ROAD SAFETY REPORT 2023

Technology and People

DEKRA

Accident Statistics
We urgently need to make better use of ways to prevent accidents

The Human Factor
Complexity of systems must be controllable in any traffic situation

Technology
Modern operating concepts must not cause extra distraction


DEKRA
Our aim:
Maximum safety
for people
Automated and connected driving is the future of mobility. DEKRA offers unique expertise and opportunities for achieving maximum safety in our highly modern and state-of-the-art test centers. Be mobile with safety.
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SELF DRIVING
DEKRA On the safe side

Actively Leveraging the Potential of Automated Driving

Jann Fehlauer
Managing Director, DEKRA Automobil GmbH

Following a period of historically low traffic fatalities in 2020 – largely thanks to the pandemic – many countries have seen their numbers increase again. In 2020, 18,800 people in the European Union (EU) died in road crashes, while in 2021 it was 19,900, and in 2022 around 22,600, which brings the figure more or less back to where it was in 2019. There is no doubt that the long-term trend is a positive one, but there is still a lot that must be done if we are to achieve our ambitious targets of halving the number of traffic fatalities in the EU by 2030 and eliminating them altogether by 2050, if possible. In the context of "Vision Zero," a strategy that is gaining traction internationally, it is now more important than ever that everyone use all available opportunities in the best way possible to further improve road safety.

Given that 90 percent of accidents are caused by human error, leveraging the potential of technology and, in particular, the systems used in connected and automated driving will be key. Equipping vehicles with relevant assistance systems and designing them to communicate with one another and the road infrastructure will help detect and avoid dangerous situations early on and prevent accidents – or at least mitigate their consequences. Assistance systems, however, do not relieve drivers of their responsibility. Ultimately, it is always the human behind the wheel who has responsibility for the vehicle.

The extent to which humans and technology are interwoven in road traffic has once again been put under the microscope in this year's DEKRA Road Safety Report. Just as a reminder: in 2012, we dedicated an entire report to this complex topic. For example, no matter how useful the technology may be, it must never be allowed to distract, or even overwhelm, the driver. As a fundamental rule, assistance systems must be easy for everyone to use. Using them must not create additional risks or hazards that undermine the success achieved through implementation of road safety measures. The fact that this is a very real risk has been shown in both a forsa survey commissioned by DEKRA and a human subject research study conducted by DEKRA, the results of which will be presented in detail in this report.

Another important aspect to ensure is that any systems installed for assisted and automated driving, as well as the safety-relevant mechanical components, function reliably for the entire service life of the vehicle. Only then will they be able to achieve their desired effect. Periodical technical inspections (PTI), which many countries around the world have been conducting for many years now, will therefore become even more important in future than they already are today – given the higher complexity of vehicle systems and the risk of electronic manipulation.

The DEKRA Road Safety Report 2023 shines a light on several problem areas in terms of the human-machine interface from the perspective of accident research, traffic psychology, vehicle technology, infrastructure design, and legislation. I am particularly pleased that renowned national and international experts have once again agreed to provide statements, in which they report on their respective experiences and any measures taken. These statements complement our own expertise and further underscore how relevant our report is in specialist circles. I hope you find this report a stimulating read.

Technological Progress Can Help Make Our Roads Safer

Kristian Schmidt
European Road Safety Coordinator

The EU's road safety policy framework for 2020-2030 reflects the major transformations in the transport sector. It sets out how policies and practices will need to adjust to address challenges and opportunities such as changing mobility patterns, connectivity, and automation. Three years into this framework period, it is clear that progress is too slow and more needs to be done to achieve the goal of halving the number of road deaths by 2030.

The General Vehicle Safety Regulation establishes the safety features that vehicles have to fit in order to be sold in the EU. The most recent requirements started applying in July 2022, providing for state-of-the-art safety technologies to be fit as standard equipment and establishing the legal framework for the approval of automated vehicles. Further measures will be progressively introduced until 2029.

The European Commission's technical rules focus on automated vehicles replacing the driver on motorways, as well as fully driverless vehicles like urban shuttles or robotaxis. We require a high level of safety and maturity before the fully automated vehicle is placed on the EU market. Given the high level of complexity in this field, the rules encompass testing procedures, cybersecurity requirements, data recording as well as monitoring of safety performance and incident reporting requirements by manufacturers.

The Commission does not want to slow down innovation, but to make sure that only safe technologies are present on European roads. We are aiming to ensure the highest common level of safety and a single regulatory process. Providing the first ever EU legal framework for automated and fully automated vehicles also enhances the global competitiveness of EU car manufacturers.

Automated driving systems (ADS) are a game changer for mobility. They affect the entire vehicle and mobility chain, including roadworthiness, driving licences, insurance and enforcement.

There are challenges that remain to be addressed, for example the divergence in approaches in Member States on defining the driver. Physical infrastructure, too, needs to be made ready for the safe roll-out of connected and automated mobility systems. Driver training and examination systems may need to be adapted. And finally for enforcement of traffic rules, police officers need to be able to easily recognise ADS vehicles.

Connected and automated driving has great potential to help make mobility safer and more accessible, and we are working hard to put the right framework in place. However, new challenges are emerging, including protecting cybersecurity and ensuring that highly automated vehicles operate safely in mixed traffic. We need to make sure that automated vehicles are safe before we allow them to circulate on Europe's roads. If type approval fails here the whole technology might be discredited.

Wherever the DEKRA Road Safety Report uses terms such as "road user," "pedestrian," "cyclist," etc., these terms should always be assumed to apply to all genders unless explicitly stated otherwise. Unless explicitly stated otherwise, the terms "bicycle" and "cyclist" always include pedelecs and pedelec riders (up to 25 km/h).

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Technology and People: A Balancing Act

There is almost no area of our modern lives that has not been influenced by the trends of digitalization and automation. The world of mobility is no exception, as both are playing an increasing role here as well. Everyone is talking about terms such as "highly automated driving" or "autonomous driving," and these concepts are purportedly the silver bullet we have been waiting for to solve fundamental traffic problems. The purpose of this report is to detail the challenges associated with these developments and set out the role that people play in this context.

"We hurtled away without anyone holding the steering wheel, whipped around corners, dodged around other equally fine vehicles, but nobody honked their horn. [...] Instead of a steering wheel, I discovered a metal plate into which an intricate but clear map of the city had been etched. A pointer working with pinpoint accuracy was positioned above it. I'd barely moved it at all before the vehicle started up and shot down streets I didn't know. It stopped just as suddenly. [...] The best thing was that the vehicle dodged out of the way of others, suddenly stopped in front of busy intersections, let other cars pass, and behaved as if it knew the ins and outs of every conceivable traffic rule."

These lines, translated freely here, are taken from a science fiction novel called "Utopolis" written by Werner Illing in 1930. When you read them, it's hard to believe how all those years ago, the German author managed to accurately predict the types of things that vehicle manufacturers are now focusing heavily on. In fact, in the course of his novel, he also touched on the topic of connectivity when he described how the "mysterious self-steering cars" worked. At the front of every vehicle was "a small prism eye" that acted on light-sensitive electric cells and communicated with electric eyes that had been "discreetly recessed into the walls of the houses." "These mechanical eyes regulate the speed and steering using alternating mirror reflections."

93 years later, in an era where road traffic is becoming increasingly digitalized, our society finds itself on the cusp of arguably the biggest revolution in mobility since the invention of the car. Software and electronics are taking over more and more tasks from drivers, turning cars into rolling high-tech machines. All renowned volume manufacturers now offer assisted and semi-automated driving, with the number of vehicles equipped with automated driving features set to increase markedly in the coming years.

Milestones Along the Way to Greater Mobility and Safety

1900 • • • • 1910 • • • • 1920

1902

- *British engineer Frederick W. Lancester invents the disk brake and files a patent for it.*
- *German inventor Otto Schulze develops the eddy-current speedometer for road vehicles.*

1911

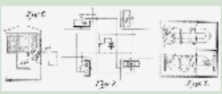
- *Road markings to separate different road lanes are invented – nowadays they form the basis for lane keeping systems.*

1914

- *Doctor Eric Gardner manufactures the precursor to a helmet for motorcyclists, made of shellac and canvas.*

1917

- *In the USA, the first automatic traffic signal is patented. In Detroit, the first traffic control tower is installed at an intersection.*



1920

- *Engineers from the Radio Air Service at the McCook air force test base in Dayton, Ohio, present the first driverless, remote-controlled automobile to the general public.*
- *Europe's first tri-color light signal system is presented in Paris.*

1921

- *The Duesenberg Model A is the first vehicle to be equipped with a hydraulic braking system.*

1925

- *The organization Deutscher Kraftfahrzeug-Überwachungsverein e.V. (now DEKRA) is founded in Berlin.*

1931

- *The League of Nations in Geneva adopts the "Convention concerning the Unification of Road Signs."*

1933

- *The first pedestrian traffic lights in Europe are installed in Copenhagen.*

1934

- *Reflective road studs ("cat's eyes") are invented by British inventor Percy Shaw.*

1935

- *The telescopic fork for BMW motorbikes is launched (still the most common design today).*

1938

- *In May, the American magazine "Popular Science" reports on the automated traffic of the future for the first time.*

Technological Progress for Greater Safety on Our Roads

Dr. Volker Wissing
German Federal Minister for Digital and Transport

Things can change in a split second when you're out on the road. For example, many car drivers will have experienced that feeling of panic when you're driving through a forest and a deer suddenly springs out from nowhere into the middle of the road. Smart wild-animal warning systems are designed to prevent these types of hazardous situations in the future. They use sensors and cameras which are fitted to the road marker posts and scan the forest around the road. The signals they send are evaluated by a data processing system which is underpinned by artificial intelligence (AI). If it detects that an animal is dangerously close, road users are immediately warned by what is known as car-to-X communication. The German Federal Ministry for Digital and Transport is supporting such a project because it leverages the benefits of our digital world to make mobility safer.

The ability to exchange information between vehicles, and between vehicles and infrastructure, offers major opportunities to make our roads safer. We want to make the most of them, but we need data to do so. It must be readily available, easy to find and access, and provided in a usable format. That is why we're currently working on a Mobility Data Act and optimizing the data policies of the entire German federal government. We are also focusing on data spaces such as the Mobility Data Space (MDS), which the business sector has set up with government support . The data that is shared in the MDS enables us to develop things like cooperative smart transport systems and applications. This also includes connected vehicles, which can identify hazards such as slippery roads in real time and warn other vehicles via their information systems.

Exchanging information in this way also benefits autonomous driving. Germany is the first country in the world to have established a dedicated legal framework for it. In Germany, it is now much easier to approve autonomous vehicles for practical testing and have them join normal road traffic in approved areas. One day, autonomous vehicles will be able to make our roads much safer – after all, more than 90 percent of accidents nowadays are still caused by human error.

In addition, vehicle assistance systems have been an essential part of modern vehicles for some time now, and also help to make things safer on the road. For example, they issue a warning if the driver becomes tired and inattentive, if there is an impending collision with other vehicles, or if cyclists are nearby when drivers make a turn. They also help drivers to reverse into a parking space, keep to the permitted speed limits, and brake and keep in lane in an emergency. These types of systems are able to detect hazardous situations in good time, prevent accidents, and ultimately save lives. For this reason, they are mandatory equipment on new vehicles as stipulated by the EU's General Safety Regulation, and we welcome this development. We are also advocating the further spread of assistance systems in cars and trucks, in motorbikes and buses.

Technology helps us and makes a lot of things easier, but it does not replace human beings. First and foremost, it is people who continue to be responsible for driving their vehicles on our roads safely and with consideration for others. That is why it is also important for assistance systems not to overwhelm or distract drivers, and why they need to be easy to understand and use. This is a prerequisite for these systems to truly make our world of mobility safer.

New and innovative vehicle technologies are playing a key role in the German federal government's Road Safety Program, which covers the years up to 2030. Together with other measures – such as promoting safe road infrastructure, improved education and training, and a better atmosphere on the road – they are all helping to achieve one important goal: Vision Zero, a future without any traffic fatalities. If we are to succeed in this endeavor, many different parties will need to play their part. DEKRA is a major campaigner and thought leader in this respect, and its commitment is clear to see in this Road Safety Report. The company is working at full speed on ways to make our roads safer and is providing valuable impetus and insights to make this a reality.

1930 · 1940 · 1950 · 1960

1946
- *French tire manufacturer Michelin has the first radial tire patented, which is launched in 1949 under the brand name Michelin-X.*

1947
- *At the Muroc test site, located in the Mojave desert in the USA, Colonel John Paul Stapp carries out the first tests on himself as part of his "deceleration project". This involves him subjecting himself to multiple rapid deceleration tests on a rocket sled until he reaches his limits.*

1951
- *Hungarian engineer Béla Barényi files a patent for his concept of a "rigid passenger cell with crumple zones at the front and rear."*

- *In collaboration with the Indiana State Police, a team of accident researchers led by engineer Hugh de Haven in the USA start the first comprehensive analysis of car accidents.*
- *Periodical technical inspection (PTI) for motor vehicles is introduced in Germany.*
- *Walter Linderer files a patent for an airbag.*

1956
- *German vehicle registration regulations (Straßenverkehrs-Zulassungsordnung) stipulate "fitness-to-drive assessments" for the first time. From 1960, they are called "medical-psychological examinations".*

1956
- *At the International Police Exhibition in Essen, Telefunken presents the first traffic radar device to monitor a vehicle's speed.*

1959

- *Volvo engineer Nils Ivar Bolin files a patent for the three-point safety belt.*
- *With the Mercedes 220 S/SE, Mercedes-Benz launches the first car equipped with a safety passenger cell.*

1960
- *Certified safety cabs for trucks are launched in Sweden.*
- *Coordinated rescue service launched in Germany*

A General Openness to New Technologies

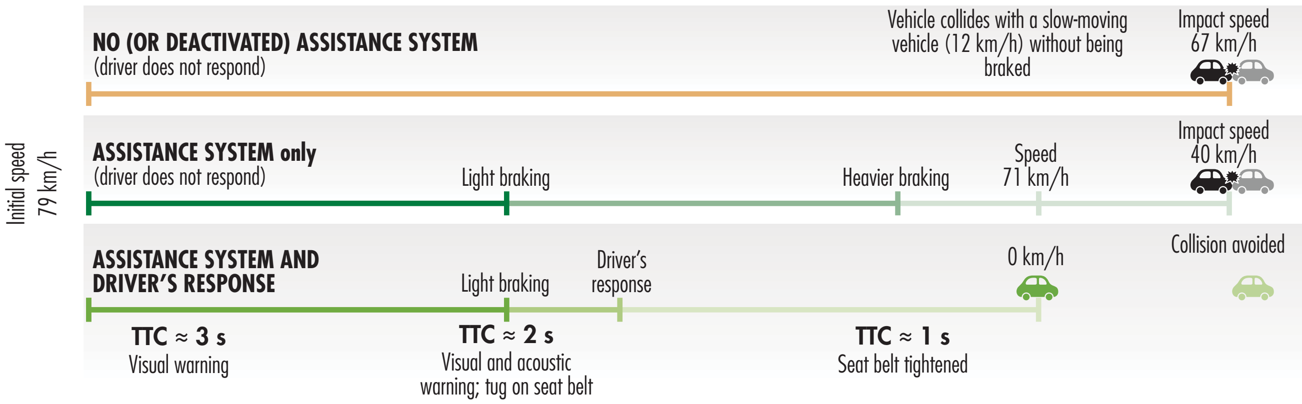
However, what do people actually think about automated driving, for example in Germany? How would car drivers behave when encountering these types of vehicle? Do they fundamentally trust the safety of automated driving functions and driver assistance systems? Are there currently problems with operating technical functions and systems in vehicles? Would people like to have standardized functions and systems in vehicles? To answer these questions, DEKRA commissioned opinion pollsters forsa to conduct a representative survey in October 2022. A total of more than 1,500 German-speaking residents aged 18 or over, systematically chosen at random, took part.

When asked how they would respond to a fully automated vehicle, 60 percent of those surveyed said that they would exercise greater caution when interacting with a fully automated vehicle than if the vehicle were controlled by a person – regardless of if they themselves were traveling in a car, on a bike, or as a pedestrian. 36 percent would exercise the same level of caution when interacting with a fully automated vehicle as they would for a vehicle controlled by a person. Skepticism of fully automated

1

The Effectiveness of Assistance Systems

This graphic shows the benefits of informing a driver about an impending collision if it appears that they are not paying attention. The primary goal is to bring them back into the control loop and cause them to take action to avoid the collision in the first place. The vehicle is also decelerated in order to reduce the collision speed or, ideally, prevent the collision altogether. The version of the system depicted here is no longer produced, but vehicles equipped with it are still out and about on our roads today. The timings (in this case Time to Collision = 1 s, 2 s, and 3 s) and the type of intervention (visual or acoustic warning, light braking, heavier braking) are determined by the respective manufacturer.



TTC = Time to Collision (TTC denotes a snapshot in time and does not have to correspond to a measurable time)

Source: DEKRA

1965 ... 1970

1963
- *Béla Barényi files a patent for his "safety steering shaft for motor vehicles."*

1964
- *Luigi Locati presents an overview of motor vehicle safety, making a distinction between active and passive safety for the first time.*

1966
- *The first mechanical anti-lock braking system (ABS), the Dunlop Maxaret, is installed in the Jensen FF.*
- *US President Lyndon B. Johnson signs the National Traffic and Motor Vehicle Safety Act and the Highway Safety Act.*

1968
- *In Vienna, the international Convention on Road Traffic and Convention on Road Signs and Signals are signed.*
- *The US Department of Transportation (DOT) launches a program to develop experimental safety vehicles and initiates the international "Technical Conference on the Enhanced Safety of Vehicles" (ESV). Today, this conference takes place every two years.*

1969
- *First motorbike with a hydraulic disk brake fitted as standard (Honda CB 750 Four).*

1970
- *The "European Enhanced Vehicle-Safety Committee" (EEVC) is founded as a European counterpart to the American ESV program, focusing on regulations-related research. For example, the EEVC developed the testing methods for ensuring occupant protection in the event of a head-on or side collision, and the component tests to ensure pedestrian protection.*

1971
- *Daimler-Benz AG files a patent for a working model of a driver's airbag.*
- *First international conferences on exchanging research results regarding the development, construction, and testing of experimental safety vehicles (ESV).*
- *The first main headlamps equipped with two-filament halogen bulbs (H4) for low and high beams are installed on vehicles.*

Mandatory Reporting of Crashes Involving Assisted and Automated Driving Systems in the EU

Antonio Avenoso
Executive Director, European Transport Safety Council (ETSC)

Last year NHTSA, a US government agency, released its first set of data on crashes involving vehicles with advanced driver assistance systems (ADAS). In the ten months since mandatory reporting began, there had been around 400 reported incidents. How about in Europe, a market comparable in size? Nobody knows.

There is no equivalent to NHTSA that covers the whole of the EU. A car approved in one Member State can be sold across the EU. For example, a car approved in the Netherlands by the Dutch type approval authority, RDW, such as a Tesla, can be sold in any EU country. The new Mercedes Level 3 automated low-speed driving assistance system was approved by the German Federal Motor Transport Authority, KBA, for the German market, and they will most likely be responsible for EU-wide approval of the Mercedes system too.

What if a driver spots a problem with a driver assistance system? In the US, anyone can report a defect to NHTSA using an easily accessible web form. Likewise, in theory, in the EU, anyone can report a vehicle defect to a national authority. But see if you can find the web page for your country to do that easily. Did you hear about Tesla vehicles and 'phantom braking' last year? If so, that was based on reports made in America to NHTSA. Is that problem occurring in Europe? Good luck finding out.

When there is a recall, it is reported in a central EU database, but the reports published there give no information on the number of incidents reported or how many people might have been injured as a result of a defect. While it's true that, in general, the EU is ahead of the USA on vehicle safety standards, on transparency on defects or potential problems with ADAS systems, not so much. And these crashes are happening in the EU. A report by the Dutch Safety Board, published in 2019, investigated several collisions involving assisted driving systems. At the EU level? Nothing.

Reporting and investigating crashes is becoming even more important now that computers are taking over some driving tasks. If computer code or sensors cause a problem that contributed to a crash, we need to know, so we can prevent future problems. That's why ETSC is calling for mandatory reporting of crashes involving assisted and automated driving systems in the EU, and a central agency to collect this data, supervise in-depth crash investigations and oversee the rollout of new assisted and automated driving technologies safely.

1975 • • • • 1980 • • • • 1985 • • •

1973
- *The German Federal Highway Research Institute (BASt) starts the "Data collection at accident sites" project at the Hanover Medical School (precursor to the "German In-Depth Accident Study" or GIDAS).*

1978
- *From October onward, Mercedes-Benz vehicles are fitted with the anti-lock braking system (ABS) as standard. The S-Class (W116) is the first model to feature ABS.*

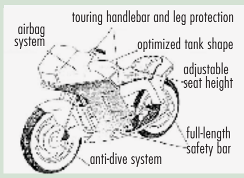
1979
- *An academic working group comprising members from the universities of Aachen, Berlin, Stuttgart, and Darmstadt starts working on the UNI-CAR research passenger car. The vehicle has a "soft face" across its entire front end. If the vehicle hits a pedestrian up to a collision speed of 45 km/h, this "soft face" is designed to keep the loads exerted on them below tolerable biomechanical limits.*
- *First electronic ABS (Mercedes-Benz S-Class and BMW 7 Series)*

- *First hydraulic anti-dive systems for individual motorbikes launched by Kawasaki and Garelli; shortly followed by series production by Suzuki and Yamaha.*

1980
- *In the 1980s, General Motors equips several of its car models destined for the US market with a black and white head-up display.*

1981
- *From July onward, Mercedes-Benz equips a model, the S-Class, with an airbag as standard for the first time.*

1985
- *Safety motorbike from the Association of German Liability, Accident, and Motor Insurers (HUK-Verband)*

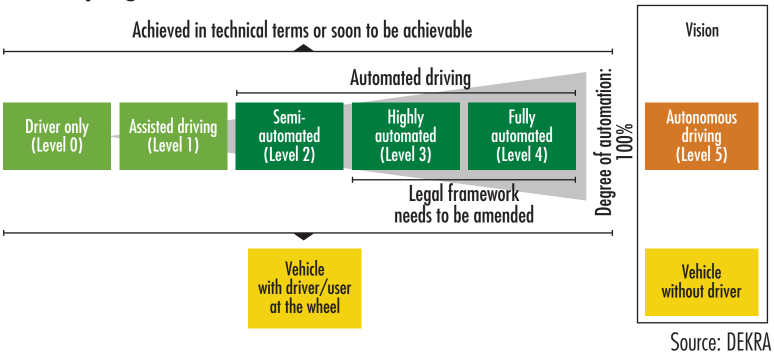


1986
- *The EUREKA research project PROMETHEUS (PROGraMme for a European Traffic with Highest Efficiency and Unprecedented Safety) conducts the first research into the possibilities afforded by automated driving.*

1987
- *First traction control system (TCS – in German ASR) installed in the Mercedes-Benz S-Class*

1988
- *BMW presents the K100, the first series-production motorbike equipped with ABS.*
- *International Traffic Safety Data and Analysis Group (IRTAD) founded.*

Classifying the Levels of Vehicle Automation



From a purely technical standpoint, automated driving through to Level 4 can already be achieved today. However, the legal framework urgently needs to be amended accordingly.

vehicles increases as the respondents get older, and women would exercise greater caution than men.

When asked about driver assistance systems that are already installed in modern cars (such as automated emergency braking systems, lane guard assistants, or adaptive cruise control), the respondents were relatively trusting with a figure of 68 percent. However, 25 percent still tend not to trust the systems, and five percent do not trust them at all. When asked about their trust in the safety of automated driving functions, around half of those surveyed said that they do not make any distinction between different car manufacturers. For 87 percent of those who trust certain car manufacturers more than others in this respect, the vehicle make plays a (very) big role. 78 percent also consider the country of manufacture to be important, while 55 percent also believe the vehicle's price is relevant.

The Different Levels of Automation

The technological evolution away from manual driving to fully automated vehicles is underpinned by a complicated, time-consuming process involving innovations in lots of different technical disciplines. The Society of Automotive Engineers (SAE) has divided this process into six levels. Level 0 denotes traditional, conventional driving. The driver controls the vehicle and additional systems help them to process information by providing orientation (navigation system with route display) or warnings (e.g., blind spot assistant or acoustic parking assistant). Level 1 denotes assisted driving, where assistance systems take over specific driving tasks in certain situations. This includes things like speed control, distance control, or active parking assistants that act like a digital butler in that they handle the entire process of parking the vehicle in a parking space. Level 2 is semi-automated driving, where the vehicle keeps to its lane under defined conditions and independently brakes or accelerates.

Level 3 is highly automated driving, which enables the driver to temporarily turn their attention away from driving the vehicle and monitoring traffic. The vehicle drives itself in the Operational Design Domain (ODD) set by the manufacturer, but the person behind the wheel is still required to take control at short notice if the system requires it. This level marks the point at which the person in the driver's seat takes on a hybrid role, switching between being a traditional driver of the vehicle and a vehicle user while the vehicle is moving in automated mode. A current example of Level 3 automation is the Drive Pilot system from Mercedes-Benz. On December 2, 2021, the German Federal Motor Transport Authority issued the world's first type approval for this kind of automatic lane guard system. Its use in the Mercedes-Benz S-Class is currently still restricted to a speed of 60 km/h on freeway-type roads, and is only allowed in daylight, with good visibility, and if there is no frost. The person behind the wheel must always be ready to take over control of the vehicle if prompted to do so.

