights nine topic clusters and locates them in the area of tension between technology and society. The clusters in question are derived from the opinions and ideas of the experts.

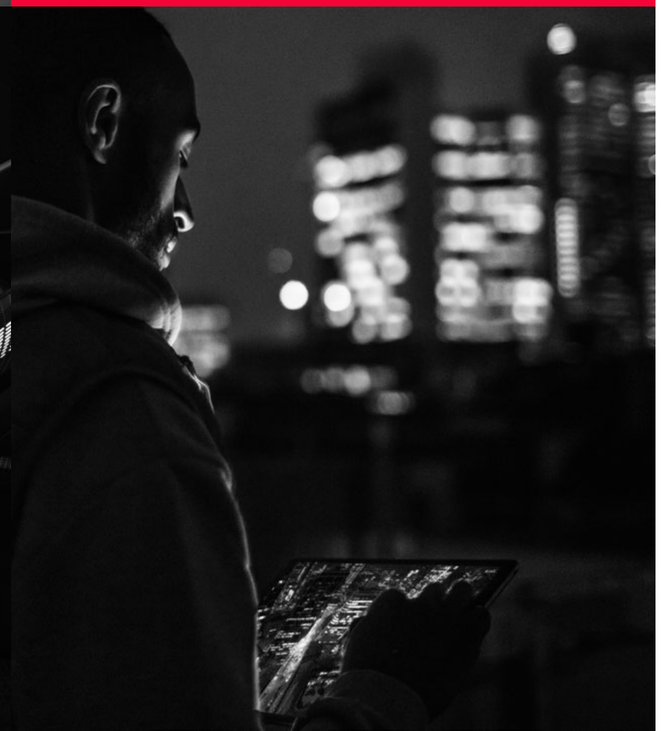
For the sake of clarity, each topic cluster was assigned to one of our three focus areas: ethics, law and data. Clusters were classified according to the area they were most closely linked to in terms of content and with reference to the experts interviewed.

Naturally, however, the three areas are strongly interdependent. Thus, questions with an ethical focus, such as “trust in the machine”, are partly answered in the legal system. In turn, the use of data, for instance, must be both ethically justifiable and regulated in law.

Law **Ethics** **Data**



The Focus Areas



Law

Legal framework and approval – provides an insight into the current situation regarding lawmaking and legislation. Also covers legal foundations for next-generation vehicles and the regulation of the transport system.

Questions of liability and guilt – discusses the regulation and allocation of liability and guilt in accident situations.

Harmonization of legal systems and market conditions – considers the opportunities and challenges facing autonomous driving technology internationally.

Ethics

Responsibility and ethical standards – explores existing ethical policies and practices.

Road traffic safety – addresses the interaction between society and software as well as the opportunities and limits of technology in terms of safety.

Trust in the machine – considers ideas and concepts for building trust between society and software.

Data

Data as the most precious asset and property – addresses the question of ownership as well as the right to use data in the context of autonomous driving.

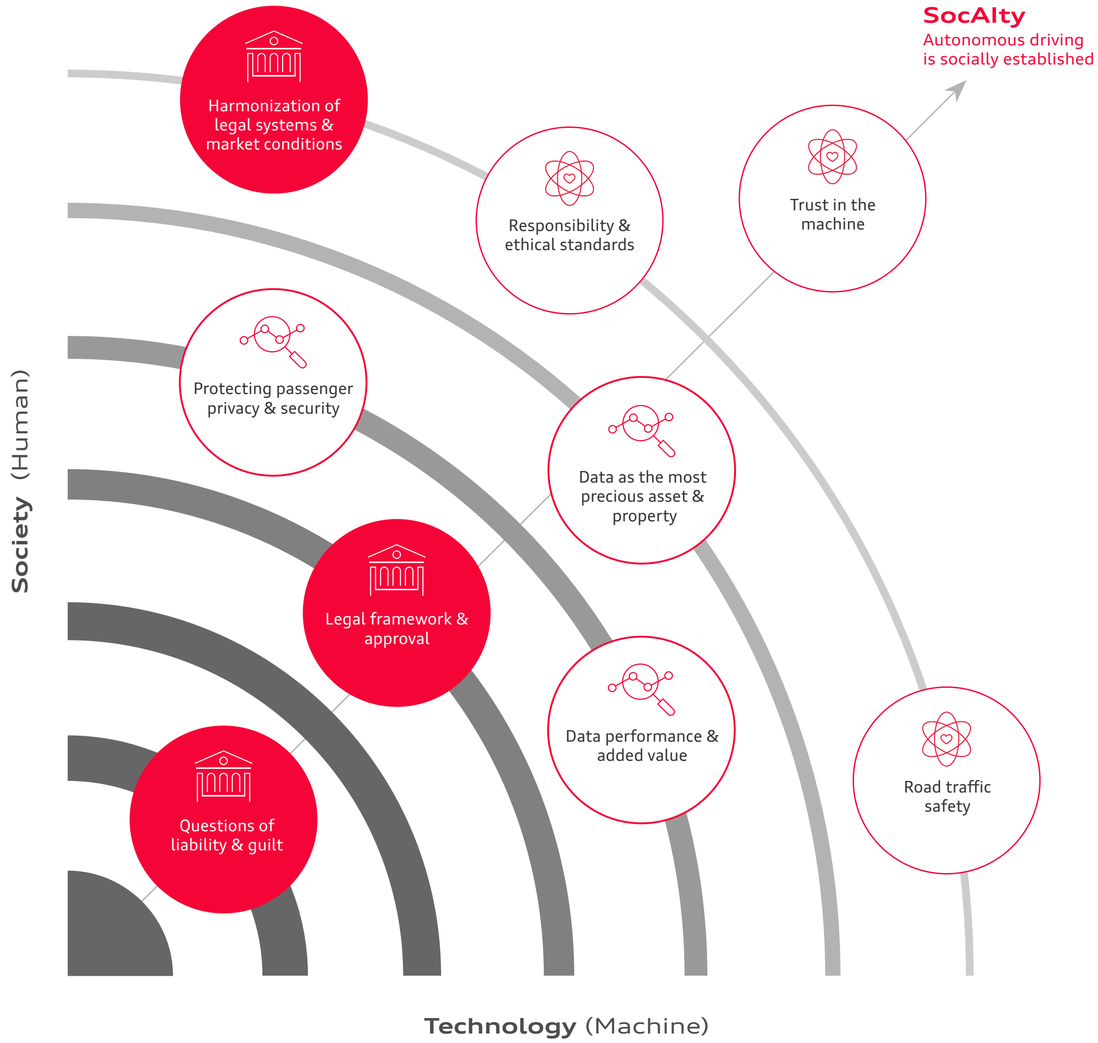
Protecting passenger privacy and security – grapples with issues surrounding data protection and security in autonomous driving.

Data performance and added value – describes the connectivity and efficient use of data. Key topics include data quality, data requirements and digital infrastructure performance.

4

Law – Understanding the Evolutionary Interplay Between Legislation & Progress

The area of tension between creating the right legal framework (legislation) and technological progress for autonomous driving raises crucial questions at both ends. On the one hand, regarding the implications of autonomous driving for society and the legal system; on the other, what the legal system will have to achieve to get there and where improvements are still needed. The interviews held with the experts identified a significant number of challenges, hurdles and outlooks for autonomous driving. From this, it was possible to distill the key factors at play for autonomous driving to achieve social viability, including the question of liability in the event of an accident, regulations regarding the approval of future vehicles and a possible harmonization of international legal systems.



Legal Framework & Approval

More generally, and optimistically, the legal framework for autonomous driving moving forward does not necessarily represent an obstacle. Sooner or later, legislation will respond to new advances in technology, and we will see corresponding regulations in place accordingly. Nevertheless, many experts also predicted major challenges here, not least because, in some countries, technological progress actually precedes the legal framework, which can entail uncertainty and insecurity on the part of companies and users. Germany stands out as the exception here, as legislators laid out an appropriate framework at a very early stage. However, upon closer inspection of the current situation regarding lawmaking and legislation or regulation of the transport system for autonomous driving, it is important to note that, at present, there are very few use-case examples for automated vehicles in regular road traffic. All systems and vehicles are in use as a prototype in a controlled environment and are only able to drive autonomously in the short term under certain conditions. Thus, the technology is yet to reach the level in series production that is being discussed in theory.
It follows that legal systems around the world are faced with the challenge of thinking in terms of what might be, with precedents only to emerge in the course of the next few years. Only then will it be possible to make a valid assessment on potential jurisdiction and the practicability of legislation.

“No manufacturer right now has a highway pilot in series production on the road yet. German legislators are leading the field worldwide when it comes to regulating automated driving functions, thereby setting out an initial legal framework for manufacturers to develop these technologies.”

Uta Klawitter

Lacking Expertise & Speed as a Risk Factor

This fact, combined with the speed and unpredictability of technological progress in fields such as artificial intelligence or big data, also creates a certain uncertainty on the part of legislators. As a result, in some cases, there is simply insufficient knowledge to develop regulations that promote technological progress without endangering users – a challenging situation on several counts. To a degree, this could obstruct technological progress as a result of unnecessary or excessive regulation. The danger also exists that individual companies will use or exploit the situation in their own interests. If regulation fails to take into account the present and future state of technology, there is a major incentive for companies to focus first on their own profitability.

A cautionary example here is the slow pace of legislation regarding areas of the Internet, where practice has seen an almost lawless space develop in some areas, at least temporarily. The experts therefore see an urgent need for a regulatory framework for autonomous driving that, insofar as possible, includes future scenarios and possible advances in technology and leaves an option to respond to such developments with flexibility.

New Challenges Need New Solutions

Many of the experts are of the opinion that, in a first phase, autonomous driving legislation is less about regulating individual vehicles or systems than about regulating a technology on a large scale. After all, this technology will have ubiquitous effects on the entire transport system. Here, the ability to respond with flexibility to the uncertainty and complexity of technological and social developments is key.
This requires, in the experts' view, a new, evolutionary approach to lawmaking and legislation. In turn, this must proactively foster an understanding among legislators that is open to technology, and in the long term, this understanding must be secured via an ongoing conversation between industry and research.

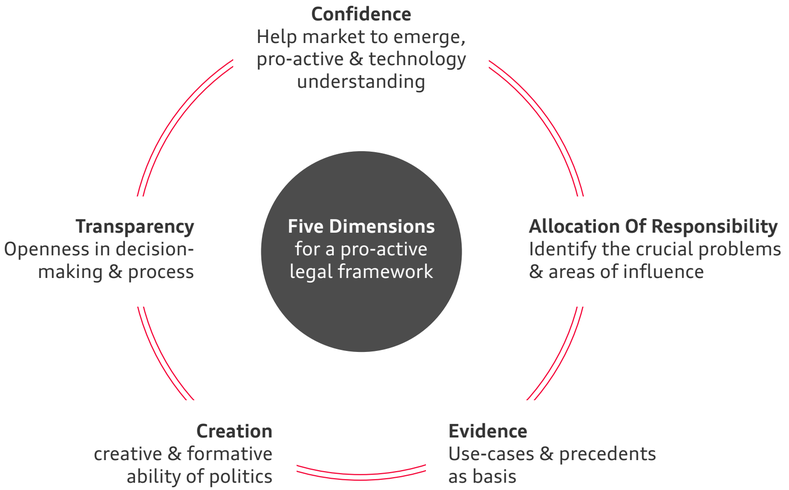
One possible approach would be the "trial and error" mechanism. This initially starts from the basis of the "imperfect status quo" – that is to say that autonomous driving technology is not expected to offer corresponding levels of safety while still at the prototype stage. Instead, the aim is to achieve the highest possible level of safety and acceptance for society in a transparent process. Particular importance is attached to ensuring an ongoing dialogue and plannable development cycles.
In addition, a permanent committee of experts from the fields of law and technology could also be set up in support of this process, securing permanent access to the necessary knowledge about relevant developments for legislators.

"A solid legal foundation is important for ensuring that these technologies ultimately benefit society. To build this foundation, policymakers need deep research, diverse expertise, and extensive connections. In many ways they need to think like hackers in the broad sense of the term."

Bryant Walker Smith

"The only way we can see this working is actually having a heavy reliance on a safety case that is curated and determined predominantly by the developer by the manufacturer. Because they know their system much better than any regulator ever will."

Jessica Uguccioni



Urgent Need for Type Approval, Certification & Data Basis

A number of experts foresee type approval, certification and the development of a strong data basis as some of the greatest challenges for legislation. They believe there is currently an urgent need to establish pragmatic standards for autonomous driving systems. Most regulatory authorities lack both expertise and resources in this area, despite the fact a corresponding technical understanding is indispensable here.

According to the experts, what is needed is coordinated knowledge transfer on an international level. This is the only way to approach the issue holistically and with the involvement of a variety of actors from academia, research and industry. In principle, Germany and the EU are already pursuing an approach of this kind to regulation – yet another reason why international experts often perceive German actors as playing a pioneering role.

"We need to put in place really strong mechanisms to pick up data and data analysis so that the regulators and those that are interacting with this technology can acquire useful knowledge and be regulating from a place of competence rather than incompetence."

Jessica Uguccioni

Germany Plays a Pioneering Role in Legislative Work

Both internationally and within the EU, Germany is seen as playing a pioneering role when it comes to autonomous vehicle legislation and regulation for regular road traffic. A number of experts maintain it seems highly likely that what is known as the "Brussels effect" (see bottom left) will see German standards have an impact on international standards. For that reason, a detailed discussion of the German legal situation will follow below.

In 2017, the German Road Traffic Act was amended to allow autonomous systems, under certain conditions, to take over activities that were previously the exclusive responsibility of humans. More specifically, this means that Level 3 systems (cf. Fig, p. 13) are in principle allowed to drive the vehicle. However, a dedicated driver must still be present, although they are also allowed to turn their attention away from driving the vehicle. This only applies, however, when the system is active and does not preclude manual intervention being required at short notice.

In addition, a new bill from 2021, which came into force on July 28, 2021, has seen the legal framework created to recognize autonomous motor vehicles from Level 4 (cf. Fig, p. 13) in public road traffic in regular operation. While the regulations apply throughout Germany, the law provides for a local restriction to specific operating areas. Within these areas, a large number of different use scenarios should, at least in principle, be possible. They are, however, yet to be conclusively regulated in the bill to ensure maximum flexibility with regard to future technological, ethical and social developments.

Thus far, however, private and individual transport has been less defined. It also becomes evident here that the above-mentioned law is only a first step toward more comprehensive regulation. Nonetheless, the experts interviewed see it as a strong starting point that can serve as a positive example for the ongoing legislative process. The German legislators themselves even see their own initiative as a law to bridge the gap. Once a European initiative arises, the focus would certainly fall on the joint development of a pragmatic transnational solution.

"Credit to Germany for doing a lot of the early foundational policy work that has helped to shape subsequent discussions."

Bryant Walker Smith

The deployment scenarios include:

- Shuttle services from point A to B;
- People movers (buses operating on an established route);
- Hub2Hub services (e.g. between two distribution centers);
- Demand-driven offers at off-peak times;
- Transport of persons and/or goods on the first or last mile;
- Dual mode vehicles such as in automated valet parking (AVP)(see p. 35, bottom right)

Among other things, the Act lays down new provisions for the following:

- Technical requirements in terms of construction, characteristics and equipment of motor vehicles with autonomous driving functions;
- Testing and procedures for the issuance of a type-approval for motor vehicles with autonomous driving functions by the Federal Motor Transport Authority (KBA);
- Obligations of the persons involved in the operation of motor vehicles with autonomous driving functions;
- Data processing with regard to the operation of motor vehicles with autonomous driving functions;
- Facilitation of the (subsequent) activation of automated and autonomous driving functions for vehicles that have already been type-approved ("dormant functions");
- Also, adaptation and creation of uniform rules to allow the trialing of automated and autonomous motor vehicles.

Taken verbatim from the German Act on Autonomous Driving (German Federal Ministry of Transport and Digital Infrastructure, 2021)

The Brussels effect

The "Brussels effect" describes the phenomenon whereby jurisdiction also indirectly affects the USA and other markets. One reason for this is that technological innovations usually face far less regulation and at a much later stage in the US than in Europe. The EU, and especially Germany, often regulate at an early stage and usually involve manufacturers from the beginning.

Provided the European market is attractive for American and other international manufacturers and companies, they will adapt their products to European standards. Some of these products are subsequently "re-imported" back into their countries of origin. The effect has already faced criticism, including from parties in the US, who deem it a kind of right-wing imperialism. (cf. Bradford, 2020)

Questions of Liability & Guilt

Who is liable in the event of an accident or in case of other damage involving an autonomous vehicle? The driver? The owner? Or the manufacturer? Perhaps even the machine or the algorithm itself? How does this issue evolve as technology advances? In order to answer these questions, the term liability must first be defined. In addition, it is vital to address the question of guilt and responsibility (see right). In principle, one point is indisputable for most of the experts: in the near future will we see, at least in Europe, machines or algorithms, no matter how intelligent they may be, being held legally responsible? No. Because it has already become culturally established that humans must assume ultimate responsibility, even where it could, at least theoretically, be borne by a machine. In the English-speaking world, this is a much-discussed topic of debate as a result of the less pronounced 'strict liability' (see right). However, this is more of an ethical-philosophical discussion that will generally be taken up and conducted time and again in the course of the progressive spread of artificial intelligence.

"Pushing liability on a machine doesn't fit our culture here in Europe."

Eric Hilgendorf

Liability

Liability is the obligation to pay damages – to compensate – for a culpable breach of duty in the event of loss or damage. For liability to be established, personal injury, damage to property or financial loss must have occurred. Failure to act contrary to one's duty to do so can also invoke liability. (cf. Beratungsgesellschaft für Arbeits- und Gesundheitsschutz [Consultancy for Occupational Health and Safety], n.d.)

Strict liability

Under German law, as well as throughout a large part of Europe, the concept of "strict liability" is also a relevant factor. This describes a liability for damages which does not require guilt but is based on the fact that the person liable to pay compensation inescapably caused a certain danger to their environment in the course of a permitted activity (for example, by keeping a motor vehicle or running a business). In German law, this also includes motor vehicle liability, whereby the owner of the motor vehicle is subject to strict liability. In other words, if a person is killed or injured or an object is damaged while the vehicle is being driven, the owner must first compensate the injured party for the resulting damage. In Germany, liability is primarily covered by motor vehicle liability insurance. (cf. Feess, n.d.)

Guilt/Culpability

In criminal law, the term "guilt" is understood to mean bearing personal fault for an act punishable by law. That is, a person, either consciously or unconsciously, violates relevant laws that are regulated by criminal law. Any natural person, that is any human being, can be culpable, barring persons under 14 years of age and those who, as a result of a mental disorder or disorders of consciousness, lack the ability to see the wrong in the act committed or to act according to this insight. Additionally, in the context of autonomous driving, the concept of civil culpability is also relevant. This describes an intentionally or negligently illegal act that may have civil consequences. Among other things, this can entail the obligation to pay for damages incurred, even if one is not primarily liable. (cf. Stöfen, n.d.)

Germany & Europe Also Legal Pioneers in Liability

As stated, Germany is, internationally speaking, a pioneer in the regulation of autonomous driving. For this reason, the topic of liability is also dealt with below using the example of the German legal situation. In terms of legislation, Germany is already in a position to give a strong prognosis regarding the issue of liability for autonomous driving. This is because, in general, the issue of liability has already been established in liability law. In traffic, the owner is generally defined as the liable person (see info box on liability). Additionally, manufacturer or distributor product liability already applies under road traffic law in the event of damage caused by safety-related product defects. Put simply, anyone to derive benefit from the technology is also liable. An important pillar of liability is liability insurance, which takes direct effect in the event of an accident or other damage.

In Germany, motor vehicle liability insurance is firmly anchored and socially accepted as a mandatory insurance. Here, whether or not insurers are willing to offer corresponding policies will prove a turning point, but their position is already becoming apparent. The experts therefore assume that a modified approach to liability and civil liability will also become established for autonomous driving. Furthermore, in the amendment to the law in 2017, German legislators made no change to the regulations on product liability with regard to autonomous driving up to Level 3, thus indicating that there is no need for a significant amendment to the liability regime. This clearly stipulates, as before, that if a Level 3 system is activated and an accident occurs due to a malfunction of this system, the vehicle manufacturer may well be held liable under product liability.

“There’s no need to reinvent the wheel. Current product liability in Germany can be applied to autonomous driving.”

Uta Klawitter

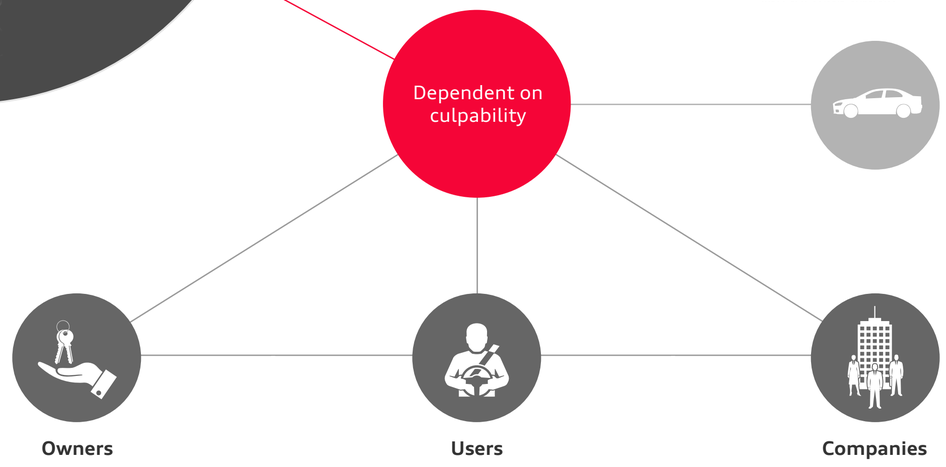
“So, you first figure out whether that’s a human error or it’s a vehicle's fault.”

Huei Peng

Even Those Not Primarily Liable Can Be Held Responsible

In the event of an accident involving an automated or autonomous vehicle, who is liable and how much is to be paid for the damage caused? The question of guilt and culpability plays a decisive role here (see p.29 right). If the owner has not met their maintenance or servicing obligations, they remain liable. If, as described above, a malfunction of the software or hardware can be identified as the cause of the accident, the manufacturer or the company placing the vehicle on the market will be held liable. In the case of Level 3–4 autonomous vehicles with a driver, it will also be necessary to check whether the driver has made a mistake and can be prosecuted accordingly.

Who is liable (in future)?



Owners

In principle, persons or service providers (e.g. shuttle service operators) are liable in the event of damage. They bear sole responsibility in particular if they have failed to meet their obligations as the owner.

Users

In the event of damage caused by human error, the person may be held jointly liable. Once guilt has been established, this means they are required to pay, either in part or in full, for the damage caused.

Companies

Product liability means vehicle manufacturers and distributors are, generally speaking, liable for product hardware and software defects. This is particularly true for safety-related defects.

Examples of culpability

- Failure to ensure software maintenance update
- Failure to ensure regular servicing
- Road traffic regulations or vehicle warning sign ignored
- Driving a vehicle under the influence of drugs or alcohol
- Faulty sensors misjudge the environment
- Software error leads to incorrect vehicle responses

Error Analysis & Identification Play a Decisive Role

Working from the assumption that in the near future an increasing number of Level 4–5 vehicles will hit the road, the search for blame and possible sources of error will become increasingly complex. After all, depending on the situation or zone in which they find themselves, these vehicles will be driven and on the road either manually, with driver assistance or even fully autonomously (cf. “Foresight 2030” – “An era of (partially) autonomous mixed traffic”, p. 15).

Determining beyond doubt who will ultimately have to pay for any damages or otherwise be legally liable will require answers to a whole host of questions. Was an autonomous system active? In what mode and at what level was the vehicle driving? Did the driver make a mistake? Did the owner fail to meet their maintenance obligations? Did the manufacturer put a faulty vehicle into circulation? Did an IT service company fail? Could the fault possibly lie with a mobile phone provider, network operator or card provider? Or with another part of the infrastructure entirely (e.g. poor roads or traffic lights)?

Such questions can be difficult to clarify and could, where there are a multitude of cases, pose a major challenge to the judiciary and tie up a great deal of capacity. For this reason, consideration is already being given to what technical solutions for fault analysis and accident tracking could look like. One option is a kind of “black box” for cars, a type of which already exists today, albeit to a limited extent. Certainly, going forward, sources of error will be much more identifiable than they are today on the basis of constantly produced vehicle data from the on-board systems. It follows, therefore, that the idea of using hardware to record the course of an accident in order to be able to determine afterwards beyond doubt the cause of an accident is not entirely a leap.

“The crucial point is that the human should not be responsible for the driving, if it’s a true self driving vehicle.”

Jessica Uguccioni

Legal Requirements For Humans Are Not Likely to Decrease

Ultimately, despite – and in part precisely because of – technological progress and the resulting changes such as mixed traffic, zone-based driving, new forms of owner-operators and black boxes, it seems unlikely that the demands on humans from a legal perspective will decrease in the foreseeable future. Especially in mixed traffic and in complex and unpredictable traffic situations, drivers must develop an awareness of the fact that even highly intelligent systems, such as a highway pilot, will probably continue to be dependent on human intervention in specific situations for a long time to come.

Conversely, this means that people themselves will continue to be a source of danger for road traffic for a long time yet and as such must continue to be taken into account in future legislation. Furthermore, it seems likely that requirements and obligations for owners will also change.

The vehicle's owner must always be aware of their vehicle's condition and, in future, understand the limitations of new functions. Equally, they must ensure that safety-relevant updates are always installed. Failure to do so could be taken a sculpability in the event of an accident. It therefore seems highly probably that, moving forward, every person who chooses to 'drive' or own an autonomous vehicle will bear a high level of responsibility and, in case of doubt, will have to accept liability for their own mistakes. This is also an important factor for industry. After all, if all responsibility for liability lies with manufacturers, fleet operators and other companies, this could well also reduce their willingness to develop and bring new technologies to market.

"At the end of the day, liability cannot be one-sided at the expense of one party. Both sides must be incentivized to behave with care. Equally, this provides the motivation for manufacturers to continue researching and regularly bring new innovations to market."

Uta Klawitter

Harmonization of Legal Systems & Market Conditions

The global mobility and automotive industries have a strong interest in the regulatory framework. This is motivated by a range of factors, not least, because they are naturally interested in harmonizing regulatory frameworks globally. After all, both passenger cars and other systems are sold worldwide – across all borders. The more uniformly the different markets are regulated, the easier it will be for manufacturers to offer their products in large numbers on the international market. Accordingly, this allows them to produce at lower unit costs and generate more profit, which in turn enables greater investments in research and development. But consumers and society as a whole also benefit from this: first, thanks to lower prices and better availability, but also as a result of improved safety standards.

Moreover, drivers of (partially) autonomous vehicles are faced with the question: “What rules and frameworks apply outside my home country?” Equally, from the perspective of legislators, further considerations apply. In the US, for instance, individual states tend to focus on deregulation to promote business, while in Europe, consumer protection plays an important role. In general, the EU in most cases regulates with industry involvement. Of course, these different approaches can represent a series of obstacles. Nonetheless, as part of a constructive discussion, they can also prove a catalyst for finding new solutions. As a result, most of the experts would like a dialogue leading to the international harmonization of legal systems.