The next level up, Level 4, denotes fully automated driving, which is when the person behind the wheel relinquishes all driving duties to the vehicle and becomes a passenger. The vehicle manages many stretches of road by itself, and after handing over control to the vehicle the driver is allowed to turn their attention away from what is happening on the road. The system must be able to detect the limits in good time, so as to ensure it can independently

1990 • • • • 1995 • • • • 2000

1990
- *The BMW 7 Series becomes the first car to be offered with Xenon headlamps, using gas-discharge lamps (Bosch). This is initially only available for the low beams.*

1992
- *The "Contrôle Technique" vehicle inspection is launched in France. New vehicles need to be inspected for the first time after four years, and then every two years thereafter.*

- *Traction control for motorbikes (Honda Pan European)*

1994
- *A navigation system is fitted as standard for the first time (BMW 7 Series).*

1995
- *Robert Bosch GmbH and Mercedes-Benz introduce the Electronic Stability Program ESP – a braking-based dynamic driver assistance system.*
- *"Vision Zero" is applied to road traffic for the first time in Sweden.*

1996
- *First motorbike to feature a combined braking system with anti-lock braking and traction control (Honda ST 1100)*

1997
- *Euro NCAP publishes crash test results for the first time and introduces pedestrian safety ratings that explicitly include children's safety.*

1998
- *First German car with adaptive cruise control (Mercedes-Benz S-Class).*

1999
- *Krone launches the Safeliner, a semitrailer with effective all-round underride guards, developed by Karl-Heinz Schimmelpfennig.*

2000
- *With the C1, BMW launches the world's first two-wheeled vehicle to protect its rider with an enclosure (aluminum space frame technology) and seat belt in the event of an accident. This means the C1 can be ridden without a helmet.*

2001
- *A multi-colored head-up display is used for the first time in the Chevrolet Corvette.*
- *Xenon high beams in what are known as bi-xenon headlamps are used for the first time in the Mercedes CL. The same light source is used for both low and high beams.*
- *First series-produced vehicle to feature a lane guard assistant (Nissan Cima).*

2002
- *Mercedes introduces the predictive occupant protection system PRE-SAFE in its S-Class.*

Vision Zero Means Thinking Holistically About People and Technology Working as One

Manfred Wirsch
President of the German Road Safety Council (DVR)

Technological developments have the potential to drive progress in our society and reduce or even entirely prevent human error. Driver assistance systems and automation can also play an important role in helping to make Vision Zero a reality. However, we can't simply assume that this will be the case. Before new technologies are launched, they need to be comprehensively tested and critically assessed to ensure that they live up to their promises and can be relied upon as dependable aids for people out on the roads.

Human error is responsible for more than 90 percent of accidents involving personal injury, making it the most common cause of such incidents. Many traffic accidents can be avoided through the use of driver assistance systems, such as automated emergency braking systems, adaptive cruise control, lane guard assistants, fatigue warning systems, or Intelligent Speed Assist. Anyone who has been in a truck equipped with an automated emergency braking system and has seen how it brakes the vehicle to a complete standstill, cannot fail to be impressed by the huge benefits of this technology. No human being is able to respond and stop the vehicle so quickly.

However, there are also significant structural risks inherent in having vehicles become more automated and in the notion of machines taking over more and more of the driving tasks, leaving humans to simply monitor the system and intervene to a limited extent. After all, if a vehicle user is not watching the road because they are preoccupied with a non-driving activity, it is very difficult – if not overwhelming – for them to suddenly have to switch back to driving and try to immerse themselves in the complexities of what is happening on the road.

For this reason, the DVR is calling for all driving-related psychological aspects to be considered in a holistic approach when it comes to the requirements for driving automated vehicles. This applies in particular to the design of the human–machine interface, and to aspects associated with the user's competencies such as driving training, testing, further training, and instruction. For example, the DVR is campaigning to make it mandatory for driving school vehicles to be fitted with certain driver assistance systems, so that learner drivers at least know that they exist and can learn about their potential to prevent accidents.

Although technical defects or inadequate servicing work on vehicles are only responsible for around one percent of accidents involving personal injury, we must remember that vehicles do not remain in a new condition for long and that driver assistance systems, including their sensors, will gradually become more susceptible to faults. So, in the context of modern vehicle inspection regulations, we must remember that humans must not simply trust intelligent assistance systems blindly, and instead always need to take a critical look and assure themselves of their reliability.

2005 · 2010

2003

- *BMW becomes the first European car manufacturer to bring the head-up display to market in its 5 and 6 Series models.*
- *On November 17, the European Parliament and the Council of the European Union enact Directive 2003/102/EC regarding the protection of pedestrians and other vulnerable road users. This legislation stipulates that a series of component impact tests must be conducted for the front end of passenger cars in order to prove that certain biomechanical limit values are not exceeded in the event of an impact. From October 2005, newly certified vehicle models need to pass such tests.*
- *The "Euskirchen" traffic barrier with underrun protection is approved, providing better protection for motorcyclists in the event of an impact. Building on this design, DEKRA later develops the "Euskirchen Plus" system on behalf of the German Federal Highway Research Institute (BASt). It further improves the level of protection, including for the occupants of cars in the event of a high-speed impact.*

2004

- *The EU Commission launches the "European Road Safety Charter." Its declared goal is to halve the number of traffic fatalities by 2010 compared with 2001 figures.*

2006

- *First series-produced vehicle with an active hood to protect pedestrians (Jaguar XK)*
- *Daimler presents the "Safety Truck" equipped with adaptive cruise control, lane keeping assistant, (cornering) stability control, and the Active Brake Assist (ABA) automated emergency braking system.*
- *Motorbike airbag (Honda Gold Wing)*

2007

- *The first DARPA Urban Challenge is held in the USA – an international competition for unmanned vehicles in an urban environment.*

2009

- *Newly registered commercial vehicles in the EU must be equipped with retroreflective contour markings.*
- *First brake-by-wire system with electronic brake force control (Honda CBR 600/1000)*

2010

- *Guidelines on policies regarding EU road safety 2011–2020*

2011

- *From November 1, 2014, the EU makes it mandatory to install Electronic Vehicle Stability Control systems (EVSC), known as ESP or ESC, for all new road vehicles (from passenger cars through to heavy coaches and trucks as well as their trailer vehicles). For vehicle models with new type approval, this requirement already comes into force from November 1, 2011.*
- *The United Nations declares that 2011–2020 will be the "Decade of Action for Road Safety."*
- *From February onward, daytime driving lights become mandatory for all new passenger cars and trucks in the EU.*

2012

- *Volvo introduces the first pedestrian airbag in the V40.*
- *From 2012, daytime driving lights are also prescribed in the EU for newly introduced truck models (N2/3).*

Ensuring Safety in an Era of Transformation for Cars

Richard Damm
President of the German Federal Motor Transport Authority (KBA) and Chair of the UNECE Working Party onAutomated/Autonomous and Connected Vehicles (WP.29/GRVA)

We find ourselves in an era of transformation when it comes to cars. Automation in motor vehicles is gaining pace, and vehicle users lie at the heart of these developments. This means that in future, drivers will no longer need to focus solely on the actual task of driving, as new systems will enable them to carry out other tasks as well.

Key to this development is ensuring the safety of the systems being used. They come in different forms, but are all designed to take over driving tasks from the drivers as either assistance or automated driving systems. Their primary purpose must be to ensure safety, because safety on the road must always be the paramount consideration for everyone concerned. To achieve this, clearly defined goals for the coming decades have been set at both German and European level, meaning other applications or use cases arising from the increasing use of automation in vehicles are only allowed to be included if they are consistent with this framework. The key issue here is not whether the system concerned is an assistance system (Level 2), highly automated system (Level 3), or fully automated system (Level 4). People's trust in the technology depends directly on how safe it is.

If we look at the development of the car from its infancy to today, we can see how safety and new technologies are not mutually exclusive. State-of-the-art assistance systems designed to help with driving tasks are now part and parcel of many new vehicles, and will increasingly become mandatory equipment in the coming years. The growing use of software in vehicles has now opened the door to "functions on demand" – previously these were too complex and difficult to implement. These functions offer additional services for users, designed to meet their specific needs and requirements. Individual mobility offerings are set to play a major role in this, both now and in the future. The number of vehicles in Germany is increasing, with passenger cars reaching a figure of around 48.8 million in 2022.

It is becoming more and more clear that the entire field of motor vehicle technology is currently being transformed from top to toe. In future, this technology will be intrinsically linked with the issues of sustainability and automation, right across the board. More than ever, we will need to give new technologies and innovations a chance to succeed, because the possibilities are enormous (just think of new mobility offerings, for instance) and the resulting benefits could help improve road safety as well. For this to work, all stakeholders will need to live up to their responsibilities.

2015 2020

2013

- *For new trucks and coaches, Lane Departure Warning Systems (LDWS) and Advanced Emergency Braking Systems (AEBS) become mandatory in the EU – initially only for commercial vehicles with air brakes and a permissible gross weight of > 8 t per air-sprung rear axle; from November 1, 2016 they become mandatory for all new commercial vehicles, and from November 1, 2018 they become mandatory for all new commercial vehicles with a permissible gross weight > 3.5 t.*

2014

- *In May, Internet company Google presents a prototype of a self-driving car.*

- *From November onward, ESP becomes mandatory for all new vehicles in the EU.*
- *Daimler AG presents the "Mercedes-Benz Future Truck 2025." Thanks to the intelligent "Highway Pilot" system, the truck is able to drive in automated mode at freeway speeds of up to 85 km/h.*

2015

- *From September onward, a section of the A9 freeway in Germany becomes an official test track for automated and connected driving.*
- *From November 1, newly registered heavy goods vehicles (with a permissible gross weight > 3.5 t) and buses with more than eight seats (other than the driver's seat) in the EU must be equipped with an Advanced Emergency Braking System (AEBS) and Lane Departure Warning System (LDWS). For newly type-approved vehicles, this equipment already became mandatory on November 1, 2013.*

2017

- *On June 21, the "Act on Automated Driving" enters into force in Germany. It permits automated systems (Level 3) to take over driving duties if certain prerequisites have been met.*

2018

- *With its "Europe on the Move" package, the EU sets itself the target of halving the number of traffic fatalities and seriously injured people on Europe's roads in the period 2021 through 2030.*

2019

- *Regulation (EU) 2019/2144 (the "General Safety Regulation") is adopted, meaning improved safety for vulnerable road users and the use of driver assistance systems gradually become part of type approval regulations.*

2020

- *On July 28, the "Act on Autonomous Driving" enters into force in Germany. This enables autonomous motor vehicles (Level 4) to operate normally on public roads within defined Operational Design Domains.*
- *The United Nations declares that 2021–2030 will be the "Second Decade of Action for Road Safety."*

2022

- *From July 6, 2022, all new models of vehicles in the EU must be equipped with an Intelligent Speed Assistant, fatigue warning system, automated emergency braking system, emergency lane guard assistant, reversing assistant, and tire pressure monitoring system (this then applies to all new vehicles from July 2024).*

adopt a safe state in compliance with the regulations and prevent damage by parking at the side of the road or on a shoulder. In effect, it should no longer be possible to hold occupants liable for any violations or damage caused when the vehicle is in fully automated mode. Vehicle driving at Level 4 is a much broader concept than Level 3 and it contains only a few specifically defined exclusion criteria.

At the highest level, which is autonomous or driverless driving (Level 5), all restrictions are lifted. There are only passengers in the vehicle, none of whom have any driving responsibilities, while, at Levels 3 and 4 the users in the vehicle are only relieved of their driving duties temporarily. At Level 5, the occupants never have to drive the vehicle. The vehicle could also make a trip without any occupants at all as the car's technology is able to handle all traffic situations completely by itself. The user simply selects their destination and can then be "chauffeured" there. They are just a passenger, like they would be if they were traveling by train or plane. At this level, the person behind the wheel is completely "out of the loop" and is no longer part of the human–machine control concept.

Automated Driving Is a Complex Matter

Just what challenges manufacturers and programmers are facing in their efforts to get to grips with automated driving from Level 3 onward, is illustrated by the Operational Design Domain, for example. The ODD is defined by the manufacturer and is intended to set out the operating parameters, covering at minimum things such as rainfall, time of day, visibility, road markings, country, and V2X dependencies. In addition, automated driving systems are subject to a whole host of crucial safety requirements, including safely driving the vehicle according to the rules of the road, safely interacting with users via status notifications, handling safety-critical driving situations, promoting a safe vehicle condition by notifying the user about upcoming servicing work, and managing faults caused by system errors or unauthorized system access.

The system also needs to be able to process different scenarios, made up of nominal scenarios (e.g., adjusting the vehicle's speed and its distance from the vehicle in front), critical scenarios (such as if another slower-moving vehicle cuts in in front and brakes), and fault scenarios covering things like the failure of a sensor. Other key criteria include the type of operation or intervention in the system, and the user's position while the vehicle is being driven. Likewise, the system needs to know how many other road users are located around the vehicle, where they are, what type of road user they are, and how they are moving, in order to be able to respond accordingly.

In a nutshell, the higher up the levels you go, the more driving duties are taken over by the technical system and the less the person is involved in the driving process. At the first three levels (Level 0 to Level 2), the assistants and systems support or supplement the driver, who still carries out the majority of the driving tasks and remains responsible. At the higher levels (from Level 3 onward), control of the vehicle is permanently delegated either in part or in full to the vehicle system. However, this opens the door to new potential risks that were previously unknown to us.

Six Aspects for Classifying a Vehicle With Automated Driving Functions

	Aspect	Details	Example – Mercedes-Benz Drive Pilot
1	**Where can the vehicle drive when its automated system is active?**	• On private premises • Within a strictly local area • On a predetermined route • On a specific category of road in a country, etc.	Freeways and similar roads
2	**Which traffic situation(s) can the automated system handle?**	• Driving in a lane • Driving in one direction with a change of lane • Traffic at intersections, etc.	Driving in a lane
3	**Which parameters apply in order to operate the automated system?**	• Daylight • Dry conditions • Speed limit • Temperature • only if connected	Daylight, temperature of at least 4 °C, maximum of 60 km/h, no tunnels
4	**Can the automated system (reliably) drive by itself, does it need to be monitored, or is there a driver as a fallback?**	• Laboratory operations (with development engineer inside the vehicle) • Safety driver in the vehicle • Vehicle monitored from a control center • Fallback ready user, etc.	Fallback ready user (driver is ready in 10 seconds)
5	**For which vehicle category is the automated system intended?**	• Passenger cars (M1) without/with a trailer • Heavy-duty commercial vehicles (N3) without/ with a trailer, etc.	Passenger cars
6	**Who can use/ operate a vehicle with a built-in automated system?**	• Manufacturer/developer • Vehicle fleet operators • Private individuals	Private individuals
	Which SAE level does the system correspond to?	1, 2, 3, 4, or 5 Level 1 and 2 are driver assistance systems (DAS) and not automated driving systems (ADS)	Level 3

Making the Most of Ways to Prevent Accidents

Distractions, fatigue, overwhelming situations – the list of common causes of traffic accidents goes on and on. Conversely, it could, however, also be distilled down to one common denominator: The human factor. If we are to believe police traffic accident reports, almost all accidents can be attributed to human behavior (or rather human error). Defective infrastructure or shortcomings in technology are only very rarely mentioned as being the cause, or one of the causes. Many people therefore still believe that the best way to prevent accidents is for vehicles themselves to take over as many driving tasks as possible.

Modern assistance systems are the foundation for the increasing degree of automation that we are seeing nowadays on our roads. Systems that automatically keep the vehicle in lane or accelerate and brake the vehicle based on the surrounding traffic are now fitted in many vehicles, as are automatic emergency braking systems. These systems offer the potential to minimize the consequences of accidents, and even prevent the accidents from occurring in the first place. Many countries around the world have declared that they want to achieve "Vision Zero" by 2050 – i.e., achieve safe road traffic where accidents cause no fatalities or severe injuries. However, if we look at how things are developing in the EU in this respect, it becomes clear that we still have a lot to do. On the one hand, the number of traffic fatalities reduced by almost 63.5 percent from 2001 to 2020, from 51,400 down to 18,800. On the other, the figures have plateaued since around 2012, and the historic low in 2020 can be attributed to the effects of the coronavirus pandemic. The figures have been rising again since then – to 19,900 in 2021 and 22,600 in 2022 **(Figure 2).** The percentage drop compared against 2001 therefore becomes less impressive, shrinking to just 56 percent. According to World Health Organization estimates, the number of traffic fatalities worldwide is currently around 1.3 million each year.

Regardless of which assistance systems are installed in a vehicle, drivers currently still need to devote their full attention to what is happening on the road and must intervene, i.e., override, the systems if necessary. Despite this, many road users are tempted to do other tasks not related

Technology Should Make Driving Safer and Easier

Mark Chung
Executive Vice President Roadway Practice
National Safety Council (NSC)

The task of driving is highly complex; it is one that places intense demands on the driver to integrate motor control of the vehicle against an ever-changing environment. Adding to the complexity are distractions that arise as the driver attempts to complete various tasks related to driving, such as adjusting navigational inputs or using touchscreen-based infotainment systems. It is no surprise that distracted driving and the associated safety risks are on the rise. Simply put, the task of driving appears to be getting more complex and increasingly dangerous.

In the United States, our roadways have become significantly more deadly during the last two decades. In 2021, the U.S. hit a 16-year high for fatalities, including the deaths of nearly 7,500 vulnerable road users (VRUs) – the most pedestrian deaths in a single year in four decades. We must reverse this deadly trend.

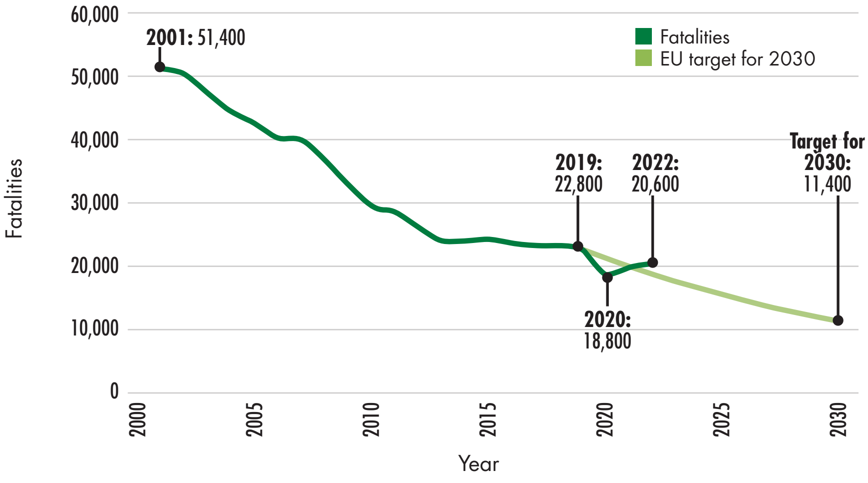
Advanced Driver Assistance Systems (ADAS) hold great promise in sensing the driver's environment to assist them in controlling the vehicle in a safer manner. ADAS features, such as Automatic Emergency Braking, have proven to deliver safety benefits to VRUs, but studies have shown that many U.S. drivers deactivate ADAS features because they don't trust their capabilities. Worse yet, there are also those who over-rely on these features due to misunderstanding their capabilities. Adding to all this confusion are OEMs who view ADAS features as brand differentiators and deploy overly-creative ADAS marketing nomenclature.
In short, ADAS should make driving safer and less complex. To date, we are seeing quite the opposite.

There are solutions to help correctly unleash the technological power of ADAS and realize its safety potential. First, OEMs need to harmonize ADAS nomenclature. For instance, the National Safety Council has worked with AAA, Consumer Reports, JD Power and SAE International in producing the "Clearing the Confusion" guidance document that recommends a common naming system for ADAS features. Second, consumers need to be better educated about each ADAS feature's capability. For this, NSC has developed a consumer-facing website, www.mycardoeswhat.org, which provides straightforward, consumer-friendly information on what ADAS features can and can't do.

In sum, we should encourage the development and deployment of advanced safety technologies. But deployment itself isn't enough to protect all roadway users, including VRUs, if the utilization of ADAS features is difficult for drivers. Technology should make the task of driving safer and easier.

2

Trend for Traffic Fatality Numbers in the EU



Source: CARE (EU Database on Road Crashes)

to driving instead, particularly if the assistance systems are reliable and work very well, such as lane guard assistants or cruise control. Multiple serious accidents have already occurred due to drivers misunderstanding a system's design in this way. These types of systems can also become a critical risk if the driver develops health problems which are not recognized by the system.

A prime example of this is an accident that occurred in the town of Aschaffenburg, Germany, in 2012. A driver of a car suffered a stroke at the wheel, rendering him incapable of driving the vehicle. However, the vehicle was kept in lane by its lane guard assistant and maintained its previous high speed as it entered the town, whereupon it collided with and killed several pedestrians. Without these systems, the vehicle would have come off the road before it reached the entrance to the town. There is no question that the potential benefits of such systems far outweigh their risks, including in terms of road safety, as long as the system's limits are openly discussed and the users of the systems exercise all necessary caution. However, it is also repeatedly the case that buyers have certain expectations of the system (based on the manufacturer's performance specifications or the names of the systems) which the system is unable to fulfill. While the system's limitations may be set out in the vehicle's operating manual, meaning the manufacturer is covered from a legal perspective, it is the bold advertising claims that stay in customers' minds.

Level 3 systems also need to be viewed with caution. With this degree of automation, drivers are allowed to divert their attention to other tasks not related to driving under certain circumstances. If the system reaches its limits, the "drivers" are prompted to take control of the wheel again. There are often discussions about the length of time required to pre-warn the driver in this case; they need this period of time to familiarize themselves with the traffic situation again and respond correctly. This responsibility places high demands on drivers, particularly if complex situations suddenly arise. A further issue is that as vehicles become more and more automated, drivers' day-to-day exposure to driving reduces. However, it is pre-

Interaction Between Humans and Machines

Florence Guillaume
Interministerial Delegate at the Directorate for Road Traffic Safety

According to the current consensus, infrastructure, users, and means of transport are the three cornerstones of every global, systematic approach taken to boost road safety. Within this triad, humans and machines have always been intertwined with one another in a very special way.

When you look at the history of mobility, all the way from draft animals through to mechanical drive systems, the common thread running through it all is people's desire to master the technology available to them. Whether it was taming horses or controlling the mechanical components in vehicles, it was essentially always about mastering something that is complex and, once in motion, sometimes unpredictable and potentially also dangerous.

Ever since it was introduced on December 31, 1922, a driver's license has been the main way that people can prove they are capable of controlling a vehicle. This principle is anchored in the German Road Traffic Act (*Straßenverkehrsordnung*) itself, in almost philosophical wording (translated freely here): "The vehicle driver must always be ready and able to execute all driving maneuvers incumbent on them confidently and without delay" (Art. R.412-6).

As a result, avoiding hazards in road traffic was all about controlling the risk arising from the vehicle to the greatest possible extent, particularly at the start of the automotive age. Things have changed since then, and vehicles themselves are increasingly playing an active role in ensuring the safety of their driver and passengers. Whether it is seat belts, ABS, or airbags, technical advancements are the main reason why fewer and fewer people are killed on the road. Our means of transport – and first and foremost we mean the motor vehicle here – has become a full-throated ally when it comes to ensuring our safety.

More and more assistance systems are coming onto the market, and they are becoming increasingly widespread, ensuring that this transformation is not only set to continue, it will in fact gain pace. It is not yet clear where this trend will ultimately take us. The Directorate for Road Traffic Safety is supporting numerous studies and research projects looking at assistance systems and the new challenges that will face us as a result. The focus is on investigating the conditions under which humans and machines can work together in a new way, and on gaining a better overarching understanding of how they interact with road users. To ensure that the systems are fully effective, drivers must be familiar with and master every detail of how they work. This is the final step in closing the loop.

Even if I do not believe in the illusion of a technological future where machines and their artificial intelligence could by themselves eliminate every single risk relating to road traffic, I do firmly believe that technical progress, ongoing improvements in assistance systems, and full acceptance of them by users give us a great opportunity to more effectively prevent traffic accidents.

cisely this experience that makes all the difference in critical driving situations where the system cannot help. This is a problem for which a truly satisfactory solution does not exist yet.

Initial findings on accidents involving highly automated vehicles in the USA have now been published. These vehicles are traveling on public roads in certain states as part of various modeling and research projects. There is always someone in the vehicles who stands ready to step in at any time. Comprehensive data on accidents involving highly automated vehicles is being recorded, particularly in the state of California. A study published by the University of Belgrade in 2019 compared the accident statistics for highly automated vehicles with those for conventionally driven vehicles at the same accident spots. The results showed that there was a change in the type of accidents that occurred. The number of broadside collisions and accidents involving pedestrians fell, but the number of rear-end collisions increased, whereby it was the conventional vehicles that were running into the highly automated vehicles.

This issue is relevant given that mixed traffic comprising both types of vehicle will be on our roads for a long time to come. Conventional drivers need to get used to the different acceleration and braking response exhibited by highly automated vehicles. This also requires them to be able to recognize that a vehicle is an automated one. The database did not contain any data about accidents between two highly automated vehicles, or about fatal accidents. Overall, the collisions tended to occur at low speeds.

In order to obtain more detailed information about accidents involving automated and highly automated vehicles, the American transport safety authority NHTSA obligated all operators of these types of vehicle to submit specific accident reports. During the period June 29, 2021 through May 15, 2022, 130 reports about accidents involving at least one vehicle from Levels 3 to 5 were received. The NHTSA subsequently analyzed the results and also came to the conclusion that the accidents were relatively minor on the whole. Only one accident resulted in severe injuries, three resulted in moderate injuries, and 12 resulted in minor injuries. Passenger cars, SUVs, vans, and pick-up trucks were usually the other party involved in the accident, accounting for 78 percent of cases. In seven cases there was a collision with a cyclist, and there were two cases each of collisions with motorbikes and e-scooters. In these cases too, collisions resulting in damage to the rear of the highly automated vehicle were significantly over-represented.

Level 3 systems also need to be viewed with caution

In the same period, 392 reports were received about accidents involving Level 2 vehicles, where the driver is fundamentally still responsible for driving. However, these data records contained a large number of unknown parameters, particularly regarding the other party involved in the accident and the most serious injuries. It was also not possible to determine which exact systems were fitted to the vehicles or whether they were even relevant to the circumstances of the accident. In contrast, it was interesting to note that in many cases – 88 of 246 – where it was clear who the other party involved in the collision was, it concerned a collision with a stationary object. Two collisions with emergency response vehicles were also noted. There were only three cases in total of collisions with cyclists or pedestrians, meaning they were very rare occurrences, even for vehi-

Having a mix of automated and conventional vehicles on the roads, as in the USA, provides an excellent basis for researching how we can further optimize road safety.

cles with this degree of automation. However, when considering these statistics, we must not forget that there are big regional differences in the role that these road user groups play in the modal split and in how they interact with one another, and that differing criteria also apply for classifying an incident that needs to be reported. In contrast to vehicles with a higher automation level, the main area of damage in this case was on the front of the vehicle.