“More agreement across borders would be terrific. Consistency will make it easier to develop automation systems, and easier to understand for those who will use them.”

Jake Fisher

Harmonization Must Take Place at Several Levels

The international differences already described with regard to legal frameworks in terms of regulation, licensing and liability, are not the only issues at play. The international community must also address an array of very specific challenges. To give two particularly striking examples: the handling of right-hand versus left-hand traffic and local and national road signs. We need to find answers to complex systemic questions. How can Europe and the various international legal systems provide uniformity and simplicity for autonomous driving technology? Will one or multiple systems win out in regulating the technology? How will the emergence of so-called mixed traffic (see “An Era of (Partially) Autonomous Mixed Traffic”, p. 15) be dealt with?

Striving for Common Solutions, Not Market Power

The experts believe the goal should be to develop regulatory frameworks and new mechanisms that promote international cooperation and advance the implementation of proven technologies worldwide. The EU and Germany are taking the first steps in this direction with a specific bill for framework autonomous driving conditions in everyday life. While this bill has the potential to lay international foundations and provide focus, it also has its critics among the experts. Some described a tendency whereby the EU and Germany, as markets, have too much influence on international regulation, meaning they do not so much promote international cooperation as determine the framework conditions. Some experts would therefore like to see an open-ended dialogue at the international level in order to find and test new ways for better cooperation.

“We need a harmonized European legal framework for these vehicles to be approved. A nationalized patchwork system is not going to get us very far.”

Richard Goebelt

“For the time being, I’d be satisfied with a standardized regulatory framework for Europe. That’s a major market, and it gives you the negotiating power to go to other countries and say: ‹If you recognize our European vehicles and regulation, we’ll recognize yours.›”

Sandy Munro

Taking the First Step With International Test Zones

A first step for international harmonization could be international test sites. These should follow international principles as far as possible and adapt local framework conditions. A whole range of use cases could be simulated and tested in different settings, for example fully automated taxis in city centers. An international initiative of this kind would go further than current legislation allows: the focus would be on testing, creating real experiences and data. In a best-case scenario, findings from these test sites could promote international technical and regulatory cooperation.

In addition, new solutions and services of international relevance may emerge. For example, it would be possible to test remote driving (i.e. control via the cloud) and establish the requirements for a robust infrastructure. As such, some of the experts called for a greater number of test areas instead of national regulatory frameworks.

The legal situation at international level: an overview
Automation Levels

Level 0 1 2	Level 3	Level 4 5
International legislation is already relatively well harmonized here. The Vienna Convention on Road Traffic lays solid foundations in this area. Since 2016, simple driver assistance systems have also been regulated here.	Initial approaches are already in place for international approval and regulation by the United Nations Economic Commission for Europe (UNECE). The goal is harmonization for 2024.	In these areas, it is still relatively unclear what harmonization might look like in more specific terms. Germany is a pioneer with its current Level 4 legislation. Presumably, European legislation will follow, before moving internationally as a result of the Brussels effect.
At present, the international automotive market offers a whole range of modern vehicles equipped with driving functions up to Level 2. In this context, advanced driver assistance systems support the driver in certain functions, providing a greater degree of safety.	In future, the regulatory framework of the UNECE road program will enable Level 3 functions. Currently, the focus is on Level 3, and regulations for the approval of Level 3 assistance systems have been set out. Regulatory provisions should come into force here by 2024 at the latest.	Over the next few years, a regulatory framework must be created to enable truly autonomous traffic in the future. Compared to Levels 1-3, the current German law is, for the time being, focused strongly on the area of what are known as people movers. The next step will be a regulation that also applies to individual traffic.
Examples of such systems include	*Examples of such systems include*	*Examples of such systems include*
parking aids, lane departure warning systems or adaptive cruise control. The vehicle is controlled by the driver.	highly automated driving systems, where the driver does not have to intervene over longer distances.	driverless systems such as shuttle services, robo-taxis or the automated valet parking (AVP) function.

Automated Valet Parking (AVP)

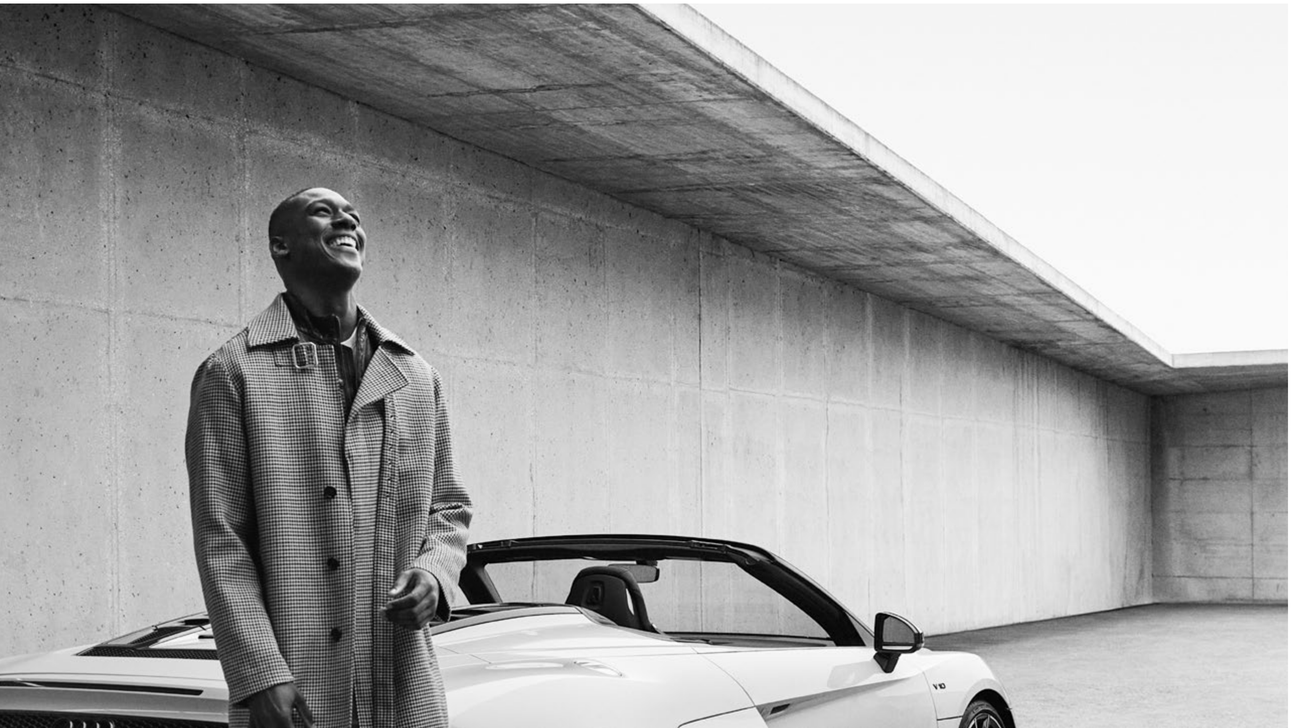
Automated valet parking is a fully automated system that not only takes the hassle out of searching for a parking spot but also handles the actual task of parking the car in the parking garage. The driver simply needs to park the car in a designated drop-off area and the intelligent parking infrastructure takes over, bringing the vehicle to a vacant spot and parking it. (cf. Audi, 2021)

International Data Handling Plays a Key Role

Moreover, the joint development and use of databases is vital for international penetration. International regulation for data governance and data services is crucial for the success of autonomous driving technologies as well as the basis for an international harmonization of regulation. Data could, for instance, be collected anonymously in so-called data pools, thus serving international cooperation in the areas of lawmaking and jurisdiction.

“A company's reputation is an important regulatory consideration. In particular: Is this a company that we can trust? Because companies are going to know their systems so much better than anyone else will.”

Bryant Walker Smith



Mixed Traffic is Also a Legal Hurdle

A functioning international cooperation, be it through databases, test areas or common regulatory frameworks, will also have to face the hurdles posed by the emergence of mixed traffic. Here, it is vital to communicate not just the doors opened by technology, but also its limitations. This can be achieved through public discourse and transparent implementation. For this to happen, significant investments must be made in technology and infrastructure as well as education, information and communication. After all, communication, including involving potential users in the discourse, will likely play a decisive role in the success of the implementation of this technology.

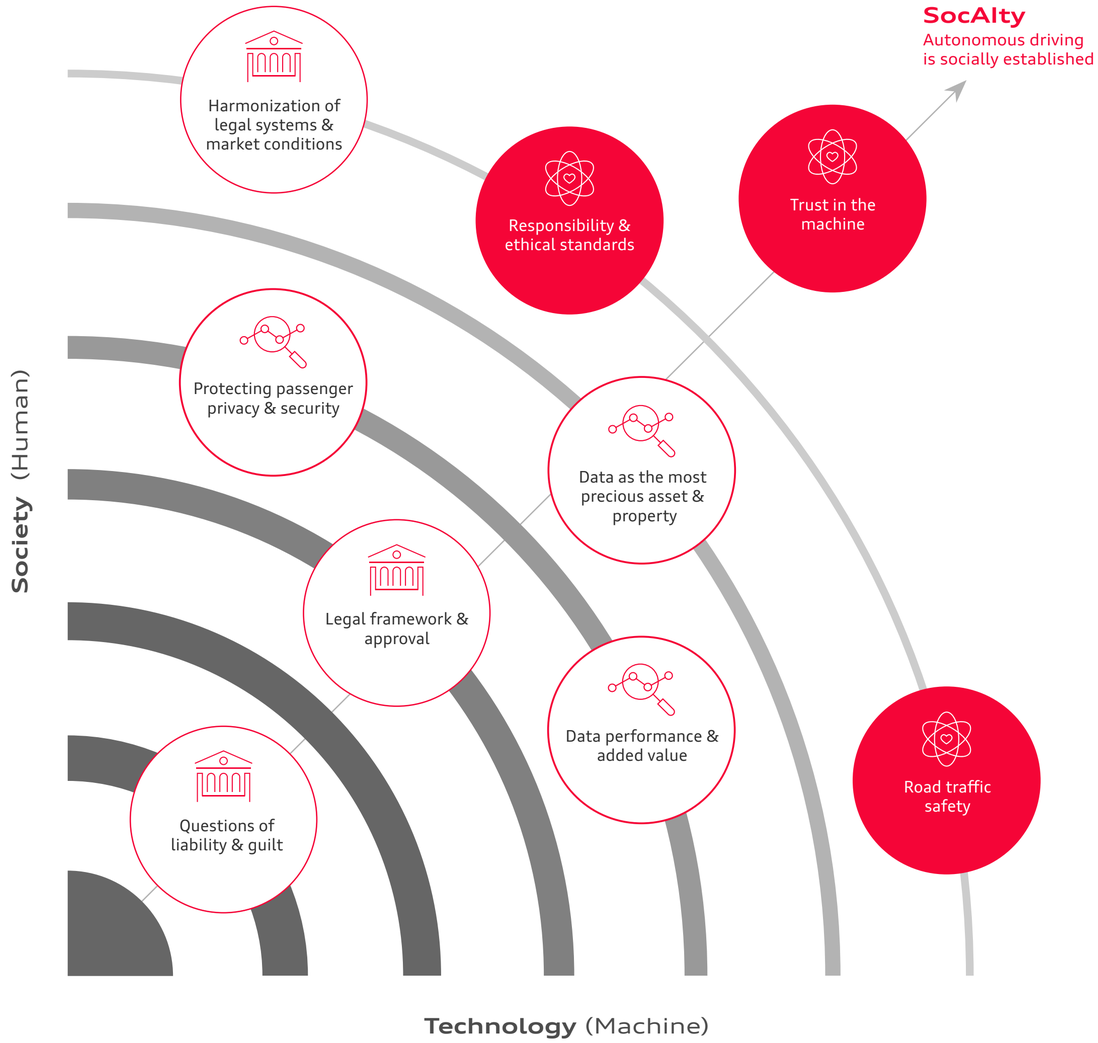
Companies Should be More Involved

Some of the experts are of the opinion that companies should play a far greater role in the regulatory process so that legislators can gain both technological expertise and insights from practice. After all, the companies themselves often have a better understanding of the technology and their own capabilities than legislators. Legislators worldwide should take advantage of this knowledge.

5

Ethics – Building a Relationship of Trust Between Society & Software

Over time, autonomous driving will become an increasingly ubiquitous part of everyday life. Just how quickly it becomes the widespread norm, however, will in part be dependent on social acceptance. According to the experts, there are still a great many challenges to overcome, with ethical and moral aspects playing a pivotal role. Responsibility, safety and trust are the cornerstones for autonomous driving to meet with social acceptance, with the focus often falling on the interaction between people and technology. Thus, the million-dollar question here is: How can we build a relationship of trust between society and software? One of the primary factors in achieving this is to demonstrate the advantages and personal benefits of the technology, for instance saving time or increased comfort. Equally, other areas also offer great potential for winning social acceptance. These include opening up access to mobility for all, even those without a driver's license or disabled people, the dream of a transportation system without traffic fatalities (Vision Zero), or when it comes to environmental issues, such as CO2 reduction.



Responsibility & Ethical Standards

This section of the study explores the existing ethical guidelines. By and large, society tends to demand “zero tolerance for error” when it comes to autonomous driving. The experts, however, believe it is important to bear in mind that, at least in the coming years, machines will not be usable outside of ODDs (see p. 15). Both now and in the near future, the greatest cause for uncertainty is human behavior. Furthermore, our exploration of the legal framework has evidenced the lack of precedent for either the machine or the algorithm behind it to be held liable, either today or in the near future. Nor will it be directly to blame should an accident arise. Indeed, the actual extent to which AI can even make the “right” decision when interacting with humans (especially in mixed traffic) remains unclear. To answer this question from an ethical perspective, it is vital to address the actual moral dilemma behind autonomous driving.