Previous findings have shown that vehicles which are automated to a high degree offer the potential to prevent accidents completely or mitigate their consequences. Nevertheless, a high risk of accidents still remains if vehicles equipped with Level 2 systems are used improperly because the driver fails to adequately monitor the traffic situation. There are also new risks to consider, due to the fact that our roads will in future accommodate a mix of both highly automated and conventionally controlled vehicles. It would be wrong to simply assume that a high degree of automation will, in and of itself, enable accident statistics to fall toward zero and completely eliminate "the human factor" as a cause of accidents. As long as our roads have highly automated vehicles interacting with the forms of mobility that people control, there will also be accidents.

This applies in particular to vulnerable road users such as pedestrians or cyclists. Whereas motor vehicles with four or more wheels protect their users in the run-up to and during a collision as well as in critical traffic situations by deploying a wide range of active and passive safety measures, vulnerable road users traveling by bike, e-scooter, or on foot are less well protected. New technologies such as sophisticated electric drives with powerful batteries are now aiming to correct this imbalance, as they lay the groundwork for protection and safety systems for such road users, e.g., ABS for cyclists.

However, these technical enhancements also entail new risks, as people will travel at higher speeds and more vulnerable user groups such as senior citizens will use their bikes more often. Additionally, while electric pedaling assistance will enable people to transport larger loads or several children at a time, this will also result in ever-longer, wider, and heavier bike models. As such, the trend toward bigger and heavier vehicles that we have already seen for motor vehicles is set to continue for bikes as well. Our infrastructure needs to be changed to accommodate these trends, but the modifications being made cannot keep pace with developments. Furthermore, an analysis of the International Road Traffic and Accident Database IRTAD from the OECD's International Transport Forum showed that there are notable differences in the trend in accident statistics around the globe.

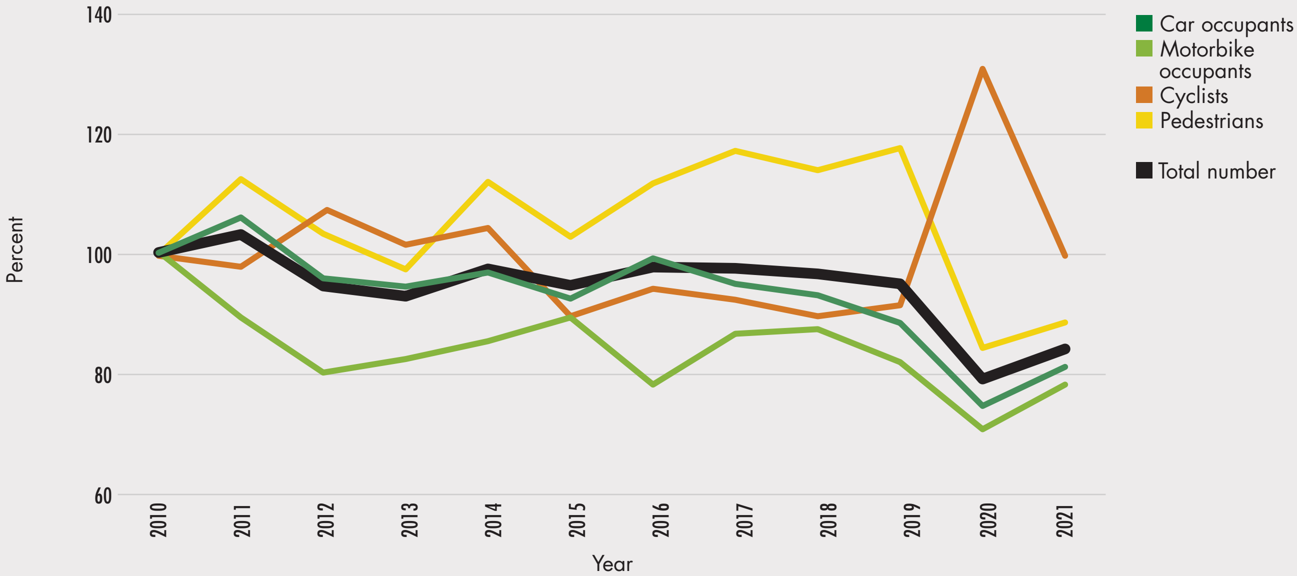
Vulnerable road users such as cyclists always end up worse off in a collision with a motor vehicle.

Global Differences in the Trend in Accident Figures

For example, in the United Kingdom (comprising Great Britain and Northern Ireland), a total of 1,608 people died in a traffic accident in 2021 **(Figure 3).** This is 297 fewer than in 2010, which registered 1,905 fatalities (a drop of 15.6 percent). Until 2019, there was a moderate reduction in the number of fatalities across all types of road user considered in the analysis, falling to 82 to 92 percent of the original figure. However, pedestrians were an exception to this, as their figures increased almost continuously to 117 percent in 2019. In 2020, the year of the coronavirus, the figures for cars and motorized two-wheelers fell significantly to 75 percent and 71 percent of 2010 levels respectively. Reflecting the falls recorded for cars, the number of all fatalities also fell to 80 percent of the original figure. There was a very clear fall in the number of fatally injured pedestrians, with the figure for 2020 falling to 85 percent of the reference value from 2010. When compared against 2019, the drop was 32 percentage points. At the same time, the number of cyclists killed on the road exploded – rising in absolute terms from 102 in 2019 to 145, equating to 131 percent compared against 2010. In 2021, a year which was still heavily impacted by the pandemic, there was an encouraging drop back down to 2010 levels in the figures for cyclists. In contrast, the figures for the other types of road user analyzed increased again, as did the absolute figures, meaning 2010 levels were not reached for these. However, although there was an enormous rise in the number of cyclists killed in 2020, we must remember that the British Department of Transport stated that the amount of bicycle traffic also increased by 46 percent in 2020 compared against 2019 levels. When considered in relation to a billion miles covered by bicycle, the Department of Transport reports an average of 28 cyclists killed in 2020, compared against 29 for 2019. The change is therefore marginal, but if we compare it against 2004, for example, which registered 52 cyclists killed per billion miles covered, it still represents a major improvement.

3

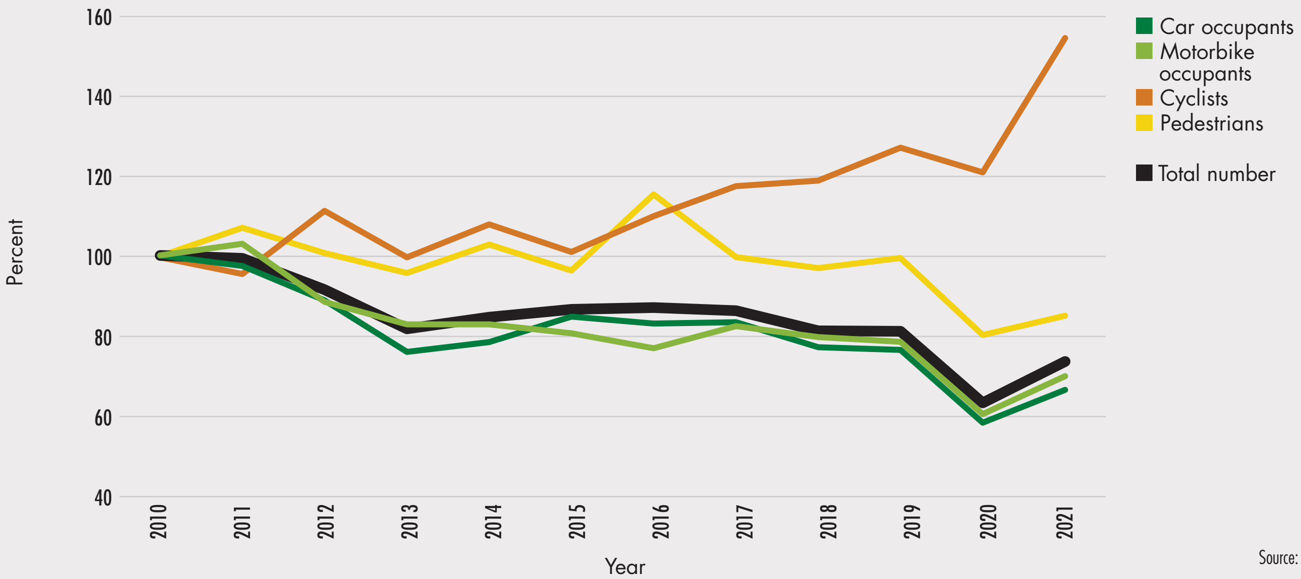
Trend for Traffic Fatality Numbers in the United Kingdom



Source: IRTAD

4

Trend for Traffic Fatality Numbers in France



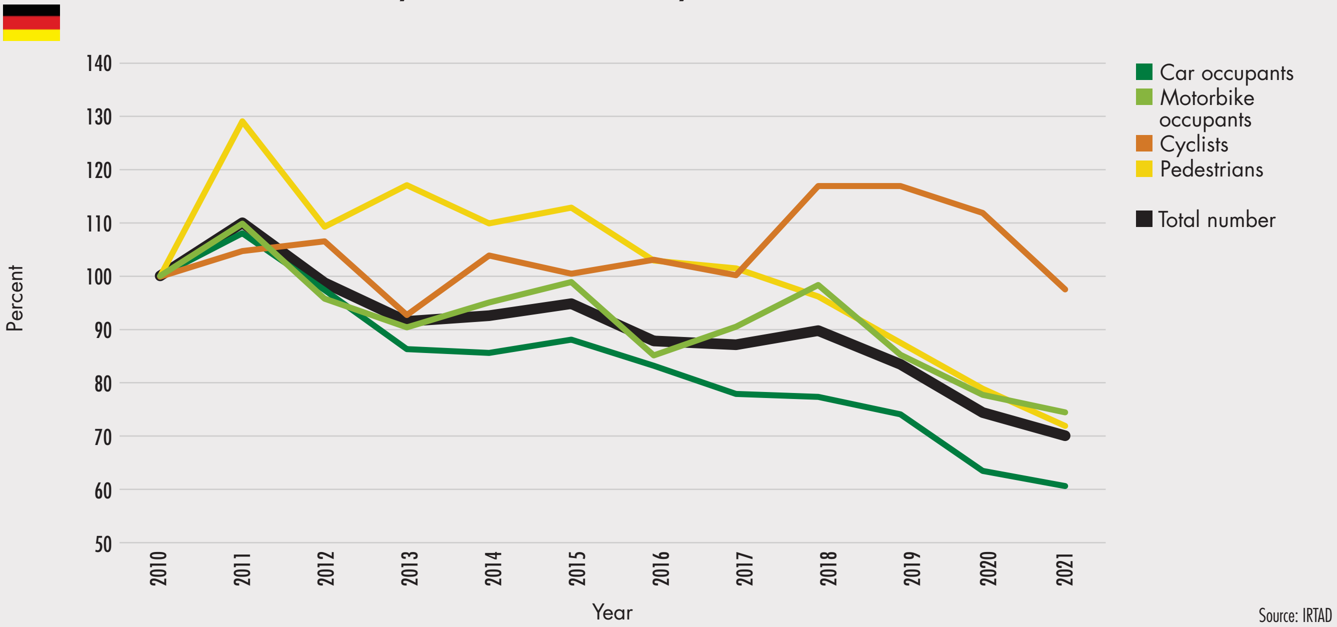
Source: IRTAD

In France, there was a significant drop in the number of fatalities in road traffic between 2010 and 2013 **(Figure 4)**, falling from 3,992 to 3,268. However, if we look at the data more closely, we can see that a positive change was only recorded for users of motor vehicles and motorized two-wheelers; the figures for cyclists and pedestrians remained at their original level. In the subsequent years up to 2019, the figures for all user groups plateaued at the level that had been reached. Only the figures for cyclists killed in an accident rose, to 127 percent of the original figure from 2010. As was seen in the United Kingdom, in the "coronavirus year" of 2020 there was a clear drop in the number of people killed in an accident. Only the figures for cyclists increased again. In 2021, France also registered higher figures for all types of road user analyzed, whereby the figures for cyclists rose disproportionately by almost 28 percentage points to 154 percent of 2010 levels. Cycling also boomed in France during the pandemic.

In Germany, the number of road users killed in an accident fell even more markedly than in France or the United Kingdom, dropping from 3,648 in 2010 to 2,562 in 2021, which is 70 percent of the original figure **(Figure 5)**. It is notable that even in 2021, Germany recorded lower figures for both the overall number and when considering all types of road user analyzed. However, according to preliminary information from the German Federal Statistical Office, there is a very clear

5

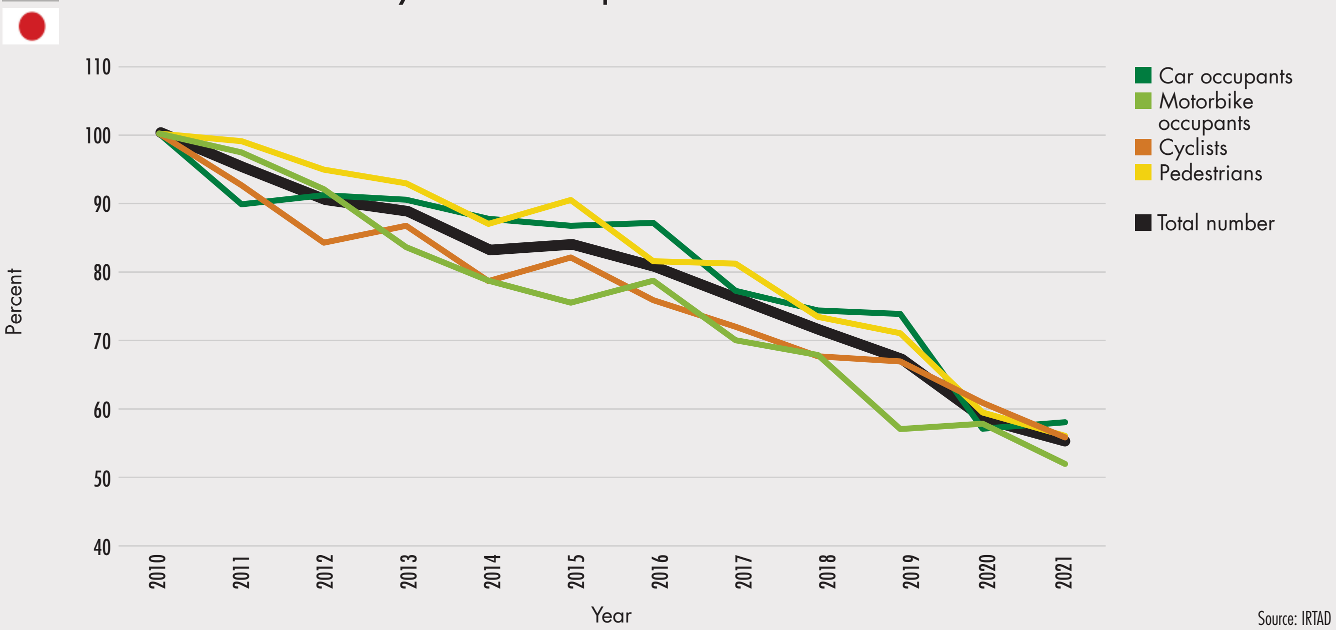
Trend for Traffic Fatality Numbers in Germany



Source: IRTAD

6

Trend for Traffic Fatality Numbers in Japan



Source: IRTAD

rise of around nine percent in 2022, with fatalities expected to reach 2,782. The number of cyclists killed remained constant until 2017, but in 2018 it increased by over 16 percent, which is due above all to the increasing use of pedelecs. This high figure was also recorded in 2019. The very strict coronavirus rules then facilitated a fall in 2020 and above all 2021, when a figure of 98 percent was achieved – just below the original figure from 2010. Here too, there was then a sharp rise in 2022 with 484 cyclists killed, well above 2010 levels again. Compared against 2021, the number of cyclists killed in Germany rose by around 26 percent, and the number of pedelec riders killed even increased by 55 percent (from 137 to 210).

Japan recorded impressively good figures, with a consistent, clear fall in the number of traffic fatalities across all types of road user analyzed **(Figure 6)**. Relative to 2010, the figure fell to 55 percent of the original figure by 2021. No particular coronavirus-related effects can be seen in the data. Japan's excellent success in this respect

Autonomous Vehicles in Brazil

Roberto Saldo
CEO of Tesla Brasil school - Development of projects with electric vehicles

One of them, perhaps the main one, is the increase in safety resulting from the monitoring systems embedded in the vehicle that guarantees management such as speed, braking, and emergency maneuvers independent of the driver's action, reducing the occurrence of accidents, personal injuries, and mortality in roads. It will change the way we see and understand mobility in Brazil and the world. This technology should mean that we do not have to worry about expensive vehicle insurance since there will be no more accidents.

Brazilian traffic is the fourth most violent on the American continent, according to WHO (World Health Organization) data. São Paulo is the state with the highest number of traffic deaths in the country, and drunk driving is the second leading cause.

Autonomous vehicles will eliminate human inaccuracies and traffic mistakes caused by inattention from tired drivers or those with other health problems. Automation offers a considerable decrease in the margin of error in driving, especially as the car's interaction with smart cities and environments increases.

As technology has gradually advanced in this line, the autonomous mode is already a reality and a path of no return. In Brazil, the difficulties in implementing a system like this would be enormous, but nothing that cannot and should be done. This is a fundamental change for our country as for the rest of the world, but here we will have some obstacles to be overcome as the infrastructure of telecommunications makes it difficult for vehicles to connect to the internet throughout the journey, and roads must be mapped and signposted so that the vehicle can read and interpret the streets, intersections, and the presence of other vehicles.

Another problem is the high cost of technology in the case of highly advanced, the package of equipment varies between US$ 65,000 and US$ 140,000, and this ends up being reflected in the price of the car and can be an even greater setback if the consumer does not is fully ready, and needs an adaptation time to have the confidence to acquire this option, while the change of ownership of the population's vehicles to sharing companies does not happen.

Our Brazilian legislation also does not seem prepared for autonomous cars at the "hands-on-the-wheel" level. Article 252 of the Brazilian Traffic Code (CTB) considers an average infraction "to drive the vehicle with only one hand, except when making regulatory arm signals, changing the vehicle's gear or activating vehicle equipment and accessories", for example.

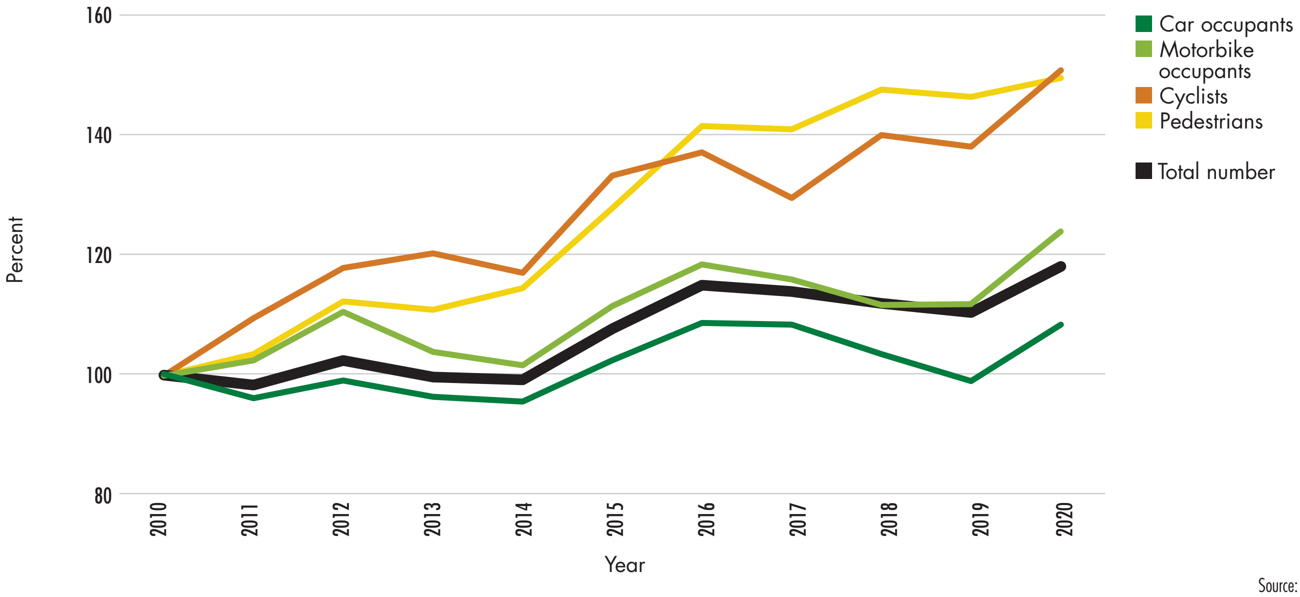
Not to mention the lack of legal bases for the operation of existing technologies in such vehicles (radars, cameras, sensors). We also remember here about artificial intelligence and the whole problem of liability in cases of accidents.

Changes are not always cheap, but if autonomous vehicles can save lives, they will justify the investment. I believe that much more than a technical issue, it is a moral issue, or we switch to this much safer technology now, or future generations will demand our attitude.

is to be commended, particularly in light of the fact that Japan has an aging population. There are many reasons for this positive trend: Targeted traffic safety programs, the fact that the vehicles on Japan's roads are predominantly small and highly suited to the infrastructure in major cities, the very limited public parking at the side of the road, a well developed and reliable public transport network, and strict traffic monitoring, to name but a few.

7

Trend for Traffic Fatality Numbers in the USA



Source: IRTAD

The figures from the USA show a very different picture. Between 2010 and 2020, the number of road users killed in an accident rose from 32,999 to 38,824 **(Figure 7)**, thereby increasing to 118 percent of the original figure. The figures for all types of road user analyzed rose, but the figures for pedestrians and cyclists increased disproportionately, to around 150 percent of the original figure in the period under review. It should be noted that both forms of mobility also became much more popular in the USA. 2019 recorded falls in the figures for all types of road user analyzed, but they were only very marginal. Another factor to consider for the US figures is that a large proportion of the vehicles on the roads are what are known as "light trucks," meaning large SUVs and pick-up trucks. They are not shown in the diagram.

Risk of Accidents Still Highest for Vulnerable Road Users

When considered as a whole, the comparison clearly shows that there are clear differences in the accident statistics despite the fact that the vehicles are fitted with comparable technology. These discrepancies are predominantly due to regional differences in the modal split (which means how traffic is managed across different forms of mobility), traffic rules, the pressure to take action in the event of violations, the quality of driver training, the condition and type of motor vehicles used and infrastructure, as

Our efforts to improve road safety must focus more intensively on pedestrians, cyclists, and the various forms of micromobility.

The Pros and Cons of Automated Driving: Does Comfort Equal Safety?

Dr. Hartmut Fischer

Specialist in forensic medicine, Brandenburg State Institute of Forensic Medicine, Potsdam

On December 29, 2022, a media report was published on German news website t-online.de stating that police had spotted what appeared to be a driver asleep at the wheel of a Tesla driving on the freeway. After a lot of difficulty, they managed to wake him. According to police reports, the vehicle traveled at a constant speed of 110 km/h and consistently maintained a precise distance to the patrol car in front. The man was sitting in the driver's seat with his eyes closed and did not have his hands on the steering wheel. When the police checked him, he is said to have exhibited "symptoms typical of drug use." According to the reports, officials discovered what is known as a steering wheel weight in the footwell. This device is attached to the steering wheel to trick the vehicle's safety system by making it think that the driver has their hands on the wheel.

Within the hierarchy of automated driving – ranging from Level 0 (where a human driver assumes full responsibility for driving) to Level 5 (where the vehicle drives itself without a driver and is autonomous) –, Teslas are considered to be semi-automated vehicles at Level 2. This means that the driver is still responsible for monitoring everything that is happening on the road. Assistance systems have the ability to take over functions such as automatic parking, lane keeping, general longitudinal guidance, acceleration, and braking. In recent years, there have been repeated reports in the media about incidents that had fatal consequences for those involved, because the person driving the vehicle failed to adequately monitor the traffic situation. They highlight the problem of overestimating what the vehicle can do and the temptation of making things easy for yourself behind the wheel.

Notwithstanding the current trend for automated systems in vehicles, in the fall of 2010 there was a head-on collision between a medium-sized vehicle and a small car coming the other way on a federal highway in Germany. The driver of the small car was only around 1.50 meters tall and obese, and was caught up in the collision through no fault of her own. The forces generated by the impact broke her cervical spine and snapped her brainstem, almost like she was decapitated internally. In addition to other moderate injuries, different seat belt marks were identified, one of which ran diagonally from top to bottom from the left side of her neck to her right side, and another running in a curve from both iliac crests almost to her belly button, upward instead of along her lower abdomen. In other words, the woman had slid out from under her lap belt and, in this specific case, had snapped her brainstem on the chest section of the three-point seat belt. This meant that she had not worn her seat belt correctly. The remaining injuries would presumably have been manageable with medical treatment, meaning her death could have been avoided.

If drivers wear thick or bulky clothing and combine this with a flat seated position and a reclined backrest (perhaps because they think it is comfortable or looks cool, or maybe simply because they are unaware of the dangers), this encourages what is known as "submarining," which is when a person slides out from under their lap belt in a head-on collision. Anyone who has ever watched a driver of a sports car knows that they always sit very upright in the vehicle. This is the only way to guarantee the safety provided by the seat belt in the event of a collision, and that the driver always has control of the steering wheel. Passengers in a vehicle are not responsible for driving it, so they often want to relax during the journey. When it comes to highly or fully automated vehicles, this then applies to all occupants in the vehicle, i.e., also the person at the wheel. Vehicle manufacturers are already responding by developing systems designed to prevent submarining by, for example, raising the thighs up in a kind of wedge shape, which keeps the pelvis away from an obstacle.