“AI will not fly without ethics.”

Christoph Lütge

“Ethics is shaped by fundamental human values. It is not ethics that must mold itself to technological progress, but rather technological progress must be guided by ethical values to ensure people remain at the center.”

Hiltrud Werner

The Moral Dilemma in the Context of Autonomous Driving

Doing the right thing while also violating a second ‘right thing’ raises what is often called a moral dilemma. In the context of autonomous driving, this is a case of making a decision in a scenario which offers multiple options but will always lead to at least one undesirable outcome. A frequently cited example is that of a hypothetical evasive maneuver where, no matter which way you turn, someone will be injured or even killed. Such scenarios bring up hypothetical questions, such as: Who is more deserving of evasion? Which life is worth more? Such questions have been the subject of ethical debate for decades now, often using the example of the “trolley problem”, and are now making a comeback in the conversation on autonomous driving. While many of the experts believe the trolley problem has since been resolved, it continues to play a central role in the public debate on autonomous driving.

In the context of autonomous driving, this begs the questions: How do we deal with this moral dilemma in the event of an accident? Who makes the ethical decisions, which are quite possibly a matter of life and death – the person or the machine? The answer here is the person – for the time being! Because upon closer inspection, behind every piece of AI, every algorithm and every decision made, a person has inputted or set out the parameters for making the decision. An autonomous vehicle merely adopts and systematically carries out the ethical decisions and values decided on by humans without any interpretation from the AI itself.

“There are cultural differences. In some cultures people care about the number of deaths. In other cultures, people put more weight on age or on law abiding.”

Iyad Rahwan

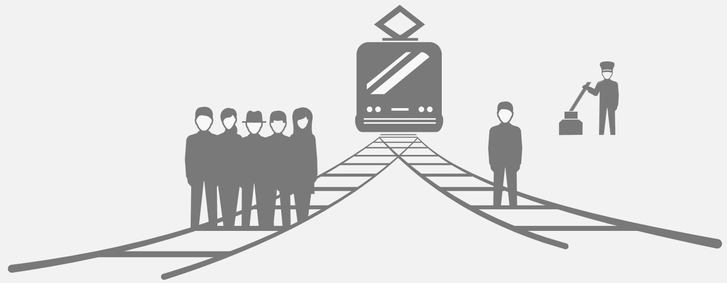
“We cannot solve these dilemmas, nor can we find the perfect approach.”

Christoph Lütge

The Trolley Problem: A Moral-Philosophical Thought Experiment (1930)

Back in 1930, it wasn’t the car but the streetcar, or trolley, that characterized urban mobility. In the thought experiment, the trolley gets out of control and is in danger of running over five people. There is a second track, but unfortunately this track also has a person on it.

The switchman can choose to divert the streetcar onto the second track, but this raises the question: Is it permissible to accept the death of one person in order to save the lives of five by switching track?



While this may change moving forward with self-learning systems, the majority of the experts conceptualize ethical decisions as something primordial to human beings and argue that technical progress should continue to orientate itself toward ethical (human) values in the future. An interesting point of note, however, is that it is also possible to identify cultural differences with regard to such ethical viewpoints. In 2017, Iyad Rahwan and his former team at the Massachusetts Institute of Technology found in a large-scale moral machine experiment that people program autonomous vehicles differently depending on the culture at hand. Some cultures focus on the number of fatalities, while others are more concerned with the age of the victims. In others, attention is paid to whether a person has behaved lawfully or unlawfully, such as crossing a street illegally.

Managing the moral dilemmas in the event of an accident is vital if we wish to understand the ethical aspects of autonomous driving. Conversely, the debate that plays out in society is often emotionally charged and, for some of our experts, artificially inflated. After all, by definition, dilemma scenarios can not find a resolution. The experts agree, therefore, that the next important step for autonomous driving is to concretize the ethical principles at play using real-world situations. We need to move away from dilemma situations, or artificially abstract discussions with theoretical problems, to the real-world challenges and issues facing companies and legislators.

Accident Prevention & Risk Assessment Not Artificial Thought Experiments

As a result, a number of experts believe efforts should be primarily concentrated on preventing possible dilemmas as best as possible before they even arise. Upon closer inspection, autonomous driving dilemmas in fact turn out to be a statistical distribution of risk. This means those designing autonomous driving rely on developing systems and applications that integrate accident avoidance and risk assessment, thereby ensuring the safety and protection of all road users. An example of an initial supporting approach here is the ANDRE research project in Germany, which puts the focus on risk ethics rather than more traditional ethical theories. If we want to further shape the discourse and make autonomous driving socially accepted, the majority of the experts advocate clear guidelines and principles formulated by committees or social representatives that meet with widespread acceptance. These would need to be designed with flexibility in mind and developed with sustainability.

“Who do we prioritize avoiding? If this is how we keep setting the agenda, we’re not going to get very far.”

Christoph Lütge

ANDRE Project – AutoNomous DRiving Ethics: from Trolley Problem to Ethics of Risk

Headed up by Prof. Christoph Lütge, the ANDRE research project at the TUM Institute for Ethics in Artificial Intelligence aims to integrate ethical behavior into the behavior planning of automated vehicles. This involves enriching contemporary algorithms with ethical theories and analyzing them in both familiar and new driving scenarios on a simulator. By and large, the aim is to minimize the overall risk and ensure any possible residual risk is fairly distributed. (cf. Institute for Ethics in Artificial Intelligence, n.d.)

Ethical Standards Lay the Foundation for Social Acceptance & Technological Progression

For autonomous driving to become socially accepted, many of the experts would like to see an easy-to-understand code of conduct in place for manufacturers, owners and users. This, along with possible scenarios, would help provide better orientation in this debate. Here, too, Germany is taking on a pioneering role, which, inter alia, has been a major factor in laying the legal groundwork at an early stage. In 2017, for instance, the German Ethics Commission published a report on autonomous driving, creating a solid foundation. The report discusses and defines initial guidelines but also identifies the need for action and development in the area of technology and society. The result is 20 ethical guiding principles for automated and connected vehicle traffic (see bottom left). At the core of these is the statement that technological progress must center around people and be guided by ethical values.

Report of the Ethics Commission: Automated and Connected Driving

As early as June 2017, the German Ethics Commission laid out 20 ethical rules for automated and connected driving in a report which represent an initial global guideline. Among other things, the guiding principles address issues of safety, responsibility, the purpose of the technology and the best approach for the legal environment. The protection and safety of people in road traffic are given number one priority.

In addition, the report considers not only data handling and access to technology for all road users, but also liability, personal responsibility, IT security and the moral dilemma at play. Eric Hilgendorf, who was also interviewed as part of the study at hand, chaired task group 1 "Unavoidable Damage Situations".(cf. German Federal Ministry of Transport and Infrastructure, 2017)

"The principle must be accident and hazard avoidance."

Richard Goebelt

The European Union Seeks to Create Transparency

In 2018, the European Parliament launched an ethical standards initiative in the field of artificial intelligence called “AI4People”. The aim is both to develop basic principles, guidelines and practices for building a “good AI society” and to draw up specific proposals for companies and the economy. All this is to be done publicly and transparently.
Christoph Lütge, who was also interviewed as part of this study, serves on the scientific advisory board of “AI4People”.

“We have to set a standard for machines.”

Pete Bigelow

Ethical AI Principles

(cf. AI4People, n.d.)

Accuracy & Robustness
to counter inconclusive evidence

Algorithmic conclusions are probabilities and therefore not infallible and they also might incur errors during execution. This can lead to unjustified actions.

Fairness
to avoid unfair outcomes

An action could be found to be discriminatory if it has a disproportionate impact on one group of people.

Explainability & Transparency
to prevent inscrutable evidence

A lack of interpretability and transparency can lead to algorithmic systems that are hard to control, monitor, and correct. This is the commonly cited ‘black-box’ issue.

Privacy
to uncover transformative effects

Algorithmic activities, like profiling, can lead to challenges for autonomy and informational privacy.

Bias
to highlight misguided evidence

Conclusions can only be as reliable (but also as neutral) as the data they are based on, and this can lead to bias.

Accountability
to improve traceability

It is hard to assign responsibility to algorithmic harms and this can lead to issues with moral responsibility.

Road Traffic Safety

In modern ethics, the ‘greatest good’ is the protection of human life and naturally this also receives top priority. With regard to autonomous driving, the German Ethics Commission already agreed back in 2017 that automated systems should primarily serve to improve the safety of all those involved in road traffic and that the protection of people should take precedence over all other considerations of utility. This means autonomous vehicles are only ethically justifiable if they can demonstrate a positive balance of risk, that is to say they result in fewer injuries and fatalities compared to vehicles driven by humans.

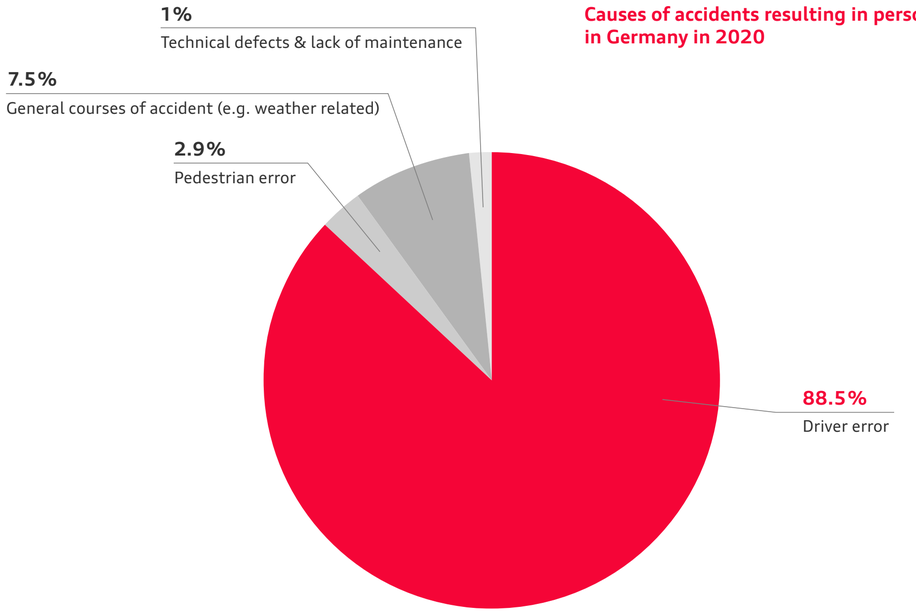
Fact check: Taking stock of human error using the example of Germany in 2020

According to the Federal Statistical Office of Germany, over 85.5 percent of all accidents resulting in personal injury in Germany in 2020 were caused by an error on the part of a person driving a vehicle. At over 62 percent, drivers of passenger cars were the largest group of people causing accidents.

“Worldwide, more than 1.2 million people got killed every year and many more got injured. Many of those can be mitigated, if not avoided. Even if we can just make sure that every car has AEB (automatic emergency breaking).”

Huei Peng

Causes of accidents resulting in personal injury in Germany in 2020



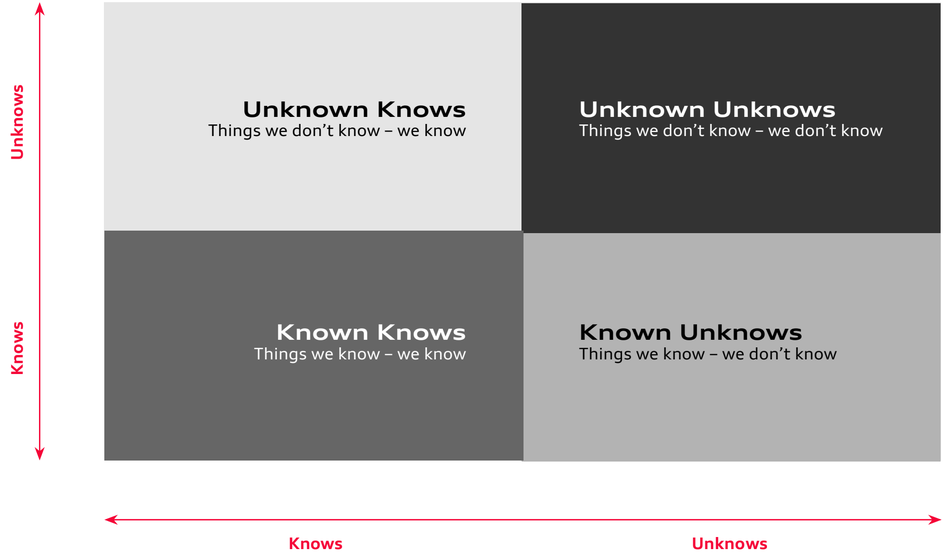
Shifting the Balance of Risk for People on the Road

In its “Global status report on road safety 2018”*, the World Health Organization (WHO) reported that the number of road deaths has increased at international level to 1.35 million people. That amounts to one death on the road every 24 seconds. Many of the experts believe the majority of these deaths are preventable. The current situation on the roads is an enormous risk for all road users – especially pedestrians and cyclists. As a result, the experts see a great deal of potential in an autonomous future, which brings with it a new kind of reliability, predictability and safety on the road.