However, even the best technical solutions will not be of any use if people behave foolishly in ways that could not have been foreseen. Moreover, if automated systems are driving the vehicle, the issues that currently only affect the passengers will also apply to the person sitting in the driver's seat. Time and again we see that passengers not only recline their backrest, but also put their feet on the dashboard in an effort to make themselves comfortable.

In summary, technology can help us, but it does not absolve us of our responsibility. In order to maintain control of the vehicle at all times, drivers always need to know what is happening on the road. The person in charge of the vehicle should not succumb to the temptation of relying too much on the technology, making themselves too comfortable, and possibly even impairing their senses by taking even minimal amounts of a substance.

The 65+ age group is particularly at risk in road traffic.

well as societal differences. It is essential to look holistically at the situation rather than think in silos, and be willing to implement the changes required to make Vision Zero a reality. However, it is also becoming clear that there needs to be a focus on cyclists, pedestrians, and the different forms of micromobility in all areas, as these forms of mobility are set to become much more important.

As already reported in the previous DEKRA Road Safety Reports and in the PIN Flash Report 38 published by the European Transport Safety Council in 2020, we need to pay particular attention to urban environments and to people aged 65 and over. For example, around 70 percent of all fatal pedestrian accidents occur in urban areas. Almost half of all traffic fatalities in the EU fall into the 65+ age group, despite the fact that they "only" made up around 21 percent of the overall population in 2021. In around 99 percent of all traffic accidents recorded EU-wide involving a fatally injured pedestrian, motor vehicles were the other party involved in the accident. However, when considering these figures, we cannot overlook the fact that accidents involving just a pedestrian but nobody else (which are generally caused by obstacles in the infrastructure) are not counted as traffic accidents. For this reason, it is not possible to conclude from the traffic accident statistics that there is, in fact, an urgent need for accessible/barrier-free, safe, intact, and self-explanatory pedestrian infrastructure, because the corresponding data has not been recorded. This is a disastrous situation given our aging society.

If we look at the number of cyclists killed in an accident in the EU, we see that the 65+ age group makes up around 45 percent, which again is considerably more than their percentage of the overall population. Just over half of all cyclists killed died in built-up areas. As already set out in the Road Safety Report 2020, when it comes to Germany, the proportion of cyclists killed in an accident involving just them and nobody else is very high, with a figure of around 37 percent for built-up areas and just over 20 percent for non-built-up areas. Across the EU, the overall proportion of people killed

Over several phases, the General Safety Regulation prescribes the installation of different safety-related driver assistance systems in new motor vehicles

in an accident involving just them and nobody else is around 16 percent, although we should assume different levels of unrecorded cases in the various Member States. When looking at accidents involving two parties, in Germany it is passenger cars (around 31 percent in built-up areas and around 50 percent in non-built-up areas) and trucks (around 18 percent in built-up areas and around 13.5 percent in non-built-up areas) that tend to collide with cyclists. Looking at the overall EU-wide figures, in just over half of cases it is passenger cars who are the other party involved in the accident (53 percent), while trucks and vans make up around 20 percent.

Regardless of who is at fault, this shows that optimizing the infrastructure is not the only way to help protect vulnerable road users – the implementation of technical measures in motor vehicles also offers huge potential to improve the safety of these users. In particular, sensor systems that recognize pedestrians and cyclists are constantly improving, and they offer a great opportunity to significantly reduce the number of accidents between motor vehicles and vulnerable road users. European legislators have addressed this precise issue with EU Regulation 2019/2144 of the European Parliament and of the Council, the Vehicle General Safety Regulation, from 2019.

New vehicles coming onto the market must have systems such as intelligent speed assistance systems, automated emergency braking systems that recognize pedestrians and cyclists, reversing warning systems, and turning assistance systems as mandatory equipment. However, it will take some time before these systems become widespread in the vehicles on our roads. Nevertheless, cities and regions could restrict entry and only allow vehicles that are equipped with certain systems. For example, they could specify that only trucks with a turning assistant are allowed to be driven in certain areas or the entire city area.

Holistic Concepts Are Required More Urgently Than Ever

However positive the technical progress and possibilities may be, they must not lead to a situation where people rely solely on them for their safety. The experience gained from DEKRA's accident research clearly shows that most accidents between vulnerable road users and motorized traffic occur at intersections and crossings. To rectify this, we need to work on infrastructure design, monitoring, and road safety education for all road users. In and of itself, vehicle technology can only ever help to prevent some of the accidents. During the coronavirus pandemic, many countries took sections of road that were previously reserved for motorized traffic and re-purposed them for cyclists, such as in the form of pop-up bike lanes. This is a fundamentally positive development in larger cities and certainly welcome, as it creates safe spaces by physically separating protected and vulnerable road users.

However, many places unfortunately failed to draw up a holistic concept for how to implement it. In many cases bicycle paths were created on stretches of road between two intersections, but then abruptly stopped directly in front of a critical intersection. The same applies to the signage marking out the hastily created cycling infrastructure, as in some places it tended to confuse everyone rather than provide clarity. It is difficult to compile statistical analyses in this respect, as accident data from the years of the pandemic cannot meaningfully be compared with the data of the pre-pandemic years. It can be assumed, however, that the false sense of security created may even have encouraged accidents in a few places.

The Facts at a Glance

- Multiple serious accidents have already occurred because a driver assistance system was not reliable or drivers had misconceptions about where its limits lie.
- There are new accident risks to consider, due to the fact that our roads will in future accommodate a mix of both highly automated and conventionally controlled vehicles.
- Drivers of conventional vehicles need to get used to the different driving behavior of highly automated vehicles, which tends to be more defensive.
- Sensor systems that recognize pedestrians and cyclists are constantly improving, and they offer a great opportunity to significantly reduce the number of accidents between motor vehicles and vulnerable road users.
- Targeted traffic safety programs, in particular in countries like Japan, have led to a steady fall in the number of road users killed over the years. By contrast, the trend in the USA is very much going in the opposite direction.

Compelling Examples of Accidents in Detail

Combination of driver errors and technical faults

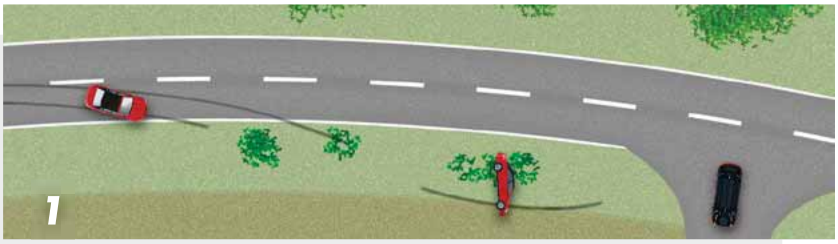
Car Skids Through a Bend

Sequence of events:

A convertible carrying three people became unstable at the end of a long left-hand bend despite good road conditions. The vehicle began to skid, came off the road on the right-hand side at the start of the next right-hand bend, and rolled onto a slope. This caused the car to overturn and come to a standstill on its roof. The front seat passenger was flung out of the vehicle.

Parties involved in the accident:

A car



1 Sketch of accident and final position
2 Car's approach to scene of accident, tire marks
3 Final position of car
4 Damage to car
5 Leaky shock absorbers, rear axle
6 Driver's seat belt

Consequences/injuries:

One passenger was hurled out of the vehicle and fatally injured, and the driver and the child on the back seat were jammed in and severely injured.

Cause/problem:

During the technical inspection, significant faults were discovered in the vehicle's rear shock absorbers (leaky) and tires (low pressure, old age). If the car had driven round the illustrated set of bends at too high a speed, even small movements in the body of the vehicle or disturbances from the road surface would have led to reduced vertical wheel forces and lower transferable cornering forces and caused the vehicle to become unstable. The driver reacted with too heavy a steering movement, which caused the vehicle to start skidding.

Prevention measures, mitigation of consequences/ strategy for road safety measures:

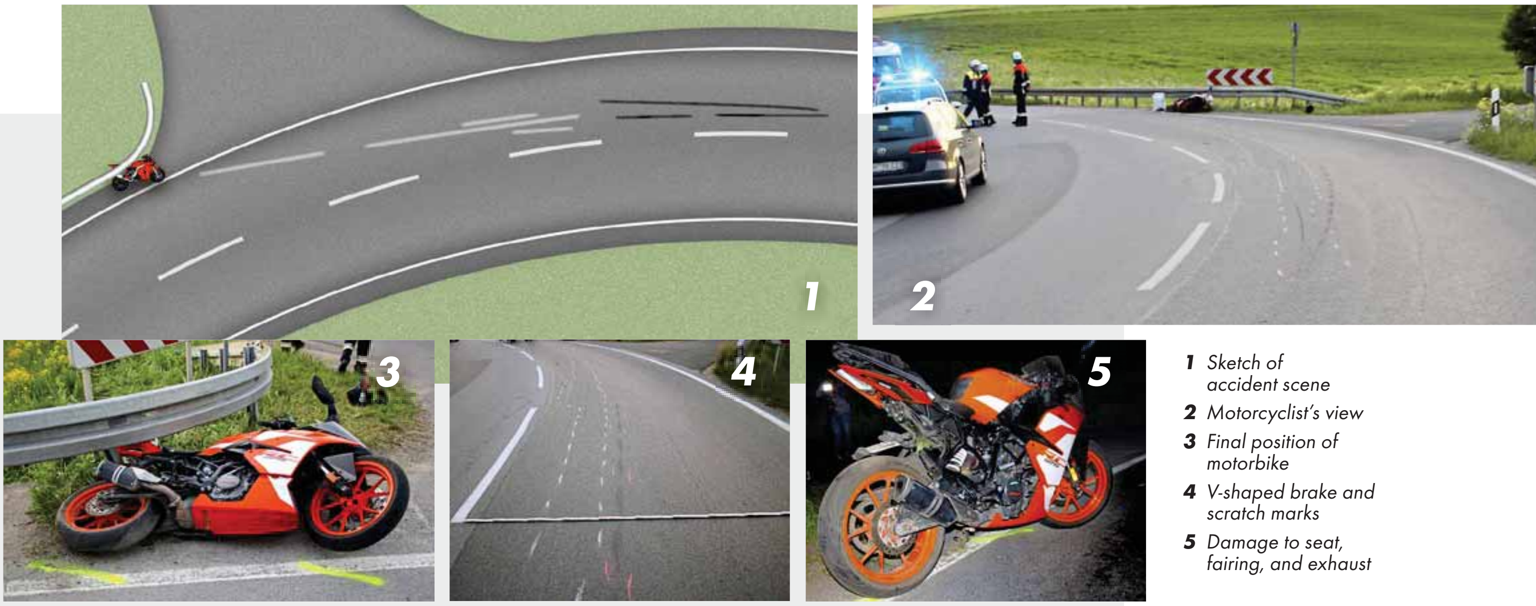
Despite keeping to the local speed limit, the driver's chosen speed was too high for the technical condition of the vehicle. The driver's over-steering reaction ended up causing the vehicle to skid off the road.

Particularly in situations such as this where high loads are placed on the driving dynamics, a mechanically perfect vehicle condition would have helped to prevent the vehicle from becoming unstable. If the driver had reacted correctly, e.g., in the manner taught in driver safety training courses, it would have reduced the likelihood of the car skidding. In a more modern vehicle, the ESP (Electronic Stability Program) would have probably been able to prevent the initial unstable vehicle state despite the technical faults.

Even today, wearing a seat belt is still a crucial, life-saving decision! Had the front seat passenger been wearing her seat belt properly, she would not have been flung from the car and the risk of sustaining fatal injuries would have been significantly lower.

Lack of motorcycling experience

Light Motorcycle Crashes in a Bend



1 *Sketch of accident scene*
2 *Motorcyclist's view*
3 *Final position of motorbike*
4 *V-shaped brake and scratch marks*
5 *Damage to seat, fairing, and exhaust*

Sequence of events:

The young rider (17 years old) of a light motorcycle was traveling at high speed along a federal highway in good road and weather conditions. Just before a sharp left-hand bend, he braked forcefully and lost control over his two-wheeled vehicle. At the start of the bend, the vehicle fell over onto its left side and slid toward the outside of the bend with its rider still seated. The vehicle crashed into the traffic barrier and the rider slid through underneath it before coming to a halt at a signpost.

Parties involved in the accident:

Light motorcycle

Consequences/injuries:

The rider was seriously injured.

Cause/problem:

The rider was traveling at a speed that was too high for the course of the road and his own ability, and his lack of motorcycling experience brought about the incorrect reaction of braking and tilting at the start of the bend. All of these factors combined caused the vehicle to crash. Furthermore, the traffic barrier – in principle designed to prevent a collision with other obstacles – ultimately did not help the rider, as he slid underneath it and hit the traffic sign behind it, thus sustaining severe injuries.

Prevention measures, mitigation of consequences/strategy for road safety measures:

The fact that young, novice riders overestimate their own vehicle-handing abilities is a well-known problem. Young riders can be made aware of this particular issue by addressing it from the outset in driving school or through targeted information campaigns. Regular rider safety training can significantly improve a rider's ability to remain in control of the vehicle and traffic situation. If cornering ABS is available for a motorbike, an investment should be made in this safety technology. This type of system could have significantly mitigated this particular situation.

In terms of infrastructure, if the traffic barrier had been designed with two-wheeled vehicle riders in mind and had underride protection, it would have prevented the rider from sliding through underneath it. And had the sharp-bend traffic sign and the post been made of plastic, it would have reduced the impact intensity when the rider crashed into it.

Manipulation affects driver assistance systems

Truck Drives Into Back of Car

Sequence of events:

Upon approaching the rear of a tailback, the driver of a car began to decelerate. The driver of an articulated vehicle behind the car detected the deceleration process too late. Despite an intervention from the automated emergency braking system and the articulated vehicle driver reacting with emergency braking and an evasive maneuver, the truck collided with the car. The car was hurled to the right and the driver fatally injured. The articulated vehicle came to a standstill in the left-hand lane.

Parties involved in the accident:

An articulated vehicle, a car

Consequences/injuries:

The car driver was fatally injured.

Cause/problem:

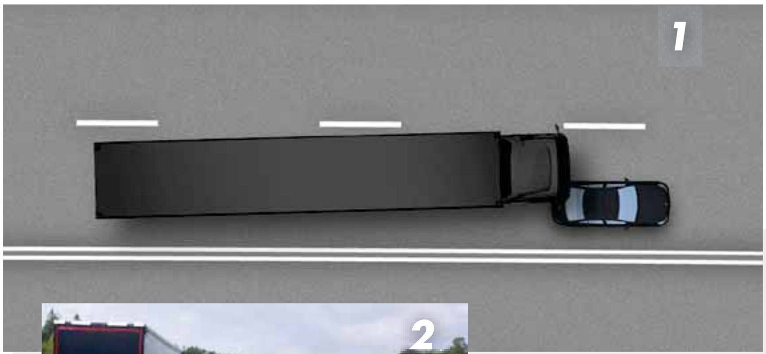
When the accident was recorded, it was determined that there was no security seal on the EC tachograph. During the accident reconstruction and technical vehicle inspection, it was also established that the vehicle had been manipulated in a way that caused a lower speed to be transmitted from the sensors than was actually the case. This meant that the vehicle could be driven at a higher speed, yet a lower speed recorded and displayed. As this lower-speed signal was also transmitted to the driver assistance systems, this severely impaired their effectiveness.

The inbuilt automated emergency braking system had detected the situation and triggered a warning to the driver and an automatic emergency braking operation. As the actual initial speed was far above the permissible speed limit of 80 km/h set by the system, the vehicle was unable to reduce its speed sufficiently, let alone completely prevent the collision.

Prevention measures, mitigation of consequences/strategy for road safety measures:

The truck driver could have prevented the accident if he had been paying attention to the traffic and kept to the permissible speed limit. He would have reacted in time to the tailback of traffic and managed to prevent the accident through normal braking or an evasive maneuver.

If the automated emergency braking system had received the correct speed signals and been able to react accordingly, this would also have helped prevent the accident or significantly mitigate the consequences. In modern, technically complex vehicles, even a seemingly simple modification can have far-reaching and often dangerous consequences.



1 Sketch of the collision position
2 Scene of the accident
3 Damage to truck
4 Damage to car
5 Truck braking marks and impact marks

Person attempts to cross road in dark

Car Hits Pedestrian

Sequence of events:

A car (1) was driving round a slight left-hand bend on an inter-urban road in the dark. At a junction with a pedestrian crossing, a drunk adolescent stepped away from a group of people onto the opposite lane on a red light. Upon noticing a car (2) approaching in that lane and sensing the danger, the adolescent began to run. He ran from the left (viewed from the direction of travel of car 1) onto the lane of the car 1, which hit him without braking and fatally injured him.

Parties involved in the accident:

A car, a pedestrian

Consequences/injuries:

The pedestrian was fatally injured

Cause/problem:

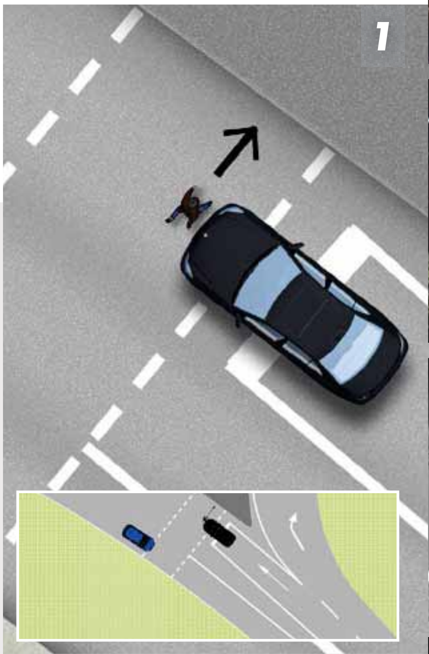
Due to the dark, low-contrast clothing worn by the pedestrian and the hampered visibility caused by the low beam headlights of an oncoming car, the car driver did not see the pedestrian until it was too late. The course of the road also meant that the pedestrian was in the car driver's peripheral vision when he stepped onto the road.

Prevention measures, mitigation of consequences/strategy for road safety measures:

To illustrate the situation, an expert assessment was performed to check the lighting conditions. Based on the assumption that the car driver would have had to detect the pedestrian's moving legs in his peripheral vision in order to react in time, it was determined that the driver was unable to detect the pedestrian until he no longer had any room to evade him and prevent the accident.

On average, half of all accidents involving pedestrians in Germany happen during the dark or at dawn/dusk. For cameras and sensors of automated emergency braking and night vision assistants to be able to perceive more clearly in the dark than the human eye, several modules have to be intelligently combined – for example radar/lidar sensors with infrared cameras. This enables hazards to be detected in time and quick reactions to follow.

The pedestrian could have avoided the accident if he hadn't crossed the road during a red light or allowed the clearly visible car to pass first.



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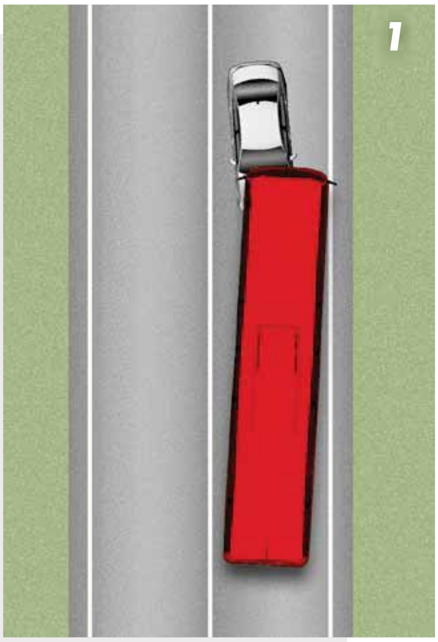
1 Sketch of the collision position
2 View from car
3 Car damage and marks
4 Driver reaction position (Visibility with luminance camera)
5 Driver reaction position (Visibility with human eye)

Typical accident scenario

Bus and Car Collide Head-On

Sequence of events:

A car and a bus were driving along a federal highway in opposite directions. Although snow was falling, the road was safe to drive on as it had been cleared of snow and gritted. The road markings were also clearly visible. Without any apparent reason, the car drove into the lane of the oncoming bus. The bus driver braked and performed an evasive maneuver but was unable to prevent the collision. The two vehicles collided head on, with 90 percent of the front of the car coming into contact with 50 percent of the front of the bus.



1 Sketch of the collision position
2 Scene of the accident
3 Damage to bus
4 Bus driver's seat
5 Damage to car
6 Collision site with impact marks on the bus's lane

Parties involved in the accident:

A car, a bus

Consequences/injuries:

The car driver was fatally injured and the bus driver sustained serious injuries.

Cause/problem:

Despite the wintry conditions that morning, the road was free of ice and snow, so the road conditions do not explain why the car driver veered out of lane. Furthermore, neither of the vehicles had a technical fault that could have caused or contributed to the accident. It was not possible to determine whether the car driver had ended up on the opposite lane due to distraction, momentary nodding off, or health problems.

Prevention measures, mitigation of consequences/strategy for road safety measures:

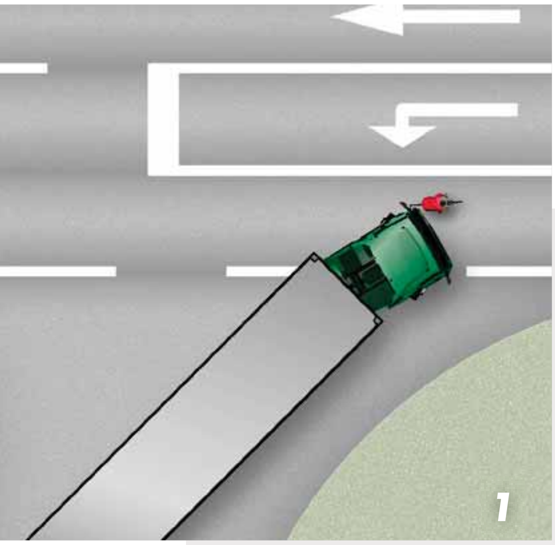
That morning, the road markings (continuous middle line, edge markings) were very clearly visible, which a lane guard assistance system would easily have been able to detect. It could have warned the driver in time or prevented him from leaving his lane through a steering or brake intervention. If the driver had momentarily nodded off, an attention assistant could have alerted him.

It is imperative to continue technological advancements in oncoming vehicle detection in order to continue improving automatic lane guard systems and automated emergency braking systems, and to integrate these in as many vehicle classes as possible.

Drivers must urgently refrain from activities that distract their attention from the road, such as using smartphones or infotainment systems, or doing other non-driving-related tasks.

Rider approaching from left not seen by driver

Truck Hits Pedelec Rider



1 Sketch of the collision position
2 Scene of the accident
3 Position of contact
4 View restriction due to A-pillar
5 Turning assistant active

Sequence of events:

A truck driver was driving off the freeway during daylight and wanted to turn right onto an inter-urban road (with the turn signal on). A pedelec rider, who had right of way, approached from the left along the right-hand side of the road. The truck driver reduced his speed and turned off onto the inter-urban road. This resulted in a collision between the pedelec rider and the front left corner of the truck. The pedelec rider was run over by the articulated vehicle's front left wheel and died at the scene of the accident.

Parties involved in the accident:

A truck, a pedelec

Consequences/injuries:

The pedelec rider was fatally injured.

Cause/problem:

Although the truck had a turning assistant, which was activated when the turn signal was turned on, the system only scanned the right-hand side of the vehicle. As the pedelec rider approached from the left, the truck driver was not warned.

It was difficult for the truck driver to see the pedelec rider as he approached the junction, as he was concealed most of the time by the left A-pillar and the mirrors.

Prevention measures, mitigation of consequences/ strategy for road safety measures:

The accident could have been prevented if the truck driver had fully decelerated the vehicle and granted the pedelec rider his right of way. The driver's restricted direct and indirect view from the truck prevented large parts of the surroundings from being visible, which is a persistent problem with trucks. Given that pedelec riders often travel at higher speeds than conventional cyclists, yet have the same narrow silhouette, there is a significant risk of them entering the blind spot of other vehicles. Junctions that have been optimized to allow vehicles to approach quickly and smoothly can further increase the risk.

The electrification of bicycles and the wide distribution of pedelecs and S-pedelecs means that these are very frequently encountered on roads in non-built-up areas. Drivers are increasingly having to watch out for fast cyclists and adjust their driving accordingly.

There is also a need for existing turning assistants to be further developed, so that they can cover situations like these and be used for left-hand traffic.

For the pedelec rider, it would only have been possible to avoid the accident if he had forfeited his right of way. Cyclists should be aware that truck drivers often have a hampered view from the cab and that truck turning-off maneuvers can be highly complex tasks.

In the blind spot

Car Collides With Motorbike When Changing Lanes

Sequence of events:

A truck, a car, and a motorbike were driving in the left lane (in this order) on a freeway connection road. Both the motorcyclist and the car driver decided to try and undertake the truck via the right-hand lane. When the car switched lanes to the right, it collided with the motorbike, which was to the right of the car at the time. The two vehicles came into contact while traveling at a similar speed, which caused the motorcyclist to fall to the ground, skid across the road, and come to a halt on the breakdown lane, heavily injured.

Parties involved in the accident:

A car, a motorbike, and a truck (indirectly)

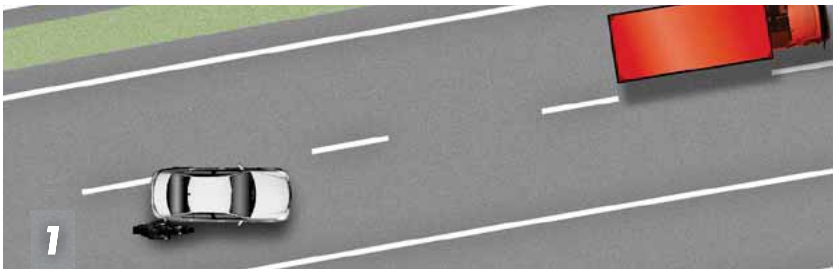
Consequences/injuries:

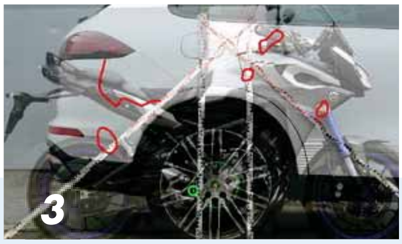
The motorcyclist was seriously injured and the car driver sustained minor injuries.

Cause/problem:

The cause of the collision was that both the car driver and the motorcyclist attempted an illegal maneuver to undertake the truck in the left-hand lane by overtaking it on the right.

In the accident reconstruction, it was not possible to determine whether the motorcyclist would have been visible to the car driver, even if the latter had systematically checked the rear-view mirrors and looked over his shoulder. Cars also have blind spots that the driver cannot see directly or via the mirrors. If the motorcyclist had been slightly further back to the right of the car and some distance away, he would not have been visible for the car driver.





1 *Sketch of the collision position*
2 *Scene of the accident*
3 *Corresponding vehicle damage*
4 *Position in blind spot*
5 *Motorbike not directly visible (over-the-shoulder view)*
6 *Motorbike not indirectly visible (mirror view)*

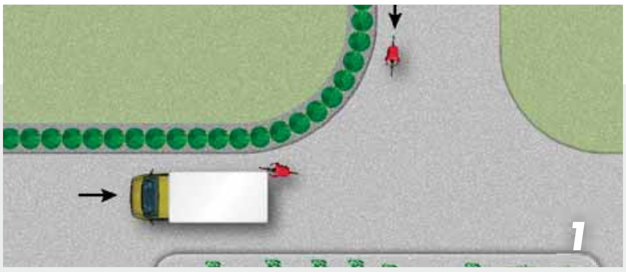
Prevention measures, mitigation of consequences/strategy for road safety measures

The accident would have been prevented if both the car driver and the motorcyclist had adhered to the traffic rules and not attempted to undertake the truck using the right-hand lane. Why the truck was not observing the obligation to keep right was unclear.

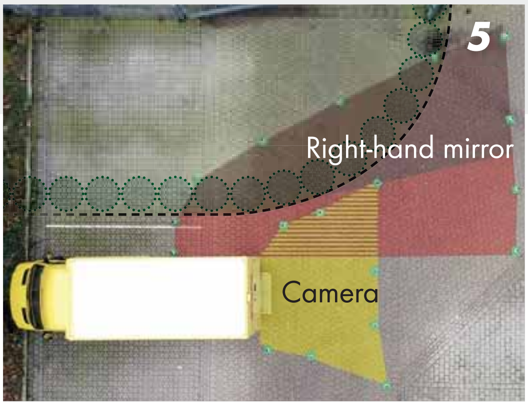
This accident could potentially have been prevented if the two overtaking vehicles had indicated their intention to change lanes clearly and in time by actuating the turn signal. If the car had had a blind spot assistant, it would have warned the car driver about the motorbike, and if the car driver had subsequently heeded the warning, he could have aborted the lane-change maneuver in time. The warning emitted by this particular assistance system is visual – on the exterior mirror – but some systems also provide an acoustic warning in especially critical situations.

Reversing assistant with emergency braking function could have helped prevent accident

Pedelec Collides With Reversing Transporter







1 Sketch of accident and collision position 2 Scene of the accident 3 Point of contact 4 Pedelec rider's view 5 Reconstructed camera and right mirror view 6 Assumed view one second before collision

Sequence of events:

A transporter was reversing down a narrow road in a residential area. At the same time, a pedelec driver wanted to turn off right down this road at a T-junction. There was a hedge and a fence at the junction area, which hampered the view. Moments after the turning-off maneuver, the pedelec rider collided with the rear right corner of the transporter. The pedelec rider then fell to the ground and sustained severe injuries.

Parties involved in the accident:

A transporter, a pedelec

Consequences/injuries:

The pedelec rider sustained severe injuries.

Cause/problem:

Both road users had a severely hampered view of the other due to the hedge and the fence. The pedelec rider did not see the transporter until moments before the collision as she was going round the bend. For the driver of the transporter, which had a vehicle backup camera, the pedelec was only momentarily visible in the right side mirror and did not appear on the vehicle backup camera until immediately before the collision.

Prevention measures, mitigation of consequences/strategy for road safety measures:

The pedelec rider could have avoided the accident if she had realized that a large vehicle was "coming toward her" down the right-of-way residential road, or had registered the illuminated reversing lights and braked accordingly.

It takes time for riders to get used to the higher vehicle and acceleration speeds of pedelecs. Corresponding rider safety training courses are therefore urgently recommended, an experience which might have helped the pedelec rider to react differently in this situation and potentially might have reduced the consequences of the accident.

Although the transporter driver had assistance from a vehicle backup camera, the pedelec did not appear in its detection zone until it was too late. Particularly delivery trucks and courier vehicles that are mainly deployed in built-up areas should preferably be fitted with a reversing warning system with emergency braking function. This could have at least reduced the collision speed of the transporter. A better reversing camera system or even a reversing warning system could also have potentially helped to prevent the accident or at least reduced its consequences.

Overwhelmed and Distracted by Controls That Are Too Complicated

In order to compensate to a certain extent for people's shortcomings and inappropriate behavior at the wheel of a motor vehicle, the automotive industry has for years been placing a particular focus on driver assistance systems that are able to detect critical traffic situations early on, provide warnings about hazards, and even actively intervene if required. There can be no doubt that they have the potential to prevent accidents altogether or at least mitigate their consequences. However, we must also remember that as vehicles become ever-more automated, the systems themselves become more and more complex, meaning people may end up struggling to operate the technology.

The increasing use of automated systems in motorized road traffic is inevitable. The hope is that they will deliver benefits such as fewer accidents resulting in personal injury, and in turn fewer fatalities and injured people. However, if we are to succeed in improving road safety for the long term, it is necessary to tap into and make the most of our human and technological strengths in equal measure. Technology can reliably and correctly carry out clearly defined operations such as counting, measuring, or executing a stimulus-response pattern, permanently and without any loss of quality, within the limits of the system's capabilities. However, our human strengths lie in our intuition, ability to understand even complex traffic scenarios, and rapid situational awareness. Multitasking does not tend to be one of our human strengths as our ability to simultaneously process information from different sources is limited.

This highlights the need for a collaborative human–machine interface that adapts the technology in line with our driving skills, which are restricted in neurobiological terms. The aim is to compensate for limitations in our human perception and performance and thus prevent mistakes. At the various levels of assisted driving, the technology is designed to help the driver to drive the vehicle by informing them, warning them, or providing mechanical control, all without placing an additional burden on them or limiting what they are responsible for. However, this requires the driver to be familiar with how the driver assistance systems (DAS) work and where their

Clarity About System Capabilities and Limits Is Essential for the Technology to Be Widely Accepted

Prof. Andreas Riener
Professor for Human Machine Interface & Virtual Reality at the University of Applied Sciences Ingolstadt (THI)

Without doubt, the technology used for automated, connected, and autonomous driving opens up major opportunities to improve road safety and make things more convenient for drivers and occupants. However, when the public hears or reads about automated driving systems, they are often presented as systems that enable them to sleep, read, and eat while the car is being driven. This, of course, is not the reality yet.

Another problem we are seeing in public discourse is the different automation levels. We must remember that it is not the vehicle as a whole that corresponds to a certain automation level, rather it is that the individual automated systems are defined according to a specific functional level. For example, an automated vehicle may be equipped with a lane guard assistant (Level 1 automation), a traffic jam assistant (Level 3 automation), and a parking assistant for "valet parking" in a car park (Level 4 automation), all at the same time. If we look at how many different functions are used in certain situations and with different automation levels, it becomes clear just how difficult it is for end consumers to understand the complex system landscape – and how hard it is for them to trust them and recognize where their limits lie and what tasks they are responsible for.

Automated systems must never give the impression that they can do everything – particularly considering that the driver always needs to be ready to take back control of the vehicle if it prompts them to do so, at least up to Level 3 automation. Therefore, I believe it is crucial to have a fundamental understanding of the Operational Design Domain, which plays a major role in the safety of highly automated vehicles. This term denotes the specific operating conditions and requirements that are required for the systems to work.

In my view, this makes it more important than ever for the manufacturers to provide precise information about which systems can do what, how they behave in a given traffic situation, and why this is the case. This information is also essential in ensuring that automated systems are accepted by as many sections of society as possible. As an example, the fact remains that if a premium manufacturer offers an assistance feature, consumers will usually fully trust in its functional capabilities. If, however, something goes wrong, it will take a long time for them to build up trust again. Another issue is that numerous systems are poorly configured and require too many acknowledgments from the driver in terms of what they are and are not allowed to do. This comes across as patronizing to the driver and they may end up being annoyed.

Regardless of how automated a vehicle is, we must not forget that there is a human being sitting behind the wheel who may make mistakes and may feel overwhelmed by the systems installed. It is therefore essential to focus adequately on how humans interact with the machine. One solution for this could be to have training sessions at regular intervals where the driver has to prove that they know how to use the systems – particularly if prompted to take control of the vehicle at Level 3. Last but not least, knowledge of how to use automated systems should be integrated into driver training – in particular for the lower automation levels where the driver frequently needs to work with the vehicle.

limits lie, as well as the level of automation in the vehicle, and feel an obligation to use the systems correctly.

Even if it is mainly minor driving tasks that are delegated to the vehicle to begin with, there are fears that we will start to lose our human driving skills and capabilities. This type of "dequalification" was already discussed in a paper by Lisanne Bainbridge around 40 years ago as part of the "Ironies of Automation." The underlying principle behind this concept is that the more something is automated, the less people are able to control it. In line with the motto of "Practice makes perfect," if we cannot actively practice driving, we will see the exact opposite: A loss of skills due to the fact that we have not trained our driving-related skills and capabilities ("use it or lose it"). In turn, this then makes it more difficult to quickly, reliably, and appropriately manage a dangerous situation.

Over-Reliance on the Technical System

A further unwanted side effect is that the driver's mental arousal decreases, meaning they become less engaged in what is going on and have problems paying attention for prolonged periods

If drivers perceive a risk as being low, they may end up driving faster

of time. This notion of being overwhelmed through insufficient mental arousal is described by the Yerkes–Dodson law, which states that people make the fewest mistakes and perform their best when they are moderately engaged. If they are not engaged enough, there is a risk that they will overlook important signals. At the same time, this lack of engagement and the resulting sense of monotony encourages the driver to end the situation (as they usually perceive it to be negative) and actively seek out a more stimulating activity. As a result, they deliberately start doing something else, e.g., using communication or information systems such as a tablet or their cell phone. The list of risks and side effects when it comes to highly automated driving is virtually endless.

The human brain draws on information it has stored to predict the types of things that might go wrong with the automated system in the future. If everything keeps going to plan, with the system working correctly and efficiently, our cognitive prediction model signals that it is fully functional and our brain starts to monitor it less effectively. We become overly reliant on the technical system, causing the driver to monitor the (semi-)automated system less or inadequately and delegate all of the responsibility to the system. Assistance systems also create a false sense of security, which may cause the driver to feel that the electronic aids are providing them with the best possible protection, potentially leading them to take more risks when driving.

In 1982, Gerald J. S. Wilde presented the "risk homeostasis theory" which can in theory explain this phenomenon. It predicts that the use of driver assistance systems may in fact eliminate improvements over the long term. According to this theory, drivers subjectively perceive a certain level of risk at any given moment and, while they are driving, continuously compare it with the maximum level of risk they are willing to accept. If the two differ from each other, drivers will adjust their behavior in order to eliminate the discrepancy. For example, if poor visibility means they perceive the level of risk to be higher than what they are willing to accept, they can reduce it by driving more slowly. However, if the level of risk they perceive is lower than what they are willing to accept, this may cause them to drive faster, for example, which entails an objectively higher risk of accidents. In simple terms, you could say that the technology may encourage drivers to think they have a kind of "guardian angel" watching over them, causing them to change their attitude to risk and be willing to accept a subjectively higher level of risk.

Whether in built-up or non-built-up areas, driving too fast or failing to adjust your speed will often cause severe traffic accidents.

Driver Assistance Systems Can Save Thousands of Lives

Mar Cogollos
Director of AESLEME (Asociación para el Estudio de la Lesión Medular = Association for the Study of Spinal Medullary Lesions)

Driver assistance technologies used in the automotive sector rectify a range of familiar but serious shortcomings caused by human error.

We know that around 90 percent of traffic accidents are caused by human error, including driving at an inappropriate speed, being distracted, feeling drowsy, driving too close to other vehicles, etc. Despite the fact that there is such a pressing need for road safety education, we must accept that even with ongoing public awareness campaigns and police checks and punishments, it is practically impossible to reduce the accident rate (and the associated catastrophic consequences) to the only acceptable value – zero.

After all, although we all know what we have to do and pay attention to when we're behind the wheel, crossing a road, or riding a scooter or bike, it's all too easy to make excuses and think: "Ach, nothing will happen." Or: "I'll watch out." Or: "I'll ignore the stop sign but only because nobody is coming the other way."

However, machines and driver assistance systems cannot be misled into making these individual considerations or decisions. Instead, they keep to the rules and parameters which have been defined for them to work properly. This means that the more autonomous the vehicles are, the less scope there is for human error at the wheel and its tragic consequences.

Various studies show that driver assistance systems have the potential to save thousands of lives as we transition to a fully automated world of transport. This applies even if they are merely visual and/or acoustic warning functions or, at the higher automation levels, by the vehicle taking control of driving, e.g., by triggering braking if there is a risk of a collision or an imminent crash.

According to the latest findings, these systems do not just warn the driver to ensure they respond if the vehicle suddenly changes lane or a pedestrian steps out onto the road, they also bring about permanent changes to driving habits. For example, company fleets can use driver assistance and telematics systems to identify and correct risky behavior so that drivers drive more safely. Such systems could also be used in the After-Sales segment, which would be a good solution considering that 44 percent of all vehicles in Spain are more than 15 years old.

Here at AESLEME, we therefore believe that driver assistance technologies are the ideal counterpart to road safety education (for which there is an ongoing need), and that they will help to reduce traffic fatalities to zero in the not-too-distant future.

Using the Systems Correctly Is Key

A further problem is that people will lose trust in the DAS if the automated system makes too many mistakes. For example, a warning function that is too sensitive and frequently sends warnings to the driver or triggers too many false alarms, will be perceived as annoying or irritating. In turn, this will make people less willing or prepared to delegate responsibility for controlling the vehicle to the system. Alongside having a positive attitude to the DAS, other important factors which determine whether drivers accept such systems are the benefits they perceive them to bring, and how user-friendly they consider them to be. Aspects such as a favorable opinion of the DAS in social environments and the compatibility and affordability of the systems, also make it easier for drivers to accept the systems. The perceived benefits are defined as the extent to which a person believes that the use of a certain system would improve their driving performance.

Irrespective of the extent to which drivers accept them, one critical factor is that the technical systems must also be used correctly and not overridden. This means that the users of (highly) automated systems also need to follow the manufacturer's instructions to avoid creating new hazardous situations. In this context, the question arises of how to deal with drivers who deliberately ignore or bypass the manufacturer's instructions.

Information and control engineering technologies are becoming more and more advanced, opening up a wide range of pos-

Safety-related functions in vehicles should not necessarily be controlled using touchscreens.

sibilities for presenting information based on the specific situation at hand or at a particular time, and for developing clear and reliable operating concepts. The design of the cockpit can also be tailored to the needs and interests of different user groups. A position paper published by the German Society of Traffic Psychology (DGVP) in 2020 looked at how to design vehicles ergonomically. It stated that a number of criteria apply in order to ensure data is presented in the best possible way to help drivers process the information and guide them. Specifically, the information must be provided promptly and it must be relevant, specific to the situation at hand, adequate, and clearly understandable. Moreover, the information must be accepted by the driver and motivate them to behave in the desired manner.

The Importance of Designing an Effective Human-Machine Interface

Requirements for effective and transparent operating concepts have been drawn up over the last few years, particularly for a DAS. As previously mentioned, the ideal assistance system will be user-friendly and accepted by drivers, and this includes aspects such as transparency and whether such systems can be controlled. Assistance systems are controllable if they not only assist with or take over certain (sub-)tasks, but can also be deactivated. The DAS must also ensure that control of the vehicle is transferred and accepted correctly under all conditions, without any malfunctions, and giving the driver sufficient advance notice.

Transparent assistance systems ensure that the driver can obtain a reliable idea of how they and the machine will interact, i.e., that they understand how the system works. The system will also be considered more user-friendly if it has a simple design and its controls are easy to learn – after all, users will be more willing to accept the system if they think it is intuitive to use. By contrast, systems that are complex and hard to understand are often less likely to be accepted and will, therefore, also be used less often, or in the worst case even used incorrectly.

The most challenging ancillary task facing drivers has become interacting with the "In-Vehicle Infotainment System" (IVIS). When the interfaces are designed effectively, this enables drivers to use the system successfully with minimal distractions, ensuring no loss of driving safety. Nowadays, the information systems installed in vehicles are often based on a touchscreen, which requires drivers to input their entries by touching specific buttons. In many cases, switches or keys are now only used to control selected functions. As new assistance systems come onto the market, users are having to deal with more and more functions and features, so it is important to ensure that the menu navigation concept is as effective as possible and does not impair road safety.

User Preferences Differ

Studies have been conducted into different web menu designs, revealing that it is easier to search for information using pull-down menus (where users move through the menu using an expanding control element) than via global or local selection menus. The effect on how people search for information was measured by giving users searching and browsing tasks where they either had to find specific information as quickly as possible, or select a suitable product from all the product offerings. When searching for information, the users required more time to use a global or local selection menu than they did for a pull-down menu.

Assistance systems are often developed with an average user in mind. However, studies have shown that user preferences differ, so it would be advantageous to provide flexible systems that users can personalize. For example, users prefer ACC systems that enable them to adjust the distance to the vehicle in front in line with their own preferences. In turn, these preferences depend on the situation at the time and the user's mood, and may change over time and as they gain experience. It is, therefore, always recommended to design information and warning systems such that they can be flexibly adapted to changing user preferences.

Modern Cockpits With Touchscreens

The cockpit around the driver plays an important role in motor vehicle traffic. Nowadays, they are increasingly designed with displays alongside the more traditional switches and pushbuttons. The dashboard often houses the rev counter, speedometer, fuel indicator, and various warning and check lamps. Newer generations of cockpits combine pushbuttons, switches, and the dashboard in an integrated, interactive operating concept based on a touch-sensitive screen known as a touchscreen. Most vehicles are equipped with resistive touchscreens, which are made up of two conductive layers that connect with one another when the user presses on them.

However, as touchscreen technology continues to advance, we are seeing indications that resistive touchscreens are becoming less user-friendly compared against new technologies such as ultrasonic waves, infrared light, or measurements of the change in capacitance. These types of touchscreen require the user to press less hard, offer a higher resolution, and support multi-touch inputs.

Technology has now also been developed to enable users to input their requests using gestures. The idea is that the user makes a certain gesture in the air, which is recorded by sensors or cameras and triggers a certain function. These innovative control technologies reduce the number of incorrect entries and make it faster for users to input their requests. This also helps them to gain experience and enables road safety risks to be minimized because, for example, they are less distracted. So far, a standardized set of gestures that is generally accepted and used for inputting requests has not been developed yet. Despite this, studies have shown that users prefer gesture-based concepts which are intuitive and natural, meaning the movements resemble the ones that humans make when communicating with one another. Furthermore, the assumption is also that gesture-based inputs are better suited to certain infotainment functions than to tasks linked to the driver's primary role of actually driving the vehicle, such as activating the turn signal.

A Combination of Touchscreens and Separate Keys Appears Advisable

As technology continues to advance, drivers are finding that there are more and more functions that they can control via touchscreens. Alongside traditional ones like operating the navigation system or using media, some manufacturers now also enable drivers to use touchscreens to control features like the air conditioning system or even the windshield wipers. In principle, drivers rate touchscreens positively in terms of their user-friendliness. They provide haptic feedback about the driver's inputs by generating a vibration that they feel on their finger. Today, features that are regularly used for the primary task of driving the vehicle (such as the turn signal) are often still controlled via levers, pushbuttons, or keys positioned near to the steering wheel. This design philosophy is supported by the results of a study conducted by German automobile association ADAC, which showed that frequently used and safety-related features should be operated by separate controls which are not positioned too far down.

Drivers must be able to use safety-related functions quickly

In the ADAC study, the best results were achieved by vehicle models equipped with controller-based operating systems which revolve around a rotary knob. Systems where important safety-related control elements are controlled using digital menu systems and electronic switches (buttons) on the touchscreen of the infotainment system fared worse. The ADAC study concluded by stating that a combination of touchscreens and separate keys for frequently used and safety-related functions appears advisable. DEKRA's own tests also came to a similar conclusion; these are described in detail in the "Technology" chapter.

When using the infotainment system with features such as navigation, communication, or media, touchscreens are a better alternative to controllers. Provided that the display is big enough and they have large touch surfaces and a lot of computing power to guarantee smooth operation, inputting requests via touchscreens is quick, less distracting, and received positively by users. In addition, inputting requests using a controller takes longer than on a touchscreen, meaning the driver is distracted for longer while driving.

Accident Risks When Car Sharing

The more often people take turns using vehicles fitted with different technical and ergonomic equipment, the more urgent it will become to have an effective human–machine interface. New mobility

Road Traffic Statistics Do Not Lie: There Are Still Too Many People Dying on Our Roads

Konrad Romik
Director of the Secretariat of the National Road Safety Council,
Ministry of Infrastructure of the Republic of Poland

Despite the fact that Poland was in the group of 9 countries which recorded a decrease in the number of road fatalities in 2021 and in the group of 5 countries where the decrease in the number of deaths compared to 2019 was greater than the EU average (-13%), there is still a lot of catching up to do.

The National Road Safety Programme 2021-2030 sets specific objectives and identifies priorities for the actions, the implementation of which should lead to a significant improvement in safety on Polish roads. The NRSP 2021-2030 assumes two main priorities to be achieved in 2030: a 50% reduction in the number of fatalities on the roads compared to 2019 and a 50% reduction in the number of seriously injured in road traffic accidents compared to 2019. We are systematically carrying out the adopted Implementation Programs for the NRSP 2021-2030 also in such a way as to preserve the synergy of changes in the safety triangle i.e. human – infrastructure – vehicle.

The National Road Safety Council and the Ministry of Infrastructure constantly conducts educational and informational activities and introduces a number of changes, among others, in the provisions of law to improve safety on the Polish roads.

On June 1, 2021, the amended provisions of the Road Traffic Act came into force, which unified the permissible speed in a built-up area regardless of the time of the day, increased the scope of pedestrian protection in the area of pedestrian crossing, imposed an obligation to exercise extreme caution for pedestrians and regulated the issues of safe distance between vehicles on motorways and expressways. The above legal changes were accompanied by a nationwide information and education campaign addressed to drivers and pedestrians.

Furthermore, on January 1, 2022, regulations improving road safety came into force, which tightened penalties for the perpetrators of the most serious road traffic offences. These changes include an increase in the number of fines for speeding, severe penalties for road traffic offences in regard to pedestrians, as well as driving under the influence of alcohol or other intoxicants. Naturally, the new changes were accompanied by a social campaign informing the public about what has been changed and the consequences of non-compliance with the regulations.

Subsequent changes which came into force on September 17, 2022, include changes in penalty point tariff, i.e. extending the period of removal of penalty points from 1 year to 2 years and increasing the amount of a one-off penalty for committing the most serious road traffic offences from 10 to 15 points, introducing the so-called recidivism, i.e. for a repeated offence within two years, the driver will pay double rate.

Whether you are using a car sharing scheme or renting a vehicle, it is essential to familiarize yourself with the most important features of the vehicle and how they work before setting off.

concepts are required due to climate change and the need to develop cities in a sustainable way. Alongside innovative technical solutions, these concepts ultimately also entail new ways of organizing how we move around. This includes car sharing, which is when motor vehicles are shared instead of being owned by one individual. Similar to when people use public transport more, car sharing has the potential to reduce traffic volumes, make it easier to integrate with other means of transport and thus select multiple ones, and reduce the demand for parking spaces and areas dedicated to traffic.

At the same time, car sharing means people need to move away from existing symbolic and emotional behavior patterns relating to driving which are regularly linked to ownership of and the right to have your own private motor vehicle. Various studies have shown that this new form of user behavior can also become a safety risk. For example, data collated in Sydney (Australia) in 2014 revealed that car sharing users were more frequently involved in accidents if they did not have a car themselves, had held their driver's license for a shorter period of time, already had accidents in the last ten years, and drove more miles in the year before the study than prior to that. Car sharing drivers who were involved in an accident were more likely to be blamed if they had driven fewer than 1,000 kilometers in the previous year and generally only use a car rarely. Furthermore, an analysis published in South Korea in 2019 showed that the number of traffic accidents in the cities under review increased after car sharing schemes were introduced, and that these schemes predominantly influenced the number of accidents by experienced drivers (those who had held their driver's license for more than three years).

Given the lack of studies conducted in Europe, and particularly in German-speaking areas, a group of researchers from Vienna (Austria) decided to run an online survey to look in more detail at car sharing in the context of road safety. They asked car sharing users (n = 125) as well as non-users (n = 194) for their input. They also held qualitative interviews and moderated discussions with users (n = 6) and non-users (n = 6) of car sharing schemes in order to identify fields of action and suggest improvements to improve road safety in the context of car sharing.

Instruction in How to Operate Vehicles

Among other findings, the results of the survey of car sharing users showed that 54 percent familiarized themselves with the car sharing vehicle and its settings before driving off. However, only 18 percent checked the driver assistance systems. Around half of those surveyed (52 percent) stated that before driving off, they only spent a maximum of two minutes checking the requirements for using the vehicle. Alongside activating the vehicle when they take possession of it, this also includes familiarizing themselves with how its basic functions work. If they only spend two minutes on this, it can only be done very superficially and as spot checks. Moreover, 37 percent of those surveyed stated that they did not, or did not really, know what assistance systems were fitted to the car sharing vehicle. It is important to note here that there are sometimes big differences in which assistance systems are fitted in the various car sharing vehicles and in how these systems are operated. One in every four respondents admitted that they had experienced a hazardous situation in these vehicles once or more. Seven percent had been involved in at least one accident in a car sharing vehicle.