*(cf. Deutsche Welle, 2018; World Health Organization, 2018)

Safety in Autonomous Vehicles

This situation poses the question: Can a machine or an algorithm control a vehicle more safely than humans? The answer: yes, under certain conditions. After all, a computer never gets tired, never forgets to signal or check in the rearview mirror, nor does it take a bend at excessive speed. In a known environment with clearly defined parameters, technology responds reliably. As such, autonomous vehicles are equipped with rules and behavior patterns that are based on safety standards and scenarios and always aim to make traffic safer. However, for this to happen, the autonomous driving system needs to be able to apply a rule or behavior pattern for any event that may occur. This is because, from a technological perspective, the system not only needs to recognize predictable scenarios, but also the “unknown unknowns” and solutions must be developed to respond to such situations. “Unknown unknowns” are previously unknown scenarios that could occur in traffic and that cannot yet be safely handled by functions designed to date. To be able to do this, the autonomous system must receive an appropriate amount of data in advance and must have “learned” the corresponding scenarios. In addition, the necessary infrastructure, such as correspondingly fast mobile data transmission, must be available at all times.



“The whole point of autonomous vehicles is to make something better than humans.”

Sandy Munro

“The computer in an automated vehicle is always awake and always working.”

Ilja Radusch

Vision Zero is a Fantastic Goal, But Ultimately a Utopia

But how safe actually is autonomous driving, both now and in the future? And just how unsafe can it be? These are the key questions for winning social acceptance. For many people, autonomous driving is still characterized by the idea of “zero error tolerance” for the technology. Also known as “Vision Zero”, this centers around making the traffic of tomorrow as safe as possible and reducing the number of traffic fatalities and injuries to zero.
In practice, however, this approach often proves to be an obstacle to implementation. The experts in this study described how theoretical models and ideals, such as Vision Zero, are often used and this distorts the reality of what this technology is currently capable of achieving. As described, current systems are only able to function without error in specific environments. In practice, this would require a total lack of entirely unpredictable situations, as current systems are not able to respond adequately to such unpredictability.

But this is not just a case of spontaneously occurring external factors, such as black ice or fog: the greatest cause of uncertainty, even in a fully autonomous vehicle, remains the human being. Without a complete penetration of traffic with autonomous vehicles and smart infrastructure, autonomous systems will still be confronted with the irrational and unpredictable actions of other (human) road users. Furthermore, even with the utmost care and a vast range of control mechanisms, the residual risk of a technical defect nevertheless always remains. For this reason, the majority of our experts believe Vision Zero is the right goal to strive for. Ultimately, however, we cannot forget that there can be no such thing as one hundred percent safety, not even in autonomous driving.

“Data of manufacturers show that with automated driving systems every 4,000,000 miles driven there’s an accident. That means it’s eight times better than normal human driving.”

Sandy Munro

“So, don’t use Level 4 systems outside of their ODD. Because outside means, the systems are not safe, they are not capable, they’re not perfect. I think that is a key problem. People always think: ‹Oh, if I only have Level 4, I can drive anywhere and any speed.› But that’s totally wrong.”

Huei Peng

Autonomous Mixed Traffic Poses a Major Challenge in the Near Future

Looking now to the near future, the experts see mixed traffic as a key challenge facing society. While overall vehicle safety will continue to increase, this type of traffic will also lead to new types of accidents. Unlike autonomous vehicles, which always follow the rules, human behavior is unpredictable, which can make it difficult for machines to predict. The machine needs to be able to take violations of the rules, such as exceeding the speed limit or a spontaneous error, into account as parameters – a major technological challenge.

Responsibility Does Not Lie With Manufacturers Alone: A Cultural Shift is Also Needed

In the end, the issue of safety on the part of the vehicle is, according to a number of the experts, less an ethical quandary and more a technological challenge waiting to be solved. Providers and manufacturers of autonomous vehicles and services have a central role to play here, and it is vital to apply, refine and further improve existing safety standards. Here, the issue of data transparency is of the utmost importance and is the motivation behind our experts calling for greater cooperation between individual manufacturers. Initiatives for disclosing safety concepts, such as the Voluntary Safety Self-Assessment (VSSA) which many manufacturers have already joined, are seen as a promising first step in this area.

If we consider, however, the issue of safety in a broader social context, another important aspect comes into play with regard to mixed traffic: individual users. Individual users will have to adapt to mixed traffic and new codes of conduct.

Aggressive driving, for example, will no longer have any place in future traffic. Instead, it will be a case of society and software learning to cooperate. Here, the machines have an important role to play, seeing as they operate without emotion and, consequently, without aggression. In the long term, people must learn to accept that a machine is far more capable of driving the vehicle than any human being. Ultimately, in the eyes of the experts, this is a major cultural shift that will not happen overnight. People need time to develop a strong relationship with autonomous driving based on trust. For this reason, many of our experts recommend introducing autonomous vehicles in protected and predictable test areas. This would allow manufacturers to optimize vehicles and collect important data, while at the same time enabling road users to gradually become accustomed to the new traffic landscape.

“The biggest barrier to technology adoption is usually humans. Or in a nutshell: Autonomous vehicles obey the rules every time - humans don't.”

Genevieve Bell

“Our aim in developing our vehicles is to offer the best possible protection for all road users. However, we will still see accidents with autonomous vehicles, even if overall safety will improve considerably.”

Hiltrud Werner

Trust in The Machine

The previous study “The pulse of autonomous driving”, from 2019, in which 21,000 people across three continents were surveyed on their attitudes toward autonomous driving, revealed that 41 percent of potential users are suspicious of autonomous driving technology. About a third are even afraid. The experts interviewed as part of this study also see the skepticism toward the technology and the fear of losing individual control as key hurdles to overcome for autonomous driving to be socially accepted. After all, the more technological progress is made, the more control will be relinquished by drivers. This finding fits with the picture painted in the previous study. Here, 70 percent of study participants expressed the loss of control as their greatest concern.

By and large, however, the experts in this study agree that mistrust of the unknown is by no means an insurmountable hurdle. Historically, mistrust has always been present when new technologies have made their way into our everyday lives. Now, for many of us, our daily lives are unimaginable without elevators, airplanes and trains. People are usually willing to trade control over procedures and processes in favor of other benefits. Here, the prerequisite is, first, a basic understanding of the technology and its reliability or safety and, second, gaining personal experience of these advantages in our own everyday lives, such as saving time or greater convenience.

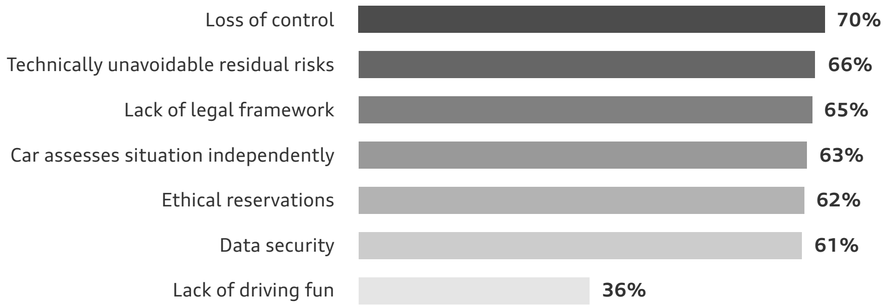
“So, I've never thought it was a problem about trusting algorithms, but it's a problem about which ones do you trust and why?”

Genevieve Bell

“So, I think the single biggest challenge to adoption over the next decade is getting the general public to trust that the technology is safe and reliable.”

Sam Abuelsamid

Critical aspects of autonomous driving, international
(cf. “The pulse of autonomous driving“ &Audi, 2019)



People Have to Understand the Technology

For people to be able to trust what technology is capable of, they first need to have a basic understanding and knowledge of it. For this reason, the experts believe there is a need for information and education on new technologies, both now and moving forward. In particular, we need to see clear and easily understandable communication around the possibilities and limitations of autonomous driving. For instance, it could be helpful to communicate a clear definition of and differentiation between the autonomous driving levels. This could then be used as the basis from which to explain the different roles and responsibilities for humans to assume in different situations.

According to the majority of the experts, scenarios that are the stuff of daydreams and science fiction are largely counterproductive, meaning research and industry should act with maximum transparency. Ultimately, the vision of comprehensively autonomous traffic will not be our reality in the short to medium term. Instead, there is a pressing need to sensitize users to specific autonomous use cases in the near future.

“Fear is usually only of the unknown – we already rely on a wide variety of technologies every day without realizing it. This must and will happen with automated driving, too.”

Hiltrud Werner

“Most people’s expectation of autonomous vehicles is that they will be like they were in the movies. But they won’t be. This is about to help people navigate both an anxiety about technical systems that might be dangerous and also a kind of naive hope they have that they'll be magical and flawless.”

Genevieve Bell

Not Underestimate the Power of Safety in Building Confidence, Nor Overestimate it as a Factor

Transparency and education have a crucial role to play in building trust in technology. Another vital prerequisite here is safety. To avoid trust being seriously shaken at an early stage, companies must succeed in bringing safety and the protection of human beings onto our roads with maximum reliability and solidity. Just as crucial, however, is ensuring people realize there will never be one hundred percent safety. Already, this does not exist in other areas of our lives. Of possible help here could be to showcase statistically proven safety advantages in information campaigns.

As already described, going forward it will also be important to sensitize road users with regard to their own behavior in autonomous mixed traffic. Here, some experts foresee public education campaigns similar to the kind seen with “don’t drink and drive”. At the same time, a number of experts expect that the topic of safety will play a much smaller role in practice than is often the case in expert circles. Experience has shown that once people have grown accustomed to the technology and enjoyed the benefits it brings, theoretical safety concerns are often put aside surprisingly quickly.

Experiencing the Personal Benefits Will Play a Decisive Role

As things stand, we have only a rather abstract understanding of the technology and its theoretical benefits. This results in the majority of society, above all in Europe, tending toward conservatism. It is rather a case of “no confidence without personal experience”. This notwithstanding, most of the experts agree that this will change the moment people experience autonomous driving for themselves and recognize the benefits it will bring to their lives. Yet if we want to convince as many people as possible of the benefits of the technology, we must also create access to said technology for a correspondingly large number of people. To achieve this, we need low-threshold options on the market in order to overcome that first hurdle of actually “getting in the car”.

A first step in introducing users to the technology is what are known as “self-driving experiences” and “proof-of-concept testing” (see bottom right). Further to this, some experts would like to see research and development in the form of citizen participation. This would help better serve citizen needs and better understand and overcome any hurdles in place.

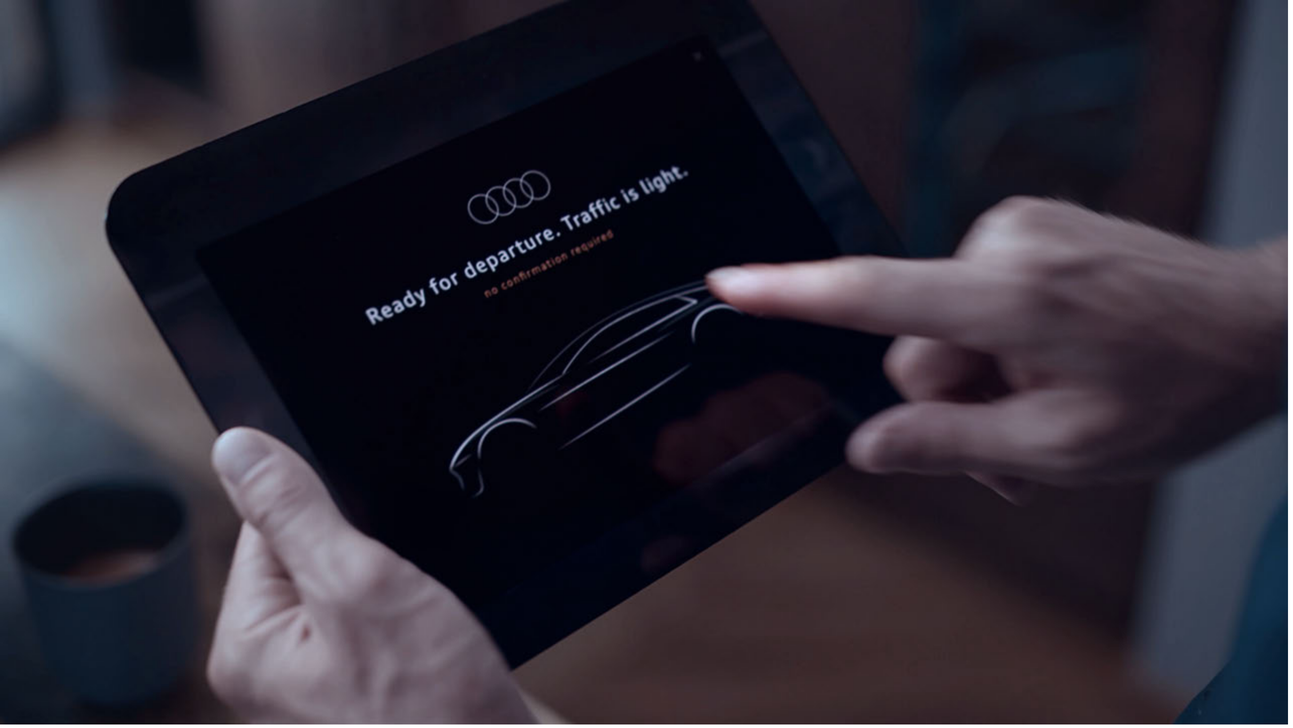
“Getting them in the vehicle is the hardest part and then it's winning them over in two minutes.”

Pete Bigelow

Self-Driving Experiences & Proof of Concept / Testing

These are initiatives that give users a chance to experience autonomous driving for themselves for the first time. Manufacturers and providers then have an opportunity to test the technological maturity and marketability of new technologies and services. At present, this often takes place as part of time-limited research projects in secure environments with restricted access. Examples here include the testing of people movers in German cities such as Berlin, Hamburg or Karlsruhe and the testing of Autonomous Valet Parking being carried out by the Volkswagen Group (see p. 34, bottom right).

Further pilot projects are also already ongoing with the aim of commercialization, particularly in the USA. Google’s sister company Waymo, for instance, has plans to launch a publicly accessible robo-taxi service in San Francisco soon. Anyone can apply via the “Waymo One” smartphone app as part of this new pilot project and participate in the “Trusted Tester” program. (cf. Bellan, 2021)



Saving Time Alone is Not Enough of an Individual Advantage

The ability to utilize the time spent in the car differently is often given as a major argument in favor of autonomous driving and one that brings decisive added value. The experts, however, emphasize that freeing up their time will not be enough for users. Instead, being able to offer a noticeably improved speed en route from A to B could be the real game changer. Particularly in the (mixed) traffic of tomorrow where we can expect a far higher number of vehicles on the road than today, autonomous vehicles could have a real advantage when it comes to efficiency, thanks to intelligent route selection and smoother traffic flow.

Combined with freedom of choice on the part of the users, this new efficiency is an excellent opportunity for widespread acceptance of the technology, at least in the eyes of many of the experts. After all, autonomous driving then equals greater freedom. Being able to eliminate the “obligation to drive” when tired or on long family journeys without eliminating the possibility of driving yourself where necessary, the technology could become widespread at a much more rapid pace. In principle, the faster, more comfortable and more reliable a vehicle is in bringing its passengers to its destination, the more likely drivers are to relinquish control. As such, technology must ultimately prove its solidity and reliability in everyday life in a wide range of situations.

“It is also about better access to mobility. Because mobility is the key in getting access to jobs, medical care, to clean food and so forth.”

Huei Peng

“Only the increase we expect to see in comfort, safety and availability will sufficiently justify acceptance and confidence in the new technology.”

Hiltrud Werner

Building Trust is a Multidimensional, Non-Linear Process

Building trust is not a linear process that can be implemented according to a standard scheme. Instead, at least in the case of autonomous driving, it is a multidimensional social discourse that takes place in parallel on several different levels. Equally, it is important to take into account that trust in new technologies varies culturally. Societies in Asian countries such as Japan, China or Korea, for example, are ready to adapt to new technologies, thanks to a strong cultural trust in progress. Nevertheless, it is possible to derive certain basic global principles for building a relationship of trust between humans and machines. This study was able to identify eight dimensions for successfully building a relationship based on trust.

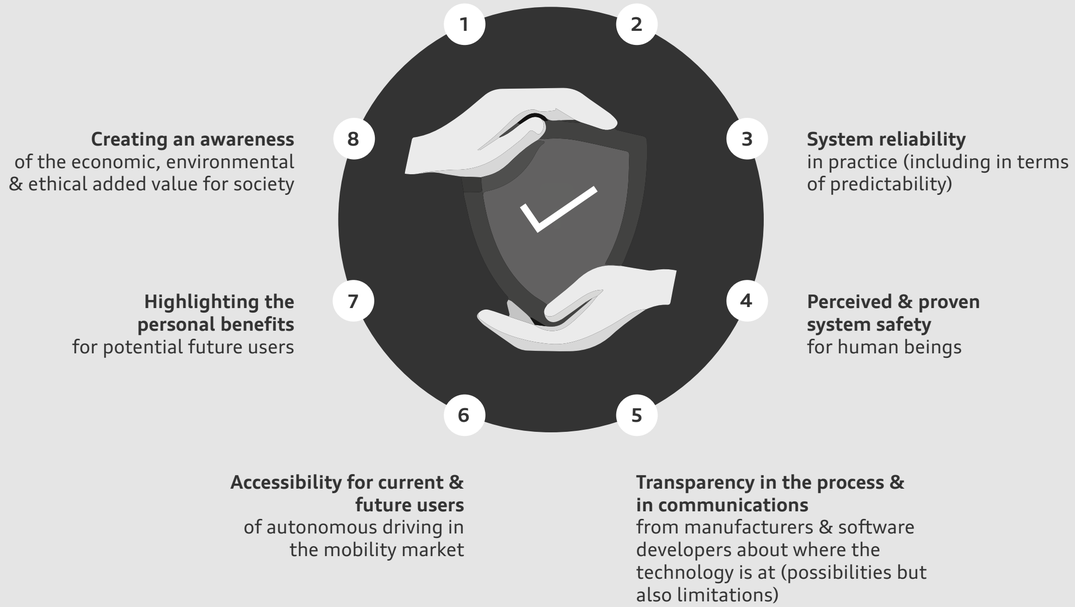
We Should Not be Aiming for People to Follow Technology Blindly

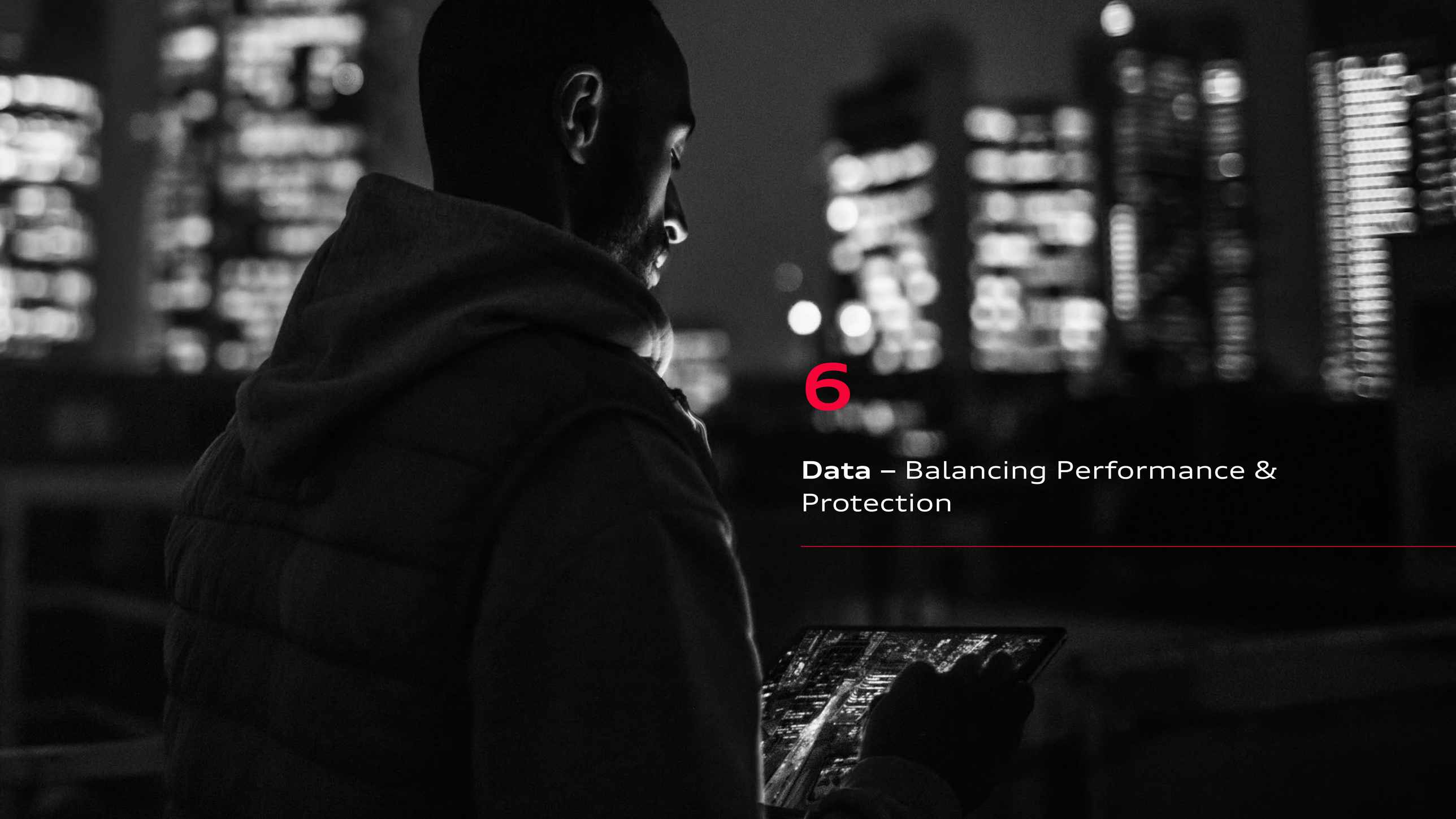
Looking forward, it is also important to consider the flip side of creating a relationship of total trust between humans and machines. After all, it is also possible to catalyze an “excessive” trust in technology, and this is a factor we need to consider and discuss in a social context. After just a short period of time driving autonomously, humans begin to discard certain behaviors and, as such, are no longer prepared to react in certain dangerous situations. Future policies must therefore account for such human factors.

“The higher the level of automation, the less engaged the human is because they just get very bored and very, very quickly, like within one ride, people will then start to pull their phone out and just not pay attention anymore.”

Deborah Hersman

Eight dimensions for successfully building a relationship based on trust



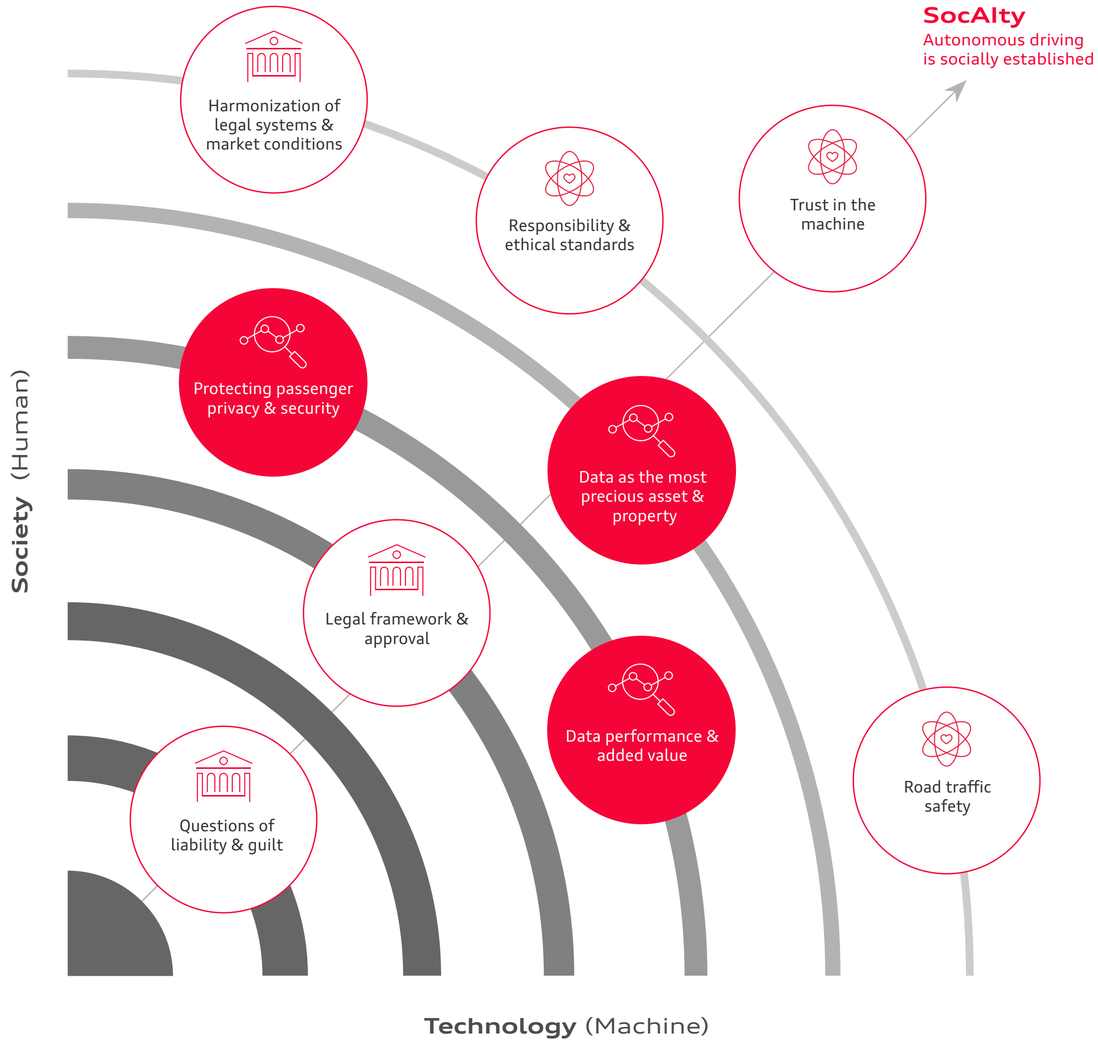


6

Data – Balancing Performance & Protection

In future, few areas in our everyday lives will see so many different types and such large amounts of data collected and processed as autonomous driving. Beyond the data that modern vehicles already generate, this primarily includes image data. This kind of data is captured by the numerous cameras both inside and outside the vehicles. In addition, data from sensors mean a vehicle can be controlled in real time in the first place. Further to environmental image data, movement data from the vehicle in question as well as from other road users is also collected and processed, not to mention the personal and movement data from users as soon as they use mobility services on their smartphone.

Handling this diverse data is a key topic and one that many experts in this study are currently addressing. When it comes to the debate within society, the almost infinite possibilities data holds both today and in future and the protection of sensitive data form two opposing poles. Within this field of tension, this study addresses the experts' opinions and solutions on the topics of data ownership, data protection and data security. It also considers the added value that data can provide in the context of autonomous driving now and moving forward and highlights the challenges the experts foresee arising.



Data as the Most Precious Asset & Property

In future, few areas in our everyday lives will see so many different types and such large amounts of data collected and processed as autonomous driving. Beyond the data that modern vehicles already generate, this primarily includes image data. This kind of data is captured by the numerous cameras both inside and outside the vehicles. In addition, data from sensors mean a vehicle can be controlled in real time in the first place. Further to environmental image data, movement data from the vehicle in question as well as from other road users is also collected and processed, not to mention the personal and movement data from users as soon as they use mobility services on their smartphone. Handling this diverse data is a key topic and one that many experts in this study are currently addressing. When it comes to the debate within society, the almost infinite possibilities data holds both today and in future and the protection of sensitive data form two opposing poles. Within this field of tension, this study addresses the experts' opinions and solutions on the topics of data ownership, data protection and data security. It also considers the added value that data can provide in the context of autonomous driving now and moving forward and highlights the challenges the experts foresee arising.