Above all, both users and non-users of car sharing schemes considered instruction in how to operate the vehicle to be important for improving road safety. 33 percent of users stated that it could make sense to change the billing model and move away from time-based tariffs. This is because time-based tariffs make it difficult to estimate the final cost as the drivers cannot predict their exact routes and journeys, so they sometimes drive faster or take more risks. Since the clock starts ticking the moment the vehicle is unlocked, drivers spend little time familiarizing themselves with the vehicle before they set off. To remedy this, car sharing providers could introduce things such as bonus minutes to ensure users have enough time to become acquainted with the often unfamiliar vehicle equipment before driving off. Information on how to operate the vehicle the user has booked should also be provided on the platform used by the car sharing provider.

The Negative Effects of Driver Assistance Systems

In very general terms, the term "driver assistance system" or DAS refers to additional electronic equipment in motor vehicles that is designed to help the driver in certain driving situations. Current DAS concepts feature a range of different standalone solutions to assist with driving tasks (providing information or warnings, helping with or executing certain actions, automatically intervening in how the vehicle is being controlled in order to avoid an imminent danger). In some cases they affect how the vehicle is guided lengthwise or sideways, or the navigation. They may be restricted to specific tasks such as parking the vehicle, or to specific situational factors such as driving at night. As valuable technological aids, they are designed to reduce the risk of accidents and make driving more convenient, comfortable, and cost-effective.

Yet all that glitters is not gold, because a DAS can also negatively affect road safety, such as by giving the driver a false sense of security or causing them to underestimate the effects of being distracted. Scientific studies have now been conducted which provide empirical evidence of both phenomena. For example, back in 2010 a study looked into whether drivers become over-reliant on a lane guard assistant system if they have used it for a long period of time, and whether this causes drivers to negatively change their behavior.

For the purposes of this study, 30 experienced car drivers (who had driven > 10,000 kilometers in the last 12 months and were > 30 years old) drove along a test section of road as part of regular road traffic in Germany, comprising freeway (245 kilometers) and inter-urban roads (105 kilometers). The vehicle was fitted with a system that used active steering movements to help the driver guide the vehicle sideways if they drifted too far from their lane. The drivers could clearly feel these steering movements. During the journey, the system was repeatedly switched off without the drivers' knowledge. The results showed that when the lane guard assistant system was active, a statistically significant larger distance was maintained from the lane/roadway markings than when the vehicle was driven without the system or when the drivers thought it was active when it was not.

Also in 2010, a driving simulator experiment was conducted in Japan to investigate whether Advanced Driver Assistance Systems (ADAS) become less effective over the long term due to the drivers adapting to them. To test this, the study compared the drivers' driv-

Fastening your seat belt is the number 1 thing you can do to save your life, both now and in the future.

Don’t Let Yourself Be Distracted When Driving

Rosário Abreu Lima
Head of Communications at the Automóvel Club de Portugal

It doesn’t take much to cause an accident – two seconds, in fact, is all it takes. 25 percent of all traffic accidents are estimated to be caused by a lack of attention, with 25 to 30 percent of the entire driving time spent on things people do to keep themselves entertained. Averting one’s gaze from the road for two seconds while driving increases the risk of having an accident 20-fold. Even just a small lapse in attention can have dramatic, or even fatal, consequences. No matter whether the mode of transport is a car, a motorbike, a bike, or your own two feet: Being a road user requires committing one’s undivided attention to the road and the traffic.

Given that technology is becoming an ever-greater part of our day-to-day lives, especially when driving a car, there are now more and more ways that we can become momentarily distracted, for example by our smartphone or the digital displays in the car. But it is not just technology that distracts us, even though it is a main distraction factor. Eating, drinking, conversing with passengers in the vehicle, or searching for a radio station are equally as dangerous, as are conducting telephone calls or searching for a destination in the navigation or entertainment system.

And more dangerous still is reading or writing text messages. These activities are some of the worst ways for us to divert our attention while driving. It takes an average of five seconds to read or write a message, which is the same time as to cross a soccer pitch from one end to the other at 90 km/h – with your eyes closed.

According to a study conducted by the Automóvel Club de Portugal (ACP) Observatory concerning the habits of Portuguese drivers (the largest study to ever be conducted in Portugal), the use of a smartphone while driving has become an alarming distraction factor. 47 percent of people surveyed said that they use their smartphone to make calls while driving, either using the hands-free system or even by holding the device up to their ear. And 70 percent stated that their vehicle was not equipped with a voice control system.

The ACP Observatory’s study revealed that there is low approval for the idea of a legal ban on using a cell phone at the wheel: Just 61 percent of respondents were in favor of punishing those who use a smartphone, including when using a hands-free system.

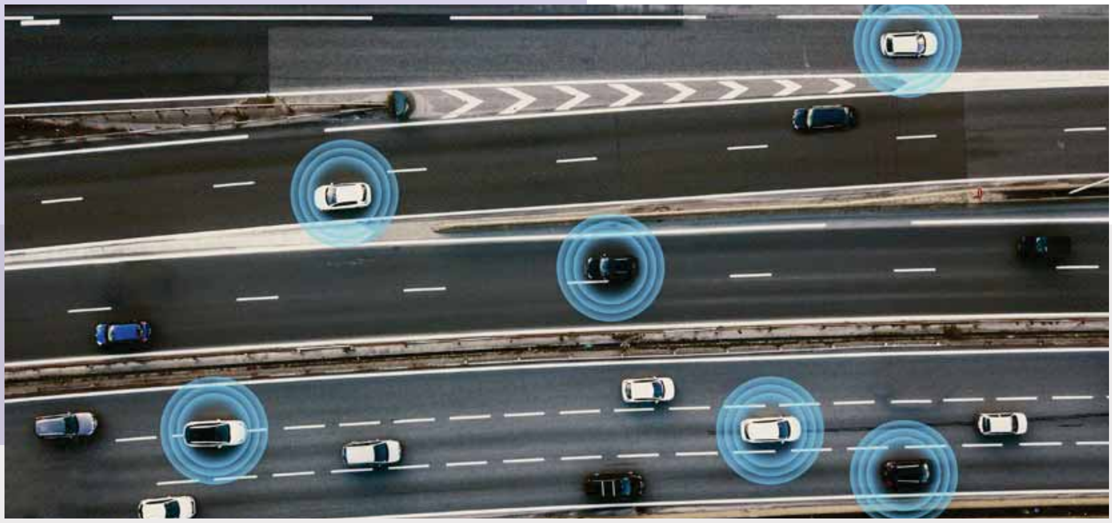
ing behavior with and without a night vision system. The participants (n=10) in the driving simulator drove down a two-lane test section of road (of around 12.2 kilometers) several times under different conditions – both without and with a Night Vision Enhancement System (NVES). During the tests, the participants were repeatedly confronted with a dangerous event (a pedestrian suddenly and unexpectedly steps out into the road).

Prior to swerving out of the way in response to this dangerous event, it was observed that the participants pressed the brake pedal earlier when the NVES was active than when they were driving without the assistance system. However, the vehicle speed was higher than when driving without the NVES, both generally and before the critical events. As the participants had been instructed to drive at a speed they considered to be safe, the higher speed may be attributable to the drivers adapting in response.

A Changed Perception of Risk

An Italian study conducted in 2015 investigated the effect of a more complex DAS on driver behavior and their acceptance of such a system. This system had on-board sensors which evaluated the surrounding traffic and warned the driver if it detected a hazard. However, it did not actively intervene. The DAS had several features and continuously assisted the driver via various HMI channels, such as by providing visual information on displays as well as acoustic warning signals. The system also warned the driver by tightening their seat belt. If the system detected a danger, it issued a warning to the driver. This warning became more and more intense as the danger level increased. Specifically, the system showed a symbol on the display to warn the driver if they had exceeded the speed limit. If the driver approached a bend in the road too quickly, the system initially showed a warning symbol on the display. The warning then became more intense by outputting an alarm tone and tightening the seat belt.

In a field test with 24 participants conducted along a 53-km test track, including sections of freeway and inter-urban road, *In the coming years, we will increasingly see a mix of conventional and automated vehicles driving together on our roads.*



positive effects were observed on the choice of lane, lane changing behavior, and compliance with the speed limit. However, there were also unwanted side effects. For example, despite the fact that the system was active, when the participants reached an intersection they turned off too quickly at a speed inappropriate for the circumstances. They also maintained an insufficient distance to the side.

Finally, a study was conducted in China in 2021 to investigate how effective an ADAS is in improving a driver's perception of risk in near misses. "Safety Margins" (SM) were used as indicators in this case. The term "Safety Margins" refers to the minimum distances that the driver wants to maintain from other road users, for example. If they remain outside these areas, the driver feels safe and does not perceive any danger. However, if a driver enters the SM area, they consider this to be dangerous and take corresponding action, such as swerving out of the way.

The study analyzed real trips made in Wuhan, comparing drivers' risk level during critical events when the ADAS was switched on with their risk level when the system was switched off. The participants drove along the test track once with ADAS and again three months later with the system deactivated. The assistance system used included a lane guard assistant, a head-on collision warning system, and a distance monitoring and warning system. Drivers who had driven more than 40,000 kilometers were defined as experienced (n=22) and those who had covered fewer kilometers were classified as inexperienced (n=22).

For the purposes of the analysis, 424 near misses were extracted from the journeys and classified into three groups: low (n=236), medium (n=154), and high risk (n=34). The analysis looked at indicators relating to the maximum deceleration while braking and the percentage reduction in the vehicle's kinetic energy. As the risk level increased, the DAS only had a significant effect on inexperienced drivers, not on experienced ones. Therefore, as the risk increased, the safety gain also increased significantly for inexperienced drivers. However, it actually reduced slightly for experienced drivers, which indicates that the DAS impaired the performance of experienced drivers in high-risk scenarios.

The mixed results indicate both safety gains but also safety losses, which is due to the ways in which the drivers mentally assess the situation. This includes the notion of relying on the automated system, but also the aforementioned theory of "risk homeostasis." Drivers become over-reliant on the technical system, meaning they fail to (properly) fulfill their own duty of care. They think that the DAS will sort everything out, and delegate their responsibilities to the DAS as a "troubleshooter" which will step in should a potential or specific danger arise.

Driver Assistance Systems Can Also Be Distracting

It is well known that distractions while driving are a major factor in ensuring road safety. For example, an analysis of the traffic accident trend for young drivers in the USA shows that, in 59 percent of the analyzed cases, the drivers had been preoccupied with a secondary activity in the seconds before the accident. The most common causes were identified as interacting with passengers (14.6 percent), using a cell phone (11.9 percent), and using items of equipment in the cockpit in the vehicle (10.7 percent). Against this backdrop, a study published by the Allianz Center for Technology in 2023 entitled "Ablenkung und moderne Technik" [Driver Distraction and Modern Technology] is also of interest. One of its findings was that the risk of accidents increased by around half for many technology-related distractions. For example, it increased by 61 percent for writing a message on a cell phone held in the driver's hand, by 54 percent if an anchored/installed device was being used, by 46 percent when using the navigation system, and by 56 percent when performing other tasks with the assistance system activated.

A comprehensive, systematic analysis of relevant literature in 2021, covering 29 papers, specifically highlighted the important link between distractions and ADAS, as the driver adopts an increasingly passive, monitoring role when tasks are delegated to automated vehicle systems. This means the driver experiences insufficient mental arousal, encouraging feelings of monotony and boredom and making them less engaged in what is going on. To compensate for this, they then distract themselves with other activities not related to driving.

Overall, the results show that drivers preoccupy themselves with a secondary activity more when they are driving with the ADAS activated. This can be attributed to the possibility that drivers subjectively feel less challenged due to the support provided by the assistance system. The findings also show that when an ADAS is being used, drivers spend more time looking at the vehicle's surroundings, which impairs their situational awareness.

On the other hand, assistance systems can themselves become direct sources of distraction or interference. A team of researchers from the University of Padua (Italy) investigated this phenomenon in 2014 and looked at how acoustic signals impact drivers. Many types of ADAS output these signals if specific parameters, such as speed, exceed a certain threshold. In a driving simulator experiment, the researchers examined whether this type of signal has an impact on a driver's ability to stay in lane and on the vehicle speed.

The participants (n=26) had to drive along a straight road. When they approached a dangerous section, a single, continuous signal tone sounded for 4.55 seconds. The results show that abruptly activating a signal tone can disrupt or startle the driver, who then reacts with uncontrolled, involuntary motor responses. Specifically, it was observed that the drivers came off the gas pedal, meaning the vehicle slowed down significantly. A slight turning of the steering wheel (a jerk-type movement) was also observed, reflecting the driver's surprise at hearing the noise and causing the vehicle to temporarily drift from the correct lane.

These fluctuations in terms of staying in lane and the vehicle's speed are probably due to motor reflexes as they occurred in a very short space of time (150 milliseconds after the signal tone had started). The fact that this lag time is so short rules out the possibility that higher cognitive functions were involved in these motor responses. The team of researchers referred to the danger posed by these reactions, and pointed out that in these types of situations, even tiny changes in driver behavior can be decisive in determining the outcome of the driving maneuver.

Mixed Traffic Comprising Manually Driven and Automated Vehicles

If we look at the safety-critical aspects of automated systems, all levels of automation – including fully automated driving – are dependent on situational factors. These include the expectation of mixed traffic comprising vehicles equipped with different levels of automation, the direct interaction between these vehicles, the behavior of other road users, and system malfunctions or even failures.

Regardless of how quickly the various levels of automation are implemented in our vehicles, we should assume that the traffic on our roads will be a mix of conventional and automated vehicles for the coming decades. A 2018 study conducted by Prognos on behalf of ADAC predicted that Germany would not see any notable registration figures for new vehicles operating purely as "door-to-door pilots" (Level 5) until 2040. For 2050, the assumption is that there will be 0.5 to 2.1 million of these types of vehicle. As things stand today, it is difficult to predict whether and to what extent automated vehicles at Levels 3 to 5 will actually be used. We must remember that a person's choice of a mode of transport is significantly shaped by their previous encounters with the dominant mode, the experiences they had using it, and the habits they have formed as a result.

There may be many different reasons why the automated system needs to be decoupled

Although the primary purpose of driving is to transport someone from A to B, secondary driving motives which tap into a person's emotions also play a role. When someone actively drives themselves somewhere, this can provide an internal sense of gratification by invoking feelings such as joy or driving pleasure – something seen in classic car enthusiasts, for example. It is often also linked with perceptions of good health, independence, and playing an active role in society. It therefore plays a part in defining a person's identity, something which a 2010 study proved. The results showed that the burden felt by a person who had had their driver's license taken away was higher than the burden felt following the breakdown of a relationship (e.g., a decision to get divorced) or the loss of a job.

All this may well curtail a lot of the euphoria about self-driving cars. Furthermore, there is also a paradox that could make it even less likely that people will buy this type of vehicle. The vehicles are expected to cost between 100,000 and 200,000 euros and will incur high costs for operation and for meeting the relevant legal requirements. Therefore, in the private sector the potential buyers will mainly be older drivers who are financially well off and can afford them. However, this group of buyers is particularly closed off to such vehicles.

Disruption to the "Harmony of the Flow of Traffic"

Studies conducted on people's intention to use, and subjective assessment of, highly or fully automated driving systems shows that it is younger and male drivers who demonstrate a more positive attitude and a greater openness to these types of vehicle, as do people with a greater need for "sensation seeking," i.e., thrill-seeking, variety, and adventure. However, it is to be expected that young, curious, and tech-savvy drivers who are much more open to these vehicles will not necessarily have the financial means required to buy and run one, and could in some cases feel that they are being deprived of driving pleasure and other secondary motives due to a "pre-programmed thwarting of their motives." As a result, it appears likely that we will see mixed traffic (comprising both manually driven and automated vehicles) on our roads for many years to come, with the idea of highly or fully automated vehicles frequently whizzing about in the coming decades still resigned to the realms of pure fantasy.

Experts consider that this mixed traffic will disrupt the "harmony of the traffic flow," as we will see a wider mix of speeds and distances maintained on our roads than is currently the case. Compared against manually driven vehicles, fully automated vehicles will drive at a much lower speed and keep further back from the vehicle in front because they necessarily have to comply with all applicable rules. This, in turn, has the potential to trigger a response by drivers of conventional vehicles, for example by overtaking or by driving into a gap between two vehicles.

If different types of vehicle share the same lane, this could result in further aggravation as drivers of conventional cars are nowhere near as compliant with the rules as they should be. Some of the most common rule violations on our roads include driving too quickly or too closely to other vehicles and a failure to give the right of way or adjust the driving style. These may well provoke frequent interventions in automated driving systems which are likely to be considered disruptive. At minimum this would result in a subjective loss of driving comfort, and possibly even traffic conflicts with the potential for damage, at least when the limits of the IT systems and the susceptibility of automatic monitoring and control systems to faults are taken into account.

In addition, there is naturally also the option of having only autonomous vehicles on the road. When the next new city is planned in Dubai or China, for example, it is conceivable that there may no longer be any provision whatsoever for manually driven private cars. Larger cities could also define specific areas reserved exclusively for autonomous vehicles.

Manually Taking Back Control From a Highly Automated System

A particularly tricky issue when it comes to vehicles at Levels 3 and 4 is traffic situations in which the automated system reaches its limits, meaning the driver has to take back manual control of the vehicle. This "decoupling" of

If the driver is too distracted by a secondary activity when the vehicle is being driven in highly or fully automated mode, they may not manage to take control of the vehicle if required.

The Need to Install Ever-More Efficient Driver Assistance Systems

Prof. Fernando Santos Osorio
USP/ICMC (Mobile Robotics Laboratory) Member of the USP Robotics Center (CRob Sao Carlos) and the USP Artificial Intelligence Center (C4AI) and Associate Coordinator of the Rota2030 Project

In the last decade, in Brazil, we went from more than 38,000 deaths in 2009 to about 44,000 to 46,000 deaths by 2014, and finally, we had a reduction in the number of traffic deaths from 39,500 to 31,300 between 2015 and 2019.

An extremely relevant first step in the context of managing public policies on traffic safety, including the implementation of ADAS to reduce fatalities, is the need to collect and have accessible and reliable data on the number of accidents, fatalities, and about their causes.

Decision-making must always be based on (good) data, where we can even decide which ADAS should be prioritized in their implementation in vehicles (such as mandatory items x accessories), sucDrah as ABS- Anti-lock Braking System, Air Bags, ACC - Automatic Cruise Control, PD/OD - Pedestrian and Obstacles detection, AEBS - Advanced Emergency Braking System, LDWS - Lane Departure Warning System, LKAS - Lane Keeping Assistance System, TSR - Traffic Sign Recognition, BSM - Blind Spot Monitoring, among others (also highlighting the V2V and V2X – Intervehicular Communication systems, which are also of great importance).

On the other hand, there is also a consensus that accidents are, nowadays, mostly caused by "human factors" since traffic in cities and on highways is still almost 100% controlled by humans. Even in situations where there are advanced intelligent systems, vehicle automation technologies and ADAS, traffic requires a "coexistence" between humans and technological systems. And the "human factor", with its limitations and other problems associated with the varied behaviors present in this human-technology "coexistence/coexistence", where human behaviors are often unruly, chaotic, irresponsible, and unpredictable, is what leads to many of the everyday accidents.

It is not enough to have an excellent autonomous car on an avenue or highway, it would be necessary for all vehicles to be automated and to have absolute control of the road conditions and the context in which they are inserted to have almost 100% safety on the streets/roads. This, however, will not happen in the next few years, and probably not in the next decade, especially in developing or poorer countries, which cannot automate their entire vehicle fleet.

That is why, in the coming years, we must invest in systems that help drivers, that allow increased safety through driver support (ADAS), that minimize damage when possible. Always acquiring and analyzing the data obtained, to "evolve" ADAS and public policies for road safety, and thus provide more and more security to vehicle occupants and people who somehow interact or share spaces with these vehicles. It is necessary to live together, to collaborate, between humans and technologies so that we can live better.

ADAS can significantly reduce the number of accidents, but for this to become a reality, public policies and governance are also needed for greater effectiveness in the implementation of ADAS in motor vehicles.

the automated system is called a disengagement and is systematically monitored and analyzed, particularly in California. The disengagements are subdivided into those initiated by the system ("automatic/autonomous") and those initiated by the driver ("manual"). At the instigation of the Californian Department of Motor Vehicles, all vehicle manufacturers are obligated to submit annual reports containing a range of information, including data on the disengagements that occurred.

Evaluations of these reports for the period 2014 through 2019 shows that as more time passed and more experience was gained with driving in fully automated mode, the number of disengagements initiated by the system on the Californian road network decreased. The researchers attributed this to the system adapting more effectively, including in complex driving situations. At the same time, a slight increase in the number of manual disengagements was observed. This suggests that people's trust in the technology is plateauing or declining, but could also be due to the fact that as the drivers gain experience with the system, they also gain a better understanding of where its limits lie.

If we look at the triggers and causes of disengagements, we can see that more than 80 percent were initiated by drivers who felt uncomfortable with the maneuver being made by the automated vehicle or who did not sufficiently trust the system and performed a manual disengagement as a preventative measure.

Adverse weather or driving conditions can also trigger disengagements.

The researchers categorized the causes of these into those relating to drivers (drivers of automated vehicles/other drivers with their vehicles), environmental factors & other, and those relating to the system (different stages of information processing: recognition = perception/localization/planning what to do/vehicle control). Most of the disengagements, both manual and automatic, were attributable to system-related causes, with three quarters due to mistakes in the automated system's perception, localization, planning, and control.

As a basic principle, drivers performed disengagements more often than the vehicle system. Most of the disengagements initiated by the system were related to hardware and software discrepancies as well as planning discrepancies. Almost all of the disengagements caused by the weather, road condition, or driving environment were initiated by drivers. In contrast, disengagements caused by planning discrepancies were not only initiated by drivers, but also recognized and triggered by the vehicle system.

Disengagements as Part of a Strategy to Prevent Accidents

The causes of disengagements during the first five years of the Californian program were compared with those from the last year that was reviewed. For 2019, this showed a clear increase in disengagements caused by the weather, road condition, and driving environment, from 12 to 31 percent. This can be explained by the fact that the vehicles are undergoing increased testing, including subjecting them to adverse weather and driving conditions that fall outside the specific application area defined by the manufacturers. In 2019 there were also fewer disengagements caused by hardware and software discrepancies and by perception discrepancies (18 and 9 percent) than in the first five years (26 and 21 percent), which indicates improvements in the vehicle design. The figures for control discrepancies (around 8 percent) and planning discrepancies (around 35 percent) did not change between 2019 and the five preceding years.

In this context, it is also interesting to look at the distance that was covered with each disengagement as an indicator of how mature the automated driving technology is. This distance increased on a sustained basis in the years in which a manufacturer took part in the Californian AVT program. If we look at Waymo, for example, we see that the initial figure of 629 miles (2014) increased to 13,219 miles per disengagement (2019). A similarly sharp rise was recorded for other development companies and license holders of technology for fully automated vehicles.

In another paper, academics from the University of Virginia in Charlottesville, USA, assessed the data records from the disengagement reports together with available accident reports and examined the correlation between disengagements and accidents. Their analysis looked at a total of 770 disengagements (from 2014 to 2018) and 124 accidents (from 2014 to 2019). The results showed that, in general, disengagements do not lead to an accident. Factors related to the automated driving systems (e.g., software errors) and factors related to other road users (e.g., incorrect maneuvers or conduct) increase the probability of a disengagement without an accident. In contrast, all aspects related to decisions made by the driver increase the probability of a disengagement with an accident.

Inadequate Situational Awareness

One problem has become apparent in the context of automated driving, which is that out in the real world, drivers predominantly do not receive any prior warning before manually needing to take back control from a highly automated system. However, this is not reflected in current research as it is dominated by a variety of studies where a prior warning was provided. The time required to take back control ranges between 2.8 and approx. 40 seconds depending on the task facing the test subjects, the type of warning given, and what exactly is defined as a driver safely taking back control. One key requirement for the driver to take back control is that they are able to correctly "read" the traffic situation, i.e., identify what is happening on the road and whether there is a danger, and then decide how to respond.

This complex process of interpreting a traffic situation is called situational awareness. According to Mica R. Endsley, it has three levels:

1. **Recognizing the presence of critical factors in your surroundings.**

2. **Understanding what these factors mean.**

3. **Understanding what the system will do in the near future.**

Different studies in this field show overall that there is a clear delay before this is achieved. Although situational awareness can be established relatively quickly at level 1 (in five to eight seconds), it takes over 20 seconds at level 2 – especially when the driver's task is to understand what other road users are doing.

A particularly critical situation arises when the driver needs to manually take back control from a highly automated system while they are preoccupied with a secondary activity such as reading a newspaper or using mobile apps. A report published by the German Insurance Association (GDV) in 2016 looked at this specific problem. The overview of different studies presented in this report showed a delay of between two and 20 seconds until the driver was able to complete the task they were faced with.

If they are holding a device in their hand, it takes much longer for them to take back control of the vehicle. And even if they are not holding a device in their hand, it will still take them longer to take back control if the task they are preoccupied with entails complex visual images and information. However, the findings obtained so far are not yet sufficient for a comprehensive analysis of all the situations in which drivers take back control of the vehicle, as most research looks at aspects of driving behavior after the driver has received prior warning about the need to take back control. Additionally, there are barely any journeys conducted under experimental conditions in the real world. Therefore, more studies on taking back control of the vehicle without a prior warning are urgently required. This is particularly important given current legislation in places like Germany, which prescribes the need to take back control of the vehicle if there is a danger to traffic or if systems are malfunctioning.