"If you get on a bus today, you don't own the data on the bus either."

Torsten Gollewski

Data Ownership & Use in Autonomous Vehicles Now & Moving Forward

In the case of public autonomous services in the near future, such as shuttle services and fleets, experts like Torsten Gollewski believe that ownership of the data, or at least the predominant right to use it, clearly lies with the service providers. Even when it comes to possible “robo-taxis”, operators and providers will use the data for their own purposes. After all, as fleet operators, they have not only have to provide the service but also improve it in their own interests, and for that they need data. Such service providers also create the infrastructure for data collection and analysis. Conversely, some of the experts believe a model in which the data belongs to the users is also quite conceivable. Here, the users would allow manufacturers and operators to utilize their data for certain purposes in a similar way to what we currently see with smartphones.

The discussion takes a more interesting, and controversial, turn when it comes to a person’s own, privately used car. In this setting, it is possible to collect personal data and information that often reaches deep into people’s private lives. This is often used to demonstrate the danger of “open-book passengers”. Currently, when users purchase and use services, they hand the rights to their data over to mobility providers or car manufacturers. Broadly speaking, users are willing to accept this so long as they gain corresponding added value in return thanks to an appealing product or well-functioning service (e.g. Uber). With other future services, too, such as autonomous shuttle services, it is generally assumed that the data collected, such as movement and usage data, belongs to the operators and service providers.

Among the experts, there is a consensus that users should be given a certain degree of protection and a certain say in the use and transfer of data in the future. It should go without saying that, in the case of personal data, users are always informed about the use or analysis of specific data and, in a best-case scenario, their consent should be obtained. For all users, a new understanding of the value of their own data and of the correct handling of sensitive and personal data should take on a new relevance in everyday life.

“Whoever is operating a mobility service will have control or will at least have custody of the data.”

Sam Abuelsamid

Personal vs. Sensitive Data

Personal data is data that can be assigned to a person and through which they can be identified. Among other things, this includes name, address, telephone number and data on the location or appearance of the person. (cf. Intersoft Consulting, n.d.)

Sensitive data is a subset of personal data that reveals information about a person’s ethnic origin, political opinions or religious beliefs, trade-union membership, genetic and biometric information, health-related data or sexual orientation. This type of data is particularly vulnerable to misuse, for example through discrimination, and therefore requires special protection. (cf. European Commission, n.d.)

Manufacturers & Mobility Service Providers Rely on Data

Manufacturers and service providers rely on the collection and processing of data to optimize and further develop technologies and services. For the experts in the study, there is therefore no question that manufacturers, providers and operators of vehicles and mobility services need to have a certain degree of control over or access to the data and will continue to need to in future, in line with any data protection regulations in place or with additional customer consent. Generally speaking, data and data quality also give companies a key competitive advantage. The better a company knows their customers or an area of its business, the more likely it will be able to deliver product improvements and develop services and business models with customer benefits and successfully bring them to market.

This has been impressively demonstrated in recent years by the big data-driven companies such as Google, Apple and others. From the companies' point of view, it is also an easy calculation to make. After all, building up the expertise, infrastructure and personnel to successfully generate, analyze and evaluate data is both time-consuming and cost-intensive. Companies will therefore only continue to invest in this area if they see opportunities to derive added value from their investment and ultimately to earn money from it.

"Generating and managing data is expensive. That is why it is important to companies that it pays off to invest in data analytics."

Alexander Pesch

With Use Comes Responsibility

The experts are also largely in agreement that a company's claim to use the data in turn implies a responsibility toward users and society. There are relatively clear guidelines in place to protect user privacy, especially in Germany and Europe.
For example, the commercial use and disclosure of personal and sensitive data to third parties without consent is prohibited by law. It is however more than just a case of meeting legal requirements. Above all, what is crucial is how users perceive the handling of "their" data. Are they consciously giving their consent, or are they simply giving it in passing, feeling not quite sure about it all?

Alongside self- and co-determination, the need for transparency is also a vital factor in winning social acceptance. More and more people are wanting to know why their data is collected and how it is used. As soon as they start feeling uneasy, their willingness to consent to the use of data in surveys and experiments rapidly diminishes.
Here, the experts believe that the way in which companies and organizations handle data will therefore play an increasingly important role in both reputation and social acceptance going forward. As such, building trust in the public discourse and among users will become an important driver for long-term company success.

"Commercially speaking, manufacturers should only use and share personal data anonymously and with user consent."

Uta Klawitter

"Transparency is critical: What is being collected? Why is it being collected? What's it being used for? Who's gonna benefit from this data? Is it just the service provider or the manufacturer? Or is the consumer going to benefit?"

Sam Abuelsamid

New Models & Greater Awareness for Handling Data

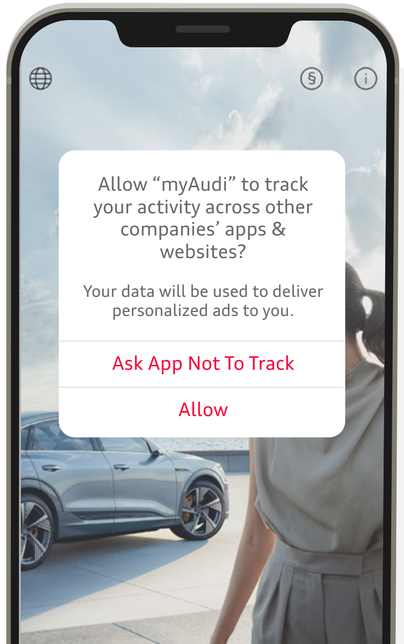
One possibility for the handling of personal data in the future is what is known as “data stewardship”. This describes a relationship of trust between individuals and organizations within which the use of personal data is regularly, and transparently, “renegotiated”. This operates on the initial assumption that all personal data belongs to the users, who then individually consent to the use of their data by the companies who wish to use it. This should empower people to make their own decisions about the use of their data. In a possible further step, access to certain personal data (especially by third parties) could only be given in return for payment to users.

“Who do I trust to handle this data respectfully? There’s a lot riding on reputation.”

Torsten Gollewski

“The user gives permission to the service provider or the manufacturer to utilize some of that data. And if it’s to be shared with a third party, it must be on an opt in basis from the customer. I think that’s the way it should be.”

Sam Abuelsamid



Data Stewardship: The Apple Example

Back in April 2021, Apple introduced a new privacy feature on all its devices. This app-tracking transparency feature ensures that before an app can collect user data or share it with third parties, a pop-up window appears on the screen and gives the user the option to either consent or reject. This gives users full control over the use of their data.
(Apple, n. D.)

“It turns out that once Apple’s app tracking transparency feature was turned on recently, something on the order of 96 percent of users said no, do not share my data with anybody else. This was specifically for sharing with third parties.”

Sam Abuelsamid

Strong Approaches Already Exist, but Much is Still in its Infancy

One example of a push toward data stewardship is that of Apple. The US company has developed its own solution for user self- and co-determination. Apple state the goal is to raise awareness among users surrounding how their own data is handled as well as to strengthen its own reputation as a trustworthy company. Upon inspection of the results of this initiative, it quickly becomes clear that users are highly skeptical about sharing their own data. For that reason, some experts argue that companies and organizations should communicate more strongly both the added value for users and the social benefit for society (for instance “in the interest of road safety”) of using and sharing data.

The objective should be to grant users a certain degree of autonomy over their own data instead of blocking the transfer and analysis of data across the board. In this way, companies could continue to build new business models on qualified data and utilize the enormous potential for technical progress and economic success that data has to offer. In Germany, the Federal Ministry of Transport and Digital Infrastructure’s “Mobility Data Space” (see bottom left) offers an interesting approach to how this could succeed in an industry-wide exchange.

“Mobility Data Space” Pilot Project

The “Mobility Data Space” is an open data space with a European orientation. As well as promoting the secure exchange of data, it facilitates the development of real-time data and links existing data platforms with one other. In future, this will allow comprehensive mobility data to be made available on a national and soon also on a European level. Based on the decentralized system architecture, the “Mobility Data Space” creates data sovereignty and builds trust as well as providing users with security in terms of data origin and quality.

By connecting public and private sector data across regional and national data platforms, the Mobility Data Space becomes a digital distribution channel for data-driven business models and reveals new possibilities for developing, connecting and utilizing data. In addition, the Mobility Data Space empowers users to participate in the potential of their own data to create value or to obtain co-determination rights in the transfer and use of their data. (acatech, n.d.)

“Mature technology is on thing. But it is also very importent to think about how humans and machines can intercat now and in the future.”

Tobias Miethaner

Protecting Passenger Privacy & Security

Technologies such as voice recognition, sensors and cameras collect a large amount of data from autonomous driving. This data can then be used to derive and interpret conclusions about the behavior of the user. In the eyes of critics, such extensive data collection and analysis in part poses a threat to the right to privacy. As such, the issue of effectively protecting users' personal data and privacy is at the heart of the debate on the social compatibility of autonomous driving. Furthermore, the extensive digital and connected infrastructure required for autonomous driving opens new doors for manipulating vehicles and infrastructure, for example through cyber-attacks. Here, we need to develop the right security standards at an early stage to avoid jeopardizing user trust.

Data Protection

Data protection relates to the protection of personal data (see p. 57, bottom right). The focus here is not on the content of the data but on the right to informational self-determination.
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Data Security

Data security addresses the general protection of data, irrespective of whether personal data is affected. As such, data security covers not just personal data but all of a company's data. Data security is therefore not a matter of whether or not data may be collected and processed but rather of the measures that must be taken to ensure this data is protected. (Siriu, 2021) (cited verbatim)

Germany & Europe are Leading the Field in Data Protection

In legal terms, the General Data Protection Regulation (GDPR) has already laid the groundwork for data protection at both European and German level. This overarching framework is intended to offer maximum protection for privacy and to promote user self-determination. The objective here is for users to be aware at all times of what data their vehicle is collecting and how they can manage this data themselves insofar as possible. For this reason, principles have been set out with regard to technology design and data protection-friendly settings. That notwithstanding, the experts believe it is also key to have bodies or institutions that guide and monitor the implementation of these principles (for instance, legislation at European level, including the Digital Services Act and the Data Governance Act). In addition, the experts stressed that what are supposed to be clear legal frameworks and laws are often undermined by requiring just a simple “click” to accept terms and conditions. Once again, this runs counter to the demand for greater transparency and the data stewardship approach (see previous chapter).

“In the case of Tesla, we find that people are willing to accept T&Cs with significant data use on the part of Tesla because they see it as personally advantageous.”

Torsten Gollewski

Digital Services Act

The Digital Services Act is a European Commission draft regulation. Among other things, the regulation aims to create a harmonized competitive framework and to ensure the clear regulation of digital services and markets throughout the European Union. (cf. Hammel & Rieke, 2021)

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Data Governance Act

The Data Governance Act is the first part of the EU Commission’s digital strategy. Inter alia, the Act aims to remove the hurdles and legal concerns for sharing sensitive data. For sensitive data to be processed, it has to be processed in an appropriate manner (e.g. pseudonymized and anonymized) by a state authority. (cf. Rieke, 2020)

Anonymization is a Key Technology for Data Protection in Autonomous Driving

Despite the legal framework in place and the extensive implementation of protective mechanisms, there remains, at best, a residual risk in terms of criminal access and manipulation. In a maximally connected world, more than ever, cyber-attacks pose a serious threat. Accordingly, anonymization and encryption are fundamental cornerstones in protecting (personal) data. This is the only way to guarantee that no conclusions can be drawn about users if user data falls into the wrong hands. One approach to anonymization that has already become common practice is data pools. These pools are an environment to collect, anonymize and interpret specific data sets with user data in patterns.

These patterns create new insights and substantiate derivations for improved algorithms and services. Operators, providers and insurers of autonomous vehicles are already able to deduce a great deal of information from this type of data pool without exposing users to disproportionate risk. User privacy does not have to be put at risk to create risk profiles or statements on maintenance and product quality.

Anonymization

Anonymization means changing personal data so that the individual details regarding personal or factual circumstances can no longer be attributed to a specific or identifiable natural person or could only be attributed to a specific or identifiable natural person with a disproportionate amount of time, cost and effort. (cf. University of Lübeck, n.d.)

Encryption

Encryption means converting data into what is called a ciphertext, which is almost impossible for unauthorized persons to make sense of. In turn, decryption converts encrypted data back into its original form to make it readable. 'Pseudonymization' may also play a role in encryption. This processes personal data in such a way that it can no longer be attributed to a specific data subject without the addition of further information.
(cf. Federal Office for Information Security, n.d.)

"In a pool of anonymized data, analysis can identify patterns, allowing conclusions to be drawn about vehicle behaviors. This information means functions can be systematically improved."

Uta Klawitter

"China has regulations regarding data in place that are comparably comprehensive to the once in the European Union. Data must be encrypted on board before it is uploaded to the cloud."

Alexander Pesch

Data & Vehicle Manipulation is a Fundamental Security Risk

As things stand today, automotive software is already made up of several million lines of code. By 2030, this will have multiplied. The enormous amount of data combined with the large number of data interfaces offers a target for cyber-attacks. In a vehicle that is always connected to the Internet, this could have fatal consequences. If this were to happen, say, for instance someone hacks into the vehicle's control system or manipulates its braking system and causes people to be harmed, this would likely shake confidence in autonomous vehicles. Furthermore, the data security risk is not just an ethical or social problem but also creates economic risk for the providers. If users perceive the technology to be insecure, a lack of customers will surely follow. This means that car manufacturers and mobility providers must develop and implement highly efficient cyber-security concepts at an early stage.