DEKRA Study on Taking Back Control From a Highly Automated System

A joint project, conducted under real-world driving conditions for the most part, was also carried out by DEKRA and TU Dresden at the DEKRA Lausitzring in Brandenburg. It examined how disruptions to the flow of information affect a driver's ability to take back control of the vehicle if system warnings are incorrect or missing. The researchers recruited a pool of almost 90 people to take part in the field study from among students at TU Dresden and the Senftenberg University of Applied Sciences, and via public networks, of which 36 ultimately took part in the test drives. Initially, the participants were not told about the real background to the study. They were between 19 and 48 years old, had held a class B driver's license for around eight years on average, and drove roughly 9,400 kilometers per year on average. For the testing, the vehicle used was modified to be a prototype for connected and highly automated driving. The systems enabled highly automated driving with full takeover of longitudinal and lateral control on a previously run-in route.

The test subjects drove around the circuit at the DEKRA Technology Center at the Lausitzring several times, keeping to a speed limit of 50 km/h. They were accompanied by a qualified DEKRA safety driver, who was able to intervene if necessary by braking. The lead experimenter was also present in the back and pressed a button at predefined points along the route to trigger different takeover scenarios. Various driving dynamics data, such as steering movements, braking force, and driving speeds, was transmitted and saved to a computer in real time for evaluation.

A "false alarm" was triggered during each of the tests, i.e., a warning to take over control of the vehicle although there was no critical situation requiring this. Additionally, there were three situations where the driver needed to take over control of the vehicle in order to avoid

There is an urgent need for more studies on drivers taking control of the vehicle without prior warning

Multitasking on the road is very risky

a dangerous situation, but the system failed to prompt them to do so (called a "silent alarm"). The silent alarms applied to driving over a stop line with a stop sign, slowly drifting over to the opposite lane, and performing a sudden evasive maneuver to avoid an erroneously detected obstacle. All four takeover scenarios were triggered after the test subject had already driven around the circuit several times without encountering any unusual events.

Some of the test subjects had the task of monitoring the automated drive passively and only intervening if they deemed it necessary. Another group was asked to perform a visually demanding secondary task on a tablet installed in a fixed position in the vehicle during the automated drive. The takeover was evaluated as successful if the test subject managed to perform the correct takeover steps before reaching the potential collision point.

Taking Over Control Can Be Problematic Even Without a Secondary Task

Overall, the takeover after a false alarm proved to be relatively unproblematic. All of the test subjects – in both the experiment group who had the tablet task and the control group who did not have a secondary activity – succeeded in taking over control of the vehicle. However, they needed an unexpectedly long period of time to do so – slightly over two seconds on average. The average reaction time reported in technical literature is 0.83 seconds, but in this case the control group needed an average of 2.44 seconds and the experiment group needed 2.24 seconds. This can be attributed to the fact that the test subject could not see any pressing need to take over control of the vehicle, meaning a sufficient level of situational awareness first needed to be established before they intervened. In the "silent alarm" scenario, participants in both groups had considerable difficulty in taking over control of the vehicle.

However, the number of unsuccessful takeovers was around double in the group that had the secondary activity in all scenarios. This means that, for the most part, the factor of a secondary activity reduces the probability of a successful takeover when there is a silent alarm. However, the researchers also noticed that even the test subjects without a secondary activity sometimes had considerable difficulties with taking over control of the vehicle. Depending on the scenario, in the experiment group with the tablet task, between 58 and 89 percent of the test subjects were unsuccessful in their takeover attempt after the silent alarm. In the control group, it was between 24 and 61 percent. The authors of the DEKRA study were surprised that in this control group, where there was no secondary activity, over 60 percent of participants were unsuccessful in their takeover attempt when driving over the stop line, and more than 30 percent were unsuccessful when drifting out of lane.

A Mix of Challenges

The study underlines once more that multitasking always entails risks when it comes to taking over control of the vehicle. For this reason, it is important to significantly reduce this safety-critical burden on the driver through clear design solutions. If the driver is preoccu-

In a field study, DEKRA investigated drivers' ability to take control of the vehicle when driving in highly automated mode, in some cases when they were preoccupied by a secondary task.

pied with a secondary activity which uses up similar visual and cognitive resources to the ones required for conventional driving, this will make it much more difficult for them to recognize system errors when the automated system is controlling the vehicle and make it harder for them to react promptly and appropriately.

On the one hand, we have the technology available today to enable drivers to stop concentrating on the road ahead while driving a motor vehicle, if only to a limited extent. However, on the other hand drivers always need to stay attentive and fulfill their obligation to manually intervene and take control of the vehicle if a malfunction occurs or the automated system reaches its limits. This, of course, creates a paradox: Automated driving is designed to eliminate human beings as a source of error, yet at the same time human beings are also expected to intervene correctly and without delay in an emergency (e.g., if the technical system fails). Some experts are therefore asking whether we should not, in fact, dispense with Level 3 vehicles altogether.

Despite these issues, if we consider extensive research conducted to date, fully automated driving also addresses a mix of challenges which are still in need of solutions. From the standpoint of passengers, fully automated driving largely resembles traditional methods of transportation by taxi, bus, or chauffeured car. However, the difference with fully automated driving is that there is no driver present in the passenger cell. In order to minimize the risks as far as possible, the underlying framework for fully automated driving should be designed to ensure that an adequate level of road safety is ensured for all road users and in all conditions, both now and in the future.

The requirements governing the Operational Design Domain for fully automated vehicles also need to be regulated clearly, as there is still a lot of uncertainty today. Can these vehicles only be deployed within a specific physical area, or do situational factors also influence how this area is defined? Should existing road traffic installations be used in mixed traffic, or should we aim to create custom design solutions for fully automated driving? How can we ensure that unauthorized vehicles or road users do not end up becoming safety risks? What physical and digital infrastructure measures are required when building roads?

Gaps in the Regulatory Framework

Another crucial aspect is data protection in all its facets – in particular software updates and cyber security. In light of the "third party principle," new challenges are arising due to the need to monitor and check all the hardware and software involved in driving the vehicle. This is where the relevant testing organizations and their technical expertise come into play, as it is essential that all software updates are included in monitoring cycles.

Considering these issues, we can see that there are a number of gaps in the regulatory framework. Scientists working in the field of human–machine interfaces are being confronted with a range of questions which we still do not have answers to, meaning more research is expected to be required. In order to make the goal of "Vision Zero" a reality, the public sector will need to manage this research on a systematic basis and provide adequate funding for it. In any case, it will be interesting to follow how evidence-based legislative initiatives in the field of fully automated driving end up being further developed, tested, and implemented in practice. Given all the euphoria concerning the benefits of digitalization in our great new automotive world, we can only hope that political ambition, technical system limits, and the pursuit of profit do not come at the expense of the "human factor" and cause an increase in accident figures.

The Facts at a Glance

- **Innovative touchscreen technologies with intelligent user guidance reduce the number of incorrect entries made and the time taken to input requests, which also minimizes road safety risks caused by distractions, for example.**
- **Key factors that determine whether users accept driver assistance systems are having a positive attitude to the system in question, the benefits the system is perceived to offer, and how user-friendly it is.**
- **In some cases, assistance systems can themselves become direct sources of distraction or interference while driving.**
- **Analyses of data records from California prove that drivers themselves decouple automated systems (known as a "disengagement") more often than the vehicle system does.**
- **A study conducted by DEKRA shows that in some cases, the test subjects have considerable difficulty in taking over control of the vehicle if it is being driven by a highly automated system – even if the driver is not preoccupied by a secondary activity.**
- **The underlying framework for fully automated driving must be designed to ensure that road safety is ensured for all road users, regardless of the situation, both now and in the future.**

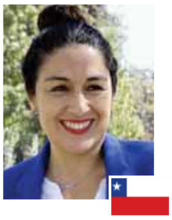
Detecting Hazards Early on and Intervening

We have more or less exhausted all of the ways that passive systems can increase safety in road traffic. Driver assistance systems, on the other hand, still offer a wide range of opportunities for preventing accidents or mitigating their consequences. Crucial to this is that drivers understand the purpose of the assistance systems and, in particular, understand their limits. There is also still the potential to get even more out of conventional active and passive safety systems – when used in conjunction with modern assistance systems. Of fundamental importance is that the various different systems remain functional throughout the entire service life of the vehicle. In future, the manner in which these are inspected will be more and more data-driven.

For a number of years now, it has been standard practice to equip modern motor vehicles with information and assistance systems in a bid to improve comfort and safety. These include a navigation system with congestion bypass recommendation function, adaptive cruise control, lane guard assistant, automated emergency braking, blind spot assistant, turning assistant, fatigue warning system, camera-based active light systems, night vision assistant, electronic stability control, and much more. Together, these systems help to inform and assist the driver, and to compensate for their errors if necessary, thus reducing the risk of an accident.

Yet despite all the additional safety systems, drivers still have to adapt their driving depending on the situation – the road and visual conditions for example – as even the best systems cannot change the laws of physics. The vehicle also has to meet several basic requirements in order for the systems to be effective, such as having a functioning braking system (mechanics, hydraulics or pneumatics, sensors, actuators, and electronics) and ensuring that the respective systems are not switched off. Another point to consider is that some systems only work based on certain conditions, including the lighting conditions, the ambient temperature, the weather, the condition of the road markings, and the speed at which the vehicle is traveling. And finally, current vehicle systems for active safety are only fully effective in terms of passive safety and accident consequence mitigation if vehicle occupants wear their seat belts and adjust their seats to the right position.

There Is Still a Lot of Work to Do



Karina Muñoz Matus
Executive Secretary of the National Road Safety Commission (CONASET)

Since the dawn of mankind, humans have always striven for improvements, solutions, and innovations, and looked to develop and use technologies to achieve these goals. Over time, most technological developments become the norm and improve our quality of life, but they also present us with new challenges that have to be overcome. Advancements in technology should help humans and provide solutions to our daily problems, making all of our lives more comfortable and safer, otherwise they are not worth it.

Over the years, there have been some important technological developments that have contributed to the difficult undertaking of reducing the number of fatalities and injuries caused by traffic accidents. Some of those that are used in our country or are in development include: the integration of technology in the monitoring and scanning for dangerous driving behavior, improvements in vehicle technology, the transition to digital systems for driver's licenses and the entire information management system connected with this process, the processing of statistical information, and the integration of different information sources to help make data analysis more comprehensive and to make it easier to steer public policies for greater road safety.

We undoubtedly still have a long road ahead of us and there is a lot to do. But if the focus is placed on humans and specifically their safety in the context of mobility, technological progress is bound to pick up pace and produce better outcomes.

A short look into the past shows that the many technological achievements of the 20th century, such as radial tires, the disk brake, rigid passenger compartment with crumple zone, and safety steering shaft, have provided the building blocks to enable us to develop the efficient systems for vehicle occupant and road user safety that we use today. For example, good controllability, especially of the hydraulic disk brake, was a significant prerequisite for assistance systems like the ABS, which prevents the wheels from locking during a braking operation, and the ESP, which stabilizes the vehicle in extreme situations. The ability to maintain a constant speed with cruise control and the availability of sensor technology led to the development of adaptive cruise control (ACC) with collision warning, and from there ultimately to automated emergency braking – which now has the ability to decelerate the vehicle until it comes to a standstill. Similarly, from the lane departure warning system evolved the lane guard assistant, which actively intervenes in the driving and brings the vehicle back into lane with a precise braking or steering intervention. Key to ensuring that the lane guard assistant performs the appropriate braking and steering intervention are the servo brake and power assisted steering system. For their part, ACC and lane guard assistant combined provide the basis for Level 2 driving (semi-automated driving), in which the vehicle maintains its lane and brakes or accelerates independently based on defined conditions and the driver's specifications.

Correctly Configured Sensors Are Crucial to Ensuring Safety

As already mentioned, sensors play a key role in the functionality of driver assistance systems. They are the vehicle's "sensory organs" and are fundamental to ensuring that the vehicle can detect the current driving status and driving situation, as they provide the necessary information and data. The sensors are often designed on the basis of camera technology. Modern systems also have radar or lidar sensors in order to produce reliable results even in the dark and, in some cases, in adverse weather conditions – for example to be able to detect road markings as well as people, animals, and vehicles.

The vehicle can detect when sensors reach their limits and warns the driver if the system seems likely to fail. But what happens if there is a slight misalignment in the sensors, such that the vehicle doesn't yet report a fault? This is a question that DEKRA experts tasked them-

Driver Assistance Systems Help Make Huge Leap in Quality of Safety

Jorge Ordás Alonso

Deputy Director General for Mobility Management and Technology of the Dirección General de Tráfico (DGT)

On November 27, 2019, Regulation (EU) No. 2019/2144 of the European Parliament and of the Council on type-approval requirements for motor vehicles and their trailers, and systems, components and separate technical units intended for such vehicles, as regards their general safety and the protection of vehicle occupants and vulnerable road users was introduced, amending various other regulations.

This regulation represents huge progress in relation to the requirements set out by the European Union on the safety of the motor vehicles manufactured within its jurisdiction . It also represents a significant change in philosophical approach, as it focuses on protecting vulnerable road users, in contrast to the previous approach, which focused exclusively on protecting vehicle occupants.

For this, various different driver assistance systems have been introduced, which represents a huge leap in the quality of the safety concept, and once again sees Europe playing a leading role in the introduction of measures for preventing traffic accidents and their consequences. To ensure that these systems are introduced effectively and to enable them to be continually monitored for compliance with the EU regulation, an ambitious implementation schedule has been set out based on the vehicle type, both for the type approval process (which has been significantly tightened) and for new registrations. For example, since July 6, 2022, it has been mandatory for all registered trucks and buses to be equipped with automated emergency braking, a lane guard assistant, and speed limitation systems.

In terms of passenger cars, since July 6, 2022, it has been mandatory for all vehicles with type approval to have a whole array of systems, including a crash recorder, an attention assistant, an interface for integrating a breath alcohol measuring device, automated emergency braking, an intelligent speed assistant, a tire pressure control system, and adaptive cruise control. From July 6, 2024, all newly registered cars will also have to feature these systems.

Keeping to these deadlines will help the industry make the desired leap to vehicle automation. This leap will enable vehicles in Europe to reach automation Level 2, which will pave the way for the next innovation steps needed to achieve fully automated vehicles. The regulation envisages that this, in turn, will ultimately reduce the number of accidents caused by human error by more than 90 percent.

In Spain, over 50 percent of all accidents occur in towns and cities, and 80 percent of all fatalities are vulnerable road users, such as pedestrians, cyclists, moped riders, and motorcyclists. These types of road users are at particularly high risk in towns and cities, as the combination of speed, distraction, and the element of surprise can have dramatic consequences. The driver assistance systems stipulated by the EU regulation will contribute to reducing the number of accidents and their consequences in our towns and cities.

selves with answering by conducting test drives on the DEKRA Technology Center grounds at the Lausitzring in Brandenburg, Germany. The aim was to establish the consequences of sensor misalignments. In the first case (A), the experts deliberately manipulated the front camera below the self-diagnosis threshold. Due to the seemingly error-free condition in the self-diagnosis, the driver would therefore not expect any limitations at all. The experts then evaluated the effects on the vehicle's behavior in standard emergency braking scenarios. In the second case (B), the experts tested the behavior of the blind spot assistant with it installed incorrectly or with the rear radar misaligned, a typical consequence of bumping into something when parking.

Case A was tested with three different test vehicles, each of which had an automated emergency braking function and highly precise measurement technology. The DEKRA experts ran two standard Euro NCAP scenarios (collision with a stationary vehicle or target, and detection of a pedestrian dummy on the road). The vehicles were configured to travel at speeds of 20, 40, and 60 km/h. When the camera was aligned properly, all three vehicles warned the driver in time and applied the brakes, bringing the vehicles to a standstill before hitting the respective target. The alignment of the front camera was subsequently altered below the self-diagnosis threshold. As a result, one of the test vehicles collided with the stationary vehicle in all attempts, even at 20 km/h, another could only have prevented a collision at 20 and 40 km/h, and only one of the three vehicles triggered a warning and braking operation in time at all three speeds. At 60 km/h, the pedestrian would have been hit by all three vehicles with the sensors just marginally impaired. And even at 40 km/h, the assistance systems in two of the three test vehicles neither triggered a warning nor intervened with a brake activation.

This means that even just a slight misalignment in the front camera can result in a safety-jeopardizing malfunction that the system, and therefore the driver, is unable to detect. These kinds of misadjustments can occur as a result of the windshield not being replaced properly, for example. As the sensors are essential to ensuring that the assistance systems function properly – as once again demonstrated by the DEKRA tests – it is imperative that these be tested as part of the periodic vehicle inspection. Given that sensors are usually installed in slightly obscured locations, conducting a purely visual inspection of the sensors is equally as insufficient as reading the self-diagnosis of the vehicle. DEKRA is therefore already working on alternative technological testing methods.

Correctly configured sensors are essential for road safety

The need to test the sensors during the periodic vehicle inspection naturally also applies to systems other than the front camera, such as the rear radar, as demonstrated in case B. The DEKRA experts carried out a simulation of a scenario that occurs time and time again on freeways: one vehicle is traveling in the left lane at high speed, while the driver of a vehicle in the right lane wants to overtake the vehicle in front and starts to pull out. For the test, the position of the rear radar was misaligned so that it was slightly transverse to the direction of travel – once again within the calibration limits so that there was no error detection during self-diagnosis. The blind spot assistant failed to warn the driver until the vehicle approaching from behind was much too close, so it would clearly have been too late to prevent an accident had this lane-changing maneuver actually been carried out.

After replacing the windshield, camera-based systems like automated emergency braking and lane guard assistants have to be recalibrated.

DEKRA conducted test drives with articulated vehicles from three different truck manufacturers to test the effectiveness of their respective automated emergency braking systems.

DEKRA Test Drives With Truck Automated Emergency Braking

Driver assistance systems in trucks are also key to improving road safety, in particular when it comes to accidents that occur at the tail end of congested traffic. These can be extremely hazardous for vehicle occupants, and it is not uncommon for those caught up in accidents involving heavy-duty goods vehicles to be severely or fatally injured. If a truck approaches a stationary or slow-moving car at a much higher speed, the car is likely to sustain extreme deformation damage and the consequences for its occupants will be catastrophic. More often than not, several vehicles will pile up into one another. When one truck crashes into the back of another truck, the occupants of the truck behind are often seriously injured. And even when a car drives into the rear of a truck that is stationary or driving at a comparatively low speed, the accident is often fatal for the car occupants.

Although optimizing the compatibility of the structure of the vehicles can help to a certain extent, the higher the difference in speed, the quicker the physical limits are reached. The mass of heavy-duty commercial vehicles is so great, that any passive safety measures are limited in their potential to mitigate the consequences of an accident. Accident prevention or accident severity reduction through the use of driver assistance systems is therefore the area where the most effective improvements can be made. This involves using suitable means to draw the attention of distracted drivers back to the traffic situation in time and to trigger a braking operation automatically directly before a collision becomes unpreventable. The efficiency of the automated emergency braking system, which has been a statutory requirement in the EU for a number of years now, was recently reaffirmed in a study published in March 2021 by the Insurance Institute for Highway Safety and the Highway Loss Data Institute. The study found that, between 2017 and 2019, the system reduced the number of truck rear-end collisions on US highways by 41 percent.

Yet there is still the question of why, despite the statutory requirement for vehicles to have automated emergency braking, catastrophic accidents sometimes still occur at the tail end of traffic jams. Is the technological potential of the systems possibly not yet being fully leveraged due to the current statutory minimum requirements? To find out, and to test whether the driver's behavior can unintentionally affect the effectiveness of the assistants, DEKRA conducted special test drives with trucks from three different manufacturers on the grounds of its Technology Center at the Lausitzring. To make them viable for tests, the vehicles were equipped with measurement technology and robots (steering and pedal actuators). The trucks drove at a speed of 50 km/h in a straight line toward a stationary dummy car, aiming for the center rear, so that it would hit 100 percent of the target.

Manual Additional Braking Can Improve Effectiveness

The researchers conducted five different variants of the test. The first variant tested how the respective automated emergency braking

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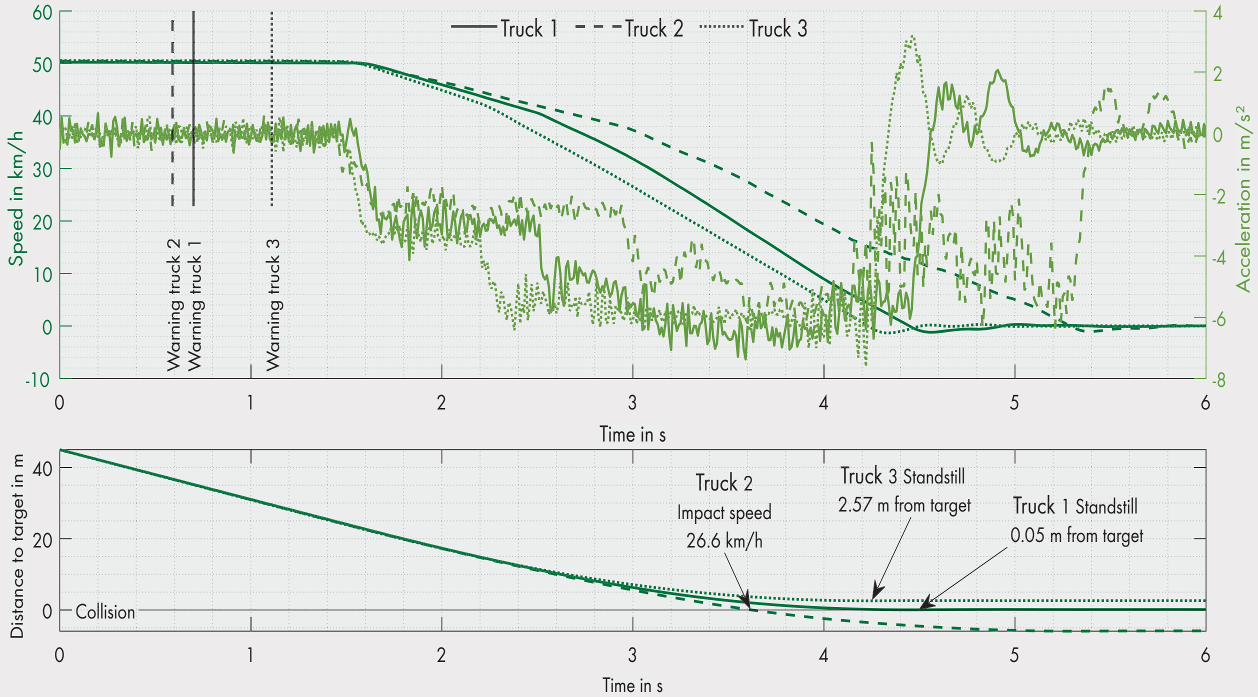
Comparison of the Three Truck Automated Emergency Braking Systems Tested in the Standardized Test

The measurement data was synchronized such that all of the trucks reached the illustrated area of 45 meters in front of the target at the same time and at the same speed. We can see that the different systems provided visual warnings at different points in time. Truck 2 was the first one to trigger a warning about the obstacle, and truck 3 was the last.
This was followed by a moderate deceleration in the collision warning phase and, thus, a reduction in speed. Next came the automated emergency braking phase, which involved decelerations of > 4 m/s² for all of the trucks, as per legal requirements.
The trucks differed in the points in time that the above-mentioned system events occurred and in the intensity of the braking decelerations. The trucks from manufacturers 1 and 3 came to a halt before the obstacle: for manufacturer 3, the distance to the dummy vehicle was a good 2.6 meters, but for manufacturer 1, it was only five centimeters. Although the system in the truck from manufacturer 2 decelerated the vehicle, it was unable to prevent it from colliding with the dummy vehicle. Nevertheless, it did manage to reduce the collision speed down to 27 km/h.



Source: DEKRA

systems performed without intervention from the driver. The other four variants comprised simulations in which the driver intervened with a different braking force and steering intervention. Robots were used to ensure the tests were identical across the different trucks. These were configured to trigger a driver intervention as soon as they detected in the collision warning phase that the truck's automated emergency braking system had already reduced the vehicle's speed by 2 km/h. The test drives without driver intervention clearly showed that the truck manufacturers' assistance systems differed considerably in design when it came to warning and braking behavior. This is illustrated in more detail in **Figure 8** and shows that, in the same traffic scenario, there are different design philosophies for automated emergency braking systems – from collision prevention to the statutory speed reduction by 20 km/h.

In all of the further simulations, the truck from manufacturer 1 triggered a warning and braking operation that brought the vehicle safely to a standstill, and it remained "unperturbed" even after the driver's interventions. With the truck from manufacturer 2, the driver's intervention produced a slightly improved outcome: a strong braking intervention reduced the collision speed to 15 km/h, and a strong steering intervention enabled the truck to at least drive past the dummy car – facilitated by the speed reduction brought about by the automated emergency braking system. A moderate steering intervention would not have been sufficient. So, although the system from manufacturer 2 meets the statutory minimum standards with regard to the prescribed 20 km/h minimum speed reduction, it is unable to reliably prevent rear-end collisions. Nevertheless, the early warning would give the driver enough time to react in most cases. The warning and braking operations triggered by truck manufacturer 3's system were reliable for the most part. However, the moderate braking intervention by the driver already caused the automated emergency braking system to switch itself off, thus depriving the driver of its safety-relevant functionality. **Figure 9** illustrates this unexpected behavior by the system and shows that the statutory requirement to be able to override the system can lead to accidents, depending on the design of the system.

In a further test, the boundary conditions of the standardized test were changed for one of the trucks. For example, the scenario was carried out in a slight bend rather than on a straight line. In this test, the automated emergency braking system triggered a warning just nine meters before the obstacle – significantly later than in the standardized test (27 meters). Initially a reliably preventable accident, the collision now occurred with the vehicle traveling at over 30 km/h. The tested change in vehicle contact overlap also produced considerably poorer test results.