"Any data interface is a potential risk to vehicle safety. This means it's up to companies to ensure that data interfaces are as technically robust and secure as possible to protect vehicles from external access."

Uta Klawitter

"The sheer amount of data is already a risk in itself. If this becomes a target, a correspondingly high volume of data is available as a pool for abuse."

Torsten Gollewski

Regulators & Industry Recognize the Urgency & are Responding

At international level, 2020 saw the UNECE (United Nations Economic Commission for Europe) adopt a Regulation* that makes it mandatory to have a comprehensive cyber-security concept in place for the approval of new vehicles (especially automated and autonomous systems). This applies equally to cars, buses, vans and trucks and includes cyber risk management and risk management along the entire value chain. Further to this, it includes identifying the sources of errors or security incidents and also software updates. Many of the experts interviewed believe this Regulation provides strong orientation for companies and users and is an important step in building trust and acceptance. According to the experts, manufacturers are now asked to consider and integrate solutions for data protection and security in the design and development of autonomous vehicles right from the very beginning. This process is called “privacy by design” and involves ensuring privacy and security through how the technology is designed.

*(cf. United Nations Economic & Social Council, 2020)

“The industry is really taking this seriously now, but it’s important for them to incorporate security from the initial design phase all the way through the process and through all aspects of the business.”

Sam Abuelsamid

Data Performance & Added Value

The experts are unanimous in stating that privacy protection and data security are central factors, without which it seems almost impossible for autonomous driving to become socially accepted. It has, however, also been demonstrated that concerns regarding safety often only prevail until a certain added value or benefit has won user enthusiasm. For some, this may be triggered by a personal experience (cf. Ethics: personal benefits), for others, it will be the enormous social potential autonomous driving and data-driven, connected mobility have to offer. As such, we can set about designing the mobility of the future with the utmost efficiency.

A large number of the experts see this as an opportunity to design mobility that is both safer for all road users and far more environmentally sustainable. Some also hope for added social value in terms of social sustainability as an increasing number of people will have extensive access to attractive mobility offers, even in infrastructurally weak areas. Here, data quality and performance play a decisive role. For the very first time in human history, we are able to develop and optimize vehicles, infrastructure and mobility services both virtually and in “real time” thanks to an enormous pool of real data.

“You really can’t do the mobility revolution without the data and the connectivity.”

Sam Abuelsamid

“Data is an inevitable enabler. Without data, you can’t train and optimize artificial intelligence systems. Only with data you can achieve maximum safety or human-like driving.”

Alexander Pesch

Collective Intelligence is Laying the Groundwork for the Mobility Revolution

Many of the experts who believe in an autonomous future believe comfort and safety hold the key to the most added value. Theoretically speaking, a future with no traffic accidents, with no traffic fatalities is well within the realms of possibility. To get there, however, all vehicles, road users and infrastructure would have to be in communication with one another and be controlled by a comprehensive system of AI. The issue is that this “Vision Zero”, as already explained, would require total autonomous vehicle market penetration, making it rather a visionary idea according to experts. The same experts do, however, expect the gradual penetration of autonomous vehicles to have an overwhelmingly positive effect on road safety and the use of infrastructure, with fewer crisis situations, more efficient road utilization and fewer accidents. To achieve this goal, Audi together with partners is continuously developing a networking technology called “Cellular Vehicle to Everything” (C-V2X). The technology can use both today’s mobile network and the future 5G network. The transmission times are in the millisecond range.

But connected and data-driven mobility concepts do not just promise enormous potential in terms of a more efficient, and therefore more environmentally sustainable, future. They can also have a wide-reaching social impact, including through the creation of new infrastructure and services oriented toward human needs. In an ideal world, this would catalyze a new form of inclusive and social mobility. Those without a driver’s license or those who are unable to obtain one, for instance, would be able to be mobile again.
For this to become the reality, the experts would like to see visionary thinkers in business, academia and politics as well as wider societal trust in the power and ability of data.

“The goal is to get to zero crashes and zero fatalities. This is theoretically possible with a fully connected, autonomous fleet.”

Jake Fisher

“There’s a lot of potential of societal benefits from that data. Things like crowdsourced map building is one.”

Sam Abuelsamid

Predictive Technology Could Prove the Breakthrough

For data and connectivity to reach their full potential, we must see the (further) development and implementation of what are known as “predictive technologies” by means of AI. According to the experts, this technology is capable of dynamically predicting traffic situations. For this to happen, the AI combines existing data and scenarios with current real-time data on road conditions, weather forecasts, environmental factors, traffic situation, etc. Alongside the collection and analysis of enormous amounts of data, including primarily data on how humans behave in traffic, this is made possible thanks to self-learning and self-programming AI. As such, a number of the experts predict that future AI will be capable of understanding, responding to and partially imitating human behavior in road traffic. This new quality of predictive driving could prove decisive in achieving widespread social acceptance and in developing the relationship of trust between the user and the machine. After all, people are less prepared to respond to a new way of driving with autonomous vehicles on the road. Instead, they expect autonomous vehicles to adapt to them.

Comprehensive Digital Infrastructure is a Must

The experts are in agreement that the corresponding digital infrastructure must be in place if we want to see the rapid and comprehensive penetration of autonomous vehicles. More specifically, we need a broadband Internet connection with as few gaps as possible which all vehicles are able to access. Indeed, the ability for all modes of transport (i.e. vehicles, road infrastructure, etc.) to interact and communicate is one of the primary cornerstones of autonomous driving. To this end, the experts recommend establishing and implementing a 5G standard at international level as quickly as possible. Another cornerstone for an autonomous future is extensive cloud edge computing or onboard edge computing. This will allow huge amounts of data to be collected, transported and processed very quickly – the only way to ensure sufficient responsivity for autonomous driving in everyday life. Furthermore, with constant communication between the cloud, autonomous vehicles and smart traffic infrastructure, cloud edge computing technology also enables ongoing further development of various functions.

“If you can achieve a very high percentage of automated vehicles in the future and ensure they’re connected, both with each other and the transport infrastructure, then you can obviously optimize traffic and e.g. get more vehicles through an intersection in a given period of time.”

Alexander Pesch

“You obviously need extensive cloud edge computing that is capable of responding in milliseconds to specific traffic situations. To do that, you also need a huge amount of computing power in the vehicle.”

Torsten Gollewski

Cloud Edge Computing

(Cloud) edge computing is part of a distributed computing topology where information is located near the edge, that is to say near where things and people are producing and consuming that information. Here, data processing is decentralized: rather than relying on a distant data center, data is processed in the very devices (or their own cloud) that are aggregating the data.

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The aim is to reduce latency, which is a major advantage in terms of speed, particularly where near real-time data is required, such as in autonomous vehicles. (cf. Bigelow, 2020)

&Audi SocAlty Study

Conclusion

By and large, the study experts are in agreement that autonomous driving will change our society, and in particularly our mobility landscape, for the better in the long run: for one thing, predictive technologies will result in greater road safety. For another, people will be able to get from A to B more comfortably and reliably despite higher volumes of traffic. Certain groups of people who have had limited mobility, such as senior citizens, children or people with special needs, will gain better access to individual mobility services. What is more, electrification and smart traffic management will make all of this even more efficient and environmentally friendly than before.

That notwithstanding, exactly how quickly and to what extent this vision will actually become our reality is largely dependent on technological and social developments – two highly interdependent factors. Technological progress depends on social acceptance, or else the technology will not be used, no matter how mature it is. In turn, safe and mature technology also promotes social acceptance. For instance, greater vehicle safety and comfort will sooner or later lead to greater social acceptance, particularly if this is something users can experience for themselves.

For that reason, both the study itself and the experts involved in its making stress that the future of autonomous driving is vitally dependent on meeting society and users in their current lived reality. As part of this, that involves not underestimating the power of people's habits and self-perception. After all, for many, driving their own car still equates to freedom, flexibility and self-determination. Often, alternative transport concepts are unable, or not yet able, to offer these same qualities. Furthermore, it must also be noted that in parts of the world, thus far, there has been a lack of awareness among the general public as to what exactly autonomous driving actually means, where technological development currently stands and what opportunities and risks are in fact associated with it. This has created a certain uncertainty and skepticism among many in terms of liability and data protection or the reliability and safety of the technology.

Certainly, at least according to the experts interviewed as part of this study, some challenges still remain to be solved in the coming years with regard to technology, infrastructure and practicality. Many key technologies, such as edge computing, are yet to be sufficiently advanced, for instance. The result is that artificial intelligence is not yet capable, for example, of interpreting the sometimes irrational and aggressive behavior of drivers and thus of selecting the "correct" response. What is more, the vast majority of global regions also currently lack the seamless mobile network infrastructure (5G) to bring autonomous driving onto the road across the board.

Yet even in face of the multitude of challenges that still need to be overcome on the road to an autonomous future, the potential for society and the economy is enormous. The study experts agree that this potential will lead to the necessary technological breakthrough. As such, to drive forward development and foster trust and acceptance among the population, they therefore recommend exposing as many people as possible to autonomous driving so that they can experience the personal benefits for themselves. That being said, the experts also repeatedly underscored that companies must manage expectations and that they must do so transparently.

Conclusion

After all, it is vital to clearly communicate the added value of autonomous driving without neglecting the current limitations. Or, to put it more simply, communications must move away from science fiction to a realistic vision that will stand the test of time. Finally, addressing potential concerns and hurdles on topics such as safety, liability and data protection will prove another key cornerstone in building trust among users. Accordingly, it follows that the communication of guidelines and laws will also play a central role in creating widespread acceptance among the population.

Alongside focusing on the key factor of active trust-building among current and future users, the study also contains further recommendations for action that could guide actors from business and politics. Here, a central point is that the experts interviewed as part of the study call for an interdisciplinary, pragmatic and solution-oriented approach – be that in the creation and implementation of international legal standards, in data handling or in addressing ethical or security-related issues. After all, the complexity and diversity of the issue at hand is such that it cannot be solved by individual stakeholders acting in isolation.

In the area of law, it is first and foremost a matter of encouraging developers of technology to contribute their expertise in order to further develop the legal basis together with regulators. This is the only way to ensure that legislators are suitably equipped with an understanding of manufacturer technical expertise. Conversely, manufacturers would benefit from legislation taking into account developments in both technology and the market. Not only will this promote a willingness to innovate and invest on the part of companies, but it will also build confidence among users. Here, Germany is a prime example in terms of both regulation and jurisdiction as, according to the experts, the legal framework established here could well serve as an international model.

With regard to the field of ethics, the majority of experts recommend a shift away from theoretical discussions about unsolvable moral issues. Instead, they call for a shift toward more solution-oriented accident prevention. Here, the key players are both the manufacturers and the development of safety technologies. For many of the experts, greater cooperation and more exchange between individual manufacturers will be a vital factor in the development of autonomous driving.

The same tendency is also apparent in the data section of the study. Today, international bodies are already creating frameworks for collaboration across key areas of research and implementation in terms of new technologies. International data pools with anonymized data sets lay the groundwork for progress and will only gain in importance moving forward. According to the experts, how companies and organizations handle data will also be an increasingly decisive reputational factor in future. As such, building trust, both as part of public discourse and among users, will become an important driver in sustainable business success.

The &Audi initiative considers itself a driving force on the road toward greater transparency, exchange and cooperation. Accordingly, the contents of the study at hand are not to be understood as an expression of absolute truth or wholeness. Rather, the opinions and expertise of the experts interviewed should serve to holistically empower the conversation and exchange surrounding autonomous driving.

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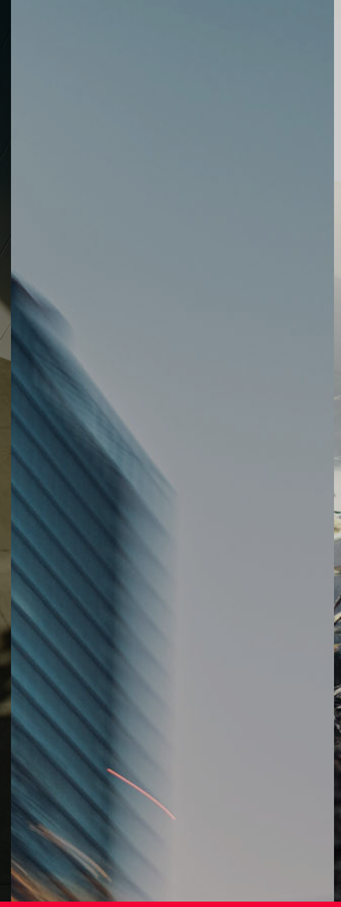

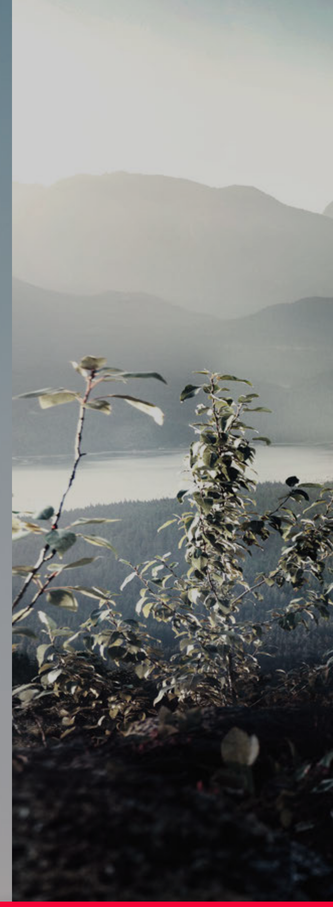

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