Summary: There is no doubt that the tested truck automated emergency braking systems comply with the legislation. But a comparison of the manufacturers' system designs and the effectiveness of a manual additional braking operation show that the technical potential of these systems is not being ful-

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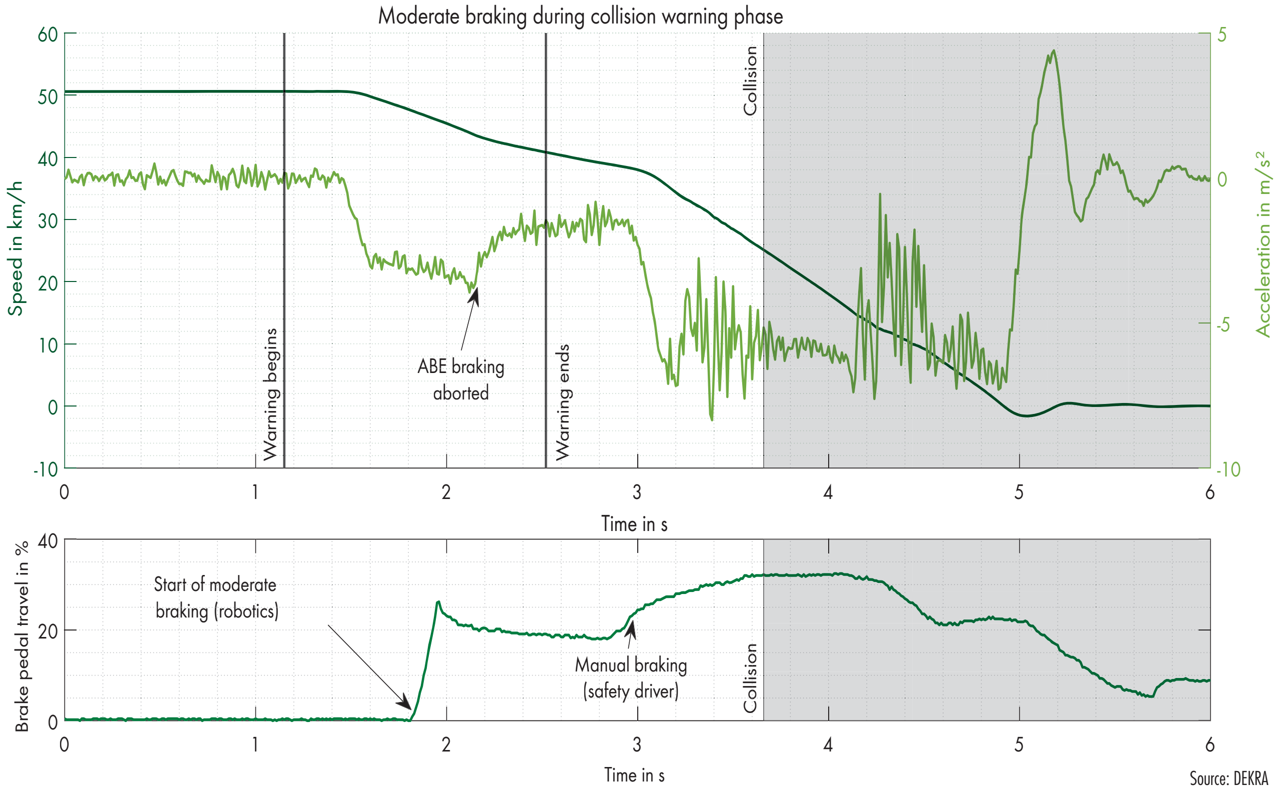
Assistance System Aborted Automated Emergency Braking Despite Hazard

Just like in the test case without manual intervention, the AEB system (Autonomous Emergency Braking) in the truck from manufacturer 3 first triggered a warning signal (from 1.2 seconds), which was followed by the collision warning and braking phase (from 1.5 seconds). From 1.8 seconds at around 20 meters before the target, the test robot applied moderate pressure to the brake pedal. We can see that the figure shows no additional deceleration, as this manual braking effect was below the braking effect of the assistance system during the warning and braking phase. At 2.2 seconds, the deceleration fell to the level of the moderate braking operation applied by the robot, which caused the AEB system to terminate the active braking process. At 2.5 seconds, which was around 12 meters before the target, the warning light of the AEB system also disappeared, which meant that the system was suddenly completely deactivated. The vehicle remained in this state for 0.5 seconds until the safety driver intervened and applied the brakes (shown by the increasing pedal travel and the greater deceleration) in order to prevent causing greater damage to the test equipment. Despite the intervention, it was ultimately not possible to prevent a collision, even though the same truck had reliably managed to do this before without the brake pedal being manually actuated. In this instance, it collided with the target while traveling at 25 km/h.



Source: DEKRA

ly leveraged by current regulations. The systems also showed, in part, strong interdependencies with the driver's behavior: in one instance, the emergency braking function aborted when the driver intervened, despite the hazardous situation. The fact that different manufacturers have different interpretations of the legal requirement for drivers to be able to override driver assistance systems at any time can cause major problems, especially when haulage or fleet drivers alternate between driving truck models from different manufacturers. A discussion about how to standardize the system designs would therefore be desirable.

DEKRA's tests also showed that the performance of the systems is considerably inferior when deviating from a "standard" situation. Manufacturers should therefore devise a much more diverse set of tests to test the functionality of their systems and test them in a wider array of scenarios. Moving forwards, the legal requirements need to be tightened so that the systems function more reliably in real traffic situations. Although the changes to the minimum requirements decided by the UN are a step in the right direction, countries now need to act quickly to turn them into legislation.

Seeing and Being Seen

Given that our roads are becoming increasingly densely packed with traffic, there has never been a more important time for motor vehicles and their trailers to be equipped with lighting and light signal sys-

Utilizing Potential and Optimization Opportunities

Dr. Othmar Thann
Director of the Austrian Road Safety Board

Active safety systems and driver assistance systems (DAS) experienced rapid further development towards the end of the 20th century. Advanced DAS can significantly help to prevent accidents and mitigate their consequences and substantially reduce the risk of road accidents. However, there is still the need to assess what opportunities these systems present for improving safety, as well as the potential risks they pose, especially if the aim of such systems is to increase user comfort and take the load off the driver in the long term.

The inherent potential of active safety systems to increase road safety has not only been proven in countless research projects, but has also been recognized at a political and legislative level. For vehicles belonging to classes M2, M3, N2, and N3 (buses and trucks), it has been compulsory for manufacturers to equip new vehicle types with automated emergency braking systems with obstacle detection and moving vehicle detection since November 2013. In November 2015, it became compulsory for new registrations, as well.

Despite this, there is still a substantial lack of awareness around driver assistance systems in the general population, for example in Austria: a survey conducted by the Austrian Road Safety Board (KFV) showed that one in five Austrian consumers felt (completely) uninformed about the topic of automated driving. On the flip side, the KFV survey also showed that modern technical assistants are considered to be important and that this importance is set to grow in future: more than half of those surveyed said they thought it important for any new car they might purchase to have driver assistance systems, listing the parking assistant, the adaptive cruise control, and automated emergency braking as the systems they would prioritize.

To be able to maximize the potential of these assistance systems, there is a need for knowledge relating to the functionality and operation of these tools. Society has to be brought up to speed and given the necessary knowledge, a mission in which the media and education sectors are likely to be highly involved.

There is a long way to go in educating the population about DAS. A large proportion of those surveyed were also in favor of making learning about DAS a core part of general driver training in future and should include both practical and theoretical elements. Almost 60 percent were even willing to attend a half day course about DAS.

People learning to drive today will spend a long time as active road users. If you consider that new vehicles are already equipped with several useful assistance systems, it becomes clear that knowledge and the practical application of DAS must be factored into driver training. The need for action is evident.

Lighting systems have potential to increase road safety

tems. Crucial to a road user's ability to handle traffic situations is being able to see other road users, being seen by them, and communicating with them, if necessary. In the dark, the most critical factor is being able to quickly and clearly understand the signal pattern of a vehicle and identify its particular design and usage types.

This is another area where new challenges are set to emerge in the context of highly and fully automated driving. If this high level of automation is to be a success, including on international roads, there will be no alternative but to introduce standardized specifications for the type, number, light color, and installation position of active and passive vehicle lighting systems. The fundamental requirements for this were initially set out in the "Vienna Convention on Road Traffic" international treaty in 1968. Two of the key specifications that now govern the construction and distribution of motor vehicles and their trailers are the internationally harmonized EU and UNECE policies, which contain substantially more detail than previous policies.

Even though lighting systems on modern vehicles are often somewhat conspicuous in design and functionality, they must always be approved within the current regulations and their updates. Against this backdrop, DEKRA has repeatedly made the case for leveraging the untapped potential of further refining conventional standard light signal systems, which would help to make their intended effects easier to identify. For instance, optimizing the way the turn signal is used to signal different events is one area with room for improvement, as the following two examples will show.

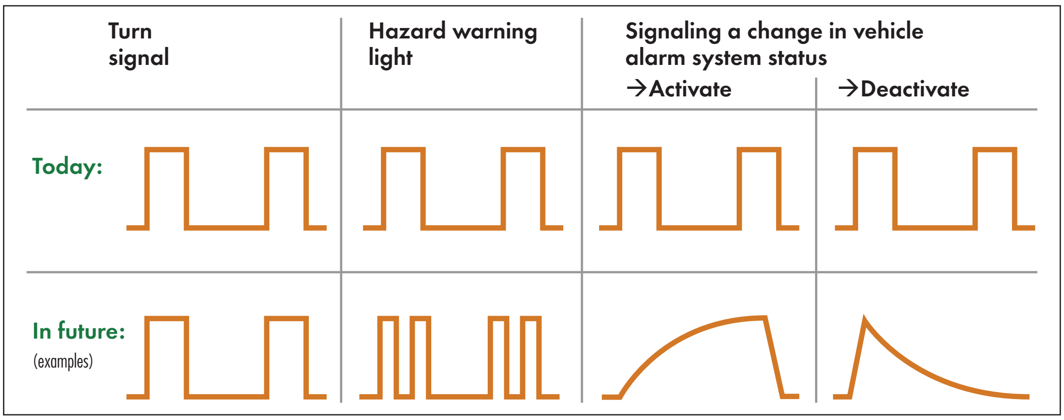
Progress Creates Opportunities for Further Improvements

The first example concerns the situational differentiation of light signal pulse patterns. Back in the 1990s, there were already deliberations around modifying the hazard warning signal to emit a double flash pulse as a way of communicating hazardous situations more clearly. The optimized pulse pattern not only improves the warning effectiveness, but also allows that particular signal pattern to be differentiated from others.

These days, for example, the amber indicator light is used to signal either an intentional change in driving direction, a general hazard (hazard warning light), activation of the emergency brakes (a recent addition), and activation or deactivation of the anti-theft alarm. Due to the multi-functional purpose of the turn signal, the DEKRA experts think that attempts should be made to differentiate the four different signals in the future. Even if the rear end or front of the vehicle is half-concealed (a regular occurrence in both congested or flowing traffic), using a double flash pulse for the hazard warning light function creates differentiation and, by way of the unique signal pattern, helps to improve safety.

Saving Lives With Simple Means

The other example concerns using the vehicle's lights to delineate more clearly a driver's intention to change lanes or turn off, especially when it comes to large commercial vehicles. The backdrop to this is the following question, which the committees responsible for vehicle light technology urgently need to readdress: how can signaling be optimized and used to more effectively counter the acute danger that these driving situations continue to pose to road users?



Source: AG Technik as part of the Road Safety Steering Committee in the Free State of Saxony

Against the backdrop of new and advanced technological ways of representing differentiated/harmonized signal patterns, the responsible international committees should revisit the discussion around the untapped potential in the optimization of the light signals that vehicles have to or are allowed to emit.

As a potential solution to this, paragraph 6.5.3.1 was added to UN Regulation No. 48. It stipulates that, as of October 8, 2015, it has been mandatory for any new heavy-duty and long commercial vehicles and their trailers seeking type approval to be equipped with at least three additional category 5 or 6 side turn signals. This level of signaling improvement can also currently be achieved if there are "at least three amber side marker lamps that flash in phase and simultaneously with the turn signals."

However, this extremely welcome approach should be put to test with a view to further improving the optical perceptual safety of this particular (hazard) signaling. Given the pace of technological development, permitting the use of the substitute variant with side marker lamps that flash in phase with the turn signals, as well as the use of category 5 turn signals, should be subject to a time limitation. The prescribed minimum light intensity of category 5 turn signals is merely 0.6 candela, whereas for category 6 it is 50, which makes these much easier to perceive. This is why DEKRA is proposing that the side marker lamps (potentially already in combination with side reflectors) be developed into compact side position lights with integrated and complete flash function via category 6 turn signals.

In conjunction with the turning assistant, this would give future vehicles an even more effective and potentially life-saving danger-averting instrument that protects both the driver and any at-risk road users.

The Consequences of Modern Operating Concepts

The progressive digital transformation of society reached the cockpits of our vehicles some time ago. A few years back, it was still physical (rotary) switches and buttons with haptic feedback function that served as the driver-vehicle interaction instruments. Fast forward to day, and we find that most modern vehicles have touch displays and touch-sensitive buttons. However, this modern technology does pose an important question for accident research: given the often hampered accessibility of the controls – buried

Technical Vehicle Inspection Set to Become More and More Data-Driven

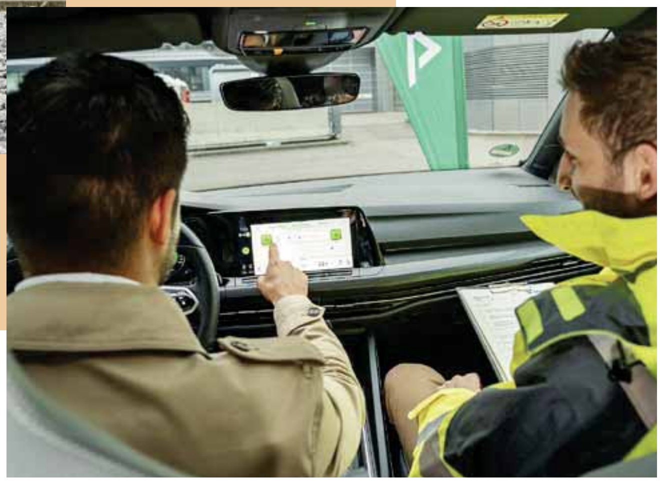
It is important to ensure as far as possible that any assisted and automated driving systems installed in a vehicle, as well as their safety-relevant mechanical components, function reliably for the entire service life of the vehicle – that much is clear. Only then are they able to achieve their desired effect. For this reason, periodic vehicle inspections, which many countries around the world have been conducting for many years now, will become even more important in future than they already are today.

Given the increasingly important role that software, sensors, and control units play in vehicle safety, it will soon no longer be sufficient to test the state of the art merely every two years, for example. In the medium term, there will be a need to inspect vehicles on an event and occasion basis, especially because vehicle manufacturers are increasingly set to provide firmware and software updates wirelessly "over the air" rather than via a cable in the workshop. A vehicle can become fundamentally different within moments if, as a result of a software update, safety-relevant driving functions relating to assistance systems or automated driving functions are changed. There are also substantial risks associated with these kinds of over-the-air-updates – the risk of hacker attacks being the most significant.

Especially after traffic accidents and traffic offenses, it will become increasingly important to establish the causes and who or what was responsible. Was a human doing the driving? Or was the automated system in control of the vehicle? And was there potentially a fault in the automated system? To enable all safety and environmental systems to be independently inspected for damage, malfunctions, and manipulation at any point throughout the entire life cycle of the vehicle, testing organizations like DEKRA will require direct, unfiltered, and non-discriminatory access to the original (i.e., unchanged) safety and environmental data from the vehicle. This will also ensure that the organizations are able to fulfill their statutory duty in accordance with EU Directive 2014/45. The data that is made available should also include the vehicle's history.

Periodic technical inspections uncover technical faults in vehicles, thereby helping to reduce accident risk.

In the tests conducted by DEKRA Accident Research, the test subjects had some considerable difficulties in using the operating functions in the vehicle.



somewhere in the menu – and the distraction caused by searching for and finding the relevant function, does this new technology put road users at a higher risk in traffic?

To find some answers, DEKRA Accident Research conducted a test in which 80 participants were asked to perform safety-relevant tasks in two test vehicles. The chosen test vehicles were two different generations of the same model that had seen a high number of sales and new registrations in Germany. This ensured that the test subjects were not confronted with two entirely different operating concepts. The age difference between the two test vehicles was ten years (model year 2012 and model year 2022). The tests were carried out with the vehicles in a stationary position and the ignition on.

In terms of demographics, there were 35 female and 45 male participants and the average age was 36.5, with 50 percent of the participants being between 29 and almost 52 years of age. The participants all owned vehicles that were significantly newer (registered after 2015) than the older test vehicle. Just under 54 percent of the test subjects drove more than 10,000 kilometers per year, around 24 percent between 5,000 and 10,000 kilometers, around 11 percent less than 5,000 kilometers, and around 11 percent did not own a car.

The test subjects were asked to perform the ten following tasks:

1. Switch on the windshield wipers and set them to the fastest level or the fastest available wiping interval.
2. Switch on the windshield ventilation to the maximum level.
3. Switch on the radio, select a specified station, and then turn the volume down to zero.
4. Switch on the rear-window heating.
5. Switch on the low beams.
6. Switch on the fog lights and the rear fog lights.
7. Switch on the hazard warning lights.
8. Operate the flasher once and then switch on the high beams.
9. Switch on the mirror heating.
10. Lower the temperature in the vehicle by two degrees.

Handing Over Control to an Electronic System Requires Radical Rethinking

Prof. Markus Caspers
Professor for Design and Media, Head of the Communication and Design for Sustainability degree program and Head of the Competence Center Corporate Communications at the Hochschule Neu-Ulm (University of Applied Sciences)

The user experience (UX) of a vehicle has already been a core element in the vehicle's interior design for a number of years. With continuing progress in vehicle automation, or "autonomous driving," switching from being a passive passenger to being an active driver will be a major challenge. The typical layout of a car, with its steering wheel, dashboard console, and two rows of seats facing the direction of travel has become second nature for us over the decades.

This is why, with autonomous driving, handing over control of the vehicle to a control system driving requires radical rethinking and complete trust in the safety and reliability of such systems. It is possible that there will be areas on the interior displays, similar to emergency-off switches on machines, which can be immediately activated in critical situations, enabling control of the vehicle to be handed back to the passenger. Artificial intelligence-based voice command systems will moderate the dialog between the vehicle occupants and the vehicle and act as an interface between humans and the machine.

We will also have to rethink how to best design the interior of vehicles: in the future, it will be possible to modify the vehicle interior by app – right down to personally configured displays that can show different content and cover the whole interior. Vehicles will assume a new role as an extension to our living space, as a mobile office, or as a personal place in which to retreat, with the UX focusing on comfort and well-being. Designing the interior to be able to facilitate a sudden switch from "comfort" mode to manually controlling the vehicle will be an immense challenge.

20 years from now, when hardly anybody has a driver's license because there is a sufficient fleet of autonomous vehicles, how can we ensure that it will be possible to switch to manual control, if required? The challenge for designers will be to design a multimedia and multi-sensory experience, for example with voice-assisted control commands, interchangeable window and colored roof panels, and travel information that can be accessed via touch screens.

Participants Somewhat Overwhelmed in Modern Vehicle

On average, the test subjects needed considerably more time in the newer vehicle for all of the tasks, with some even taking more than twice as long – for example for tasks 2 through 5. The likely reason for this is that the arrangement of the controls in the newer vehicle was different to the arrangement that they may have been used to. For example, to switch on the windshield ventilation to the maximum level in the modern vehicle, the test subjects had to press a touch-sensitive button or control knob. Although straightforward in concept, these touch buttons were actually located on the left side of the cockpit, and not, as the test subjects were used to, on the center console. Most of the test subjects, therefore, did not find them straight away – their immediate reaction on this question being to look at the center console. Here the test subjects could also switch on the maximum windshield ventilation via the "climate" menu and sub-menus on the touchscreen. However, this took significantly more time and, most importantly, diverted their gaze and distracted them for much longer – which in a real traffic situation would have distracted them from the driving.

Modern operating concepts often require an intensive induction

Some of the tasks, for example 1, 7, or 9, took a similar amount of time to complete in the newer vehicle – sometimes slightly less. However, this was mainly because the test subjects had already learned what to do in the older vehicle. This learning effect was also apparent on task 8 (activating the high beams). To a certain extent, it was even more significant than on the other tasks, as even in the older vehicle many of the test subjects did not know – or had to experiment with the controls to realize – that the high beams could only be switched on if the low beams or parking light were activated, as stipulated in the regulations. They consequently took this knowledge with them into the newer vehicle. **Figure 10**

The test subjects were given 30 seconds to complete each task, but if this time frame turned out to be insufficient, the attempt was aborted. A clear picture emerged here, too: in the newer vehicle, considerably more of the test subjects were unable to complete the tasks within 30 seconds compared to in the older vehicle. Once again, tasks 2 through 4 (windshield ventilation, radio, rear-window heating) proved challenging in this respect in the new vehicle. The test subjects' age only played a minor role in the time it took them to complete the tasks. **Figure 11**

Grouping the test subjects according to whether they personally owned or did not own a vehicle by the same manufacturer as the test vehicles also had an interesting impact on the results. Those that did own a vehicle from the same manufacturer completed almost all of the tasks in the older test vehicle faster on average than the test subjects who usually drove a vehicle from a different manufacturer. In the newer test vehicle, the results were more evenly balanced. This can be attributed to the fact that the test subjects applied what they had learned in the older vehicle and the fact that the operating concept of the newer vehicle was possibly too far removed from the previous models and therefore proved difficult to familiarize themselves with. **Figure 12**

Younger Test Subjects Pick Up Modern Operating Concept More Quickly

When asked which operating concept they would prefer, most of the test subjects voted for the one used in the older test vehicle. One reason for this could be "cognitive overload," which is when a person's working memory becomes overloaded with information. In this particular case, cognitive overload was caused by the impressions triggered by the new vehicle. In fact, the majority of the test subjects reported being confused by the operating concept of the newer test vehicle. They complained about the reaction time of the touch display and the touch-sensitive buttons, and the fact that none of these, especially the touch-sensitive buttons, provided haptic feedback.

The test subjects deemed the effort associated with learning the new operating concepts to be relatively high – especially for older people. From a safety perspective, the newer operating concept can be especially problematic for people who wear reading glasses. Without these glasses, they are unable to make out the controls, but with these glasses, they are unable to follow the situation on the road, as far away objects become almost a blur. The improvement suggestions put forward by the test subjects point toward using a combination of both concepts, for example keeping the touch display, but using a conventional rotary knob as the volume control.

Summary: Despite the vehicles being stationary during the tests, several of the test subjects were overwhelmed by the operating concept in the modern vehicle. Even if they were familiar with a function, many test subjects pressed the touch button for too long, causing it to switch

In many vehicles, the switch for the hazard warning lights is located in the middle of the dashboard – although not consistently for all of them.

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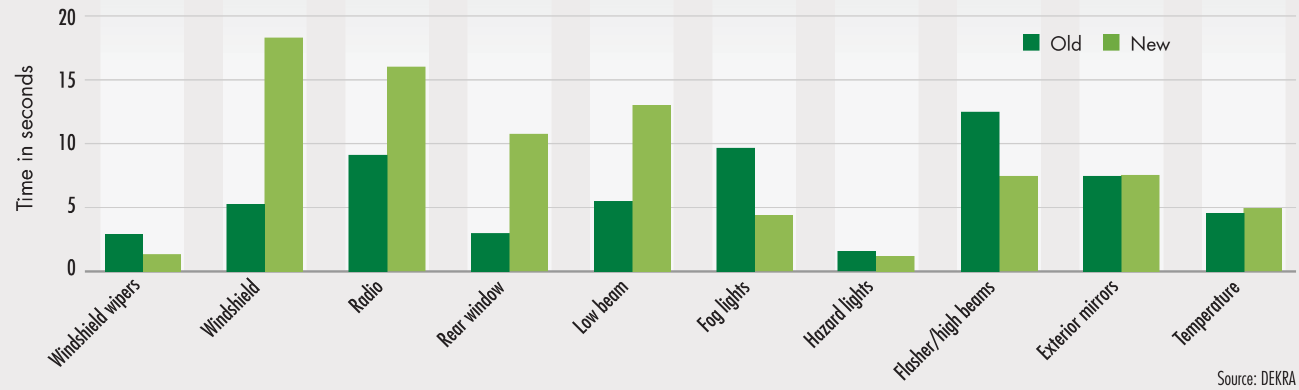
Average Time per Task



Source: DEKRA

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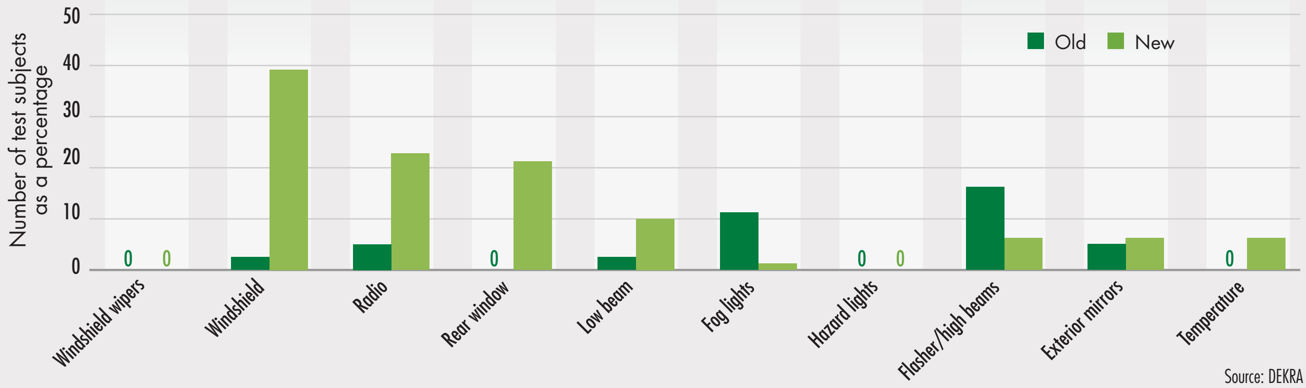
Test Subjects Who Took More Than 30 Seconds for the Task or Were Unable to Complete It



Source: DEKRA

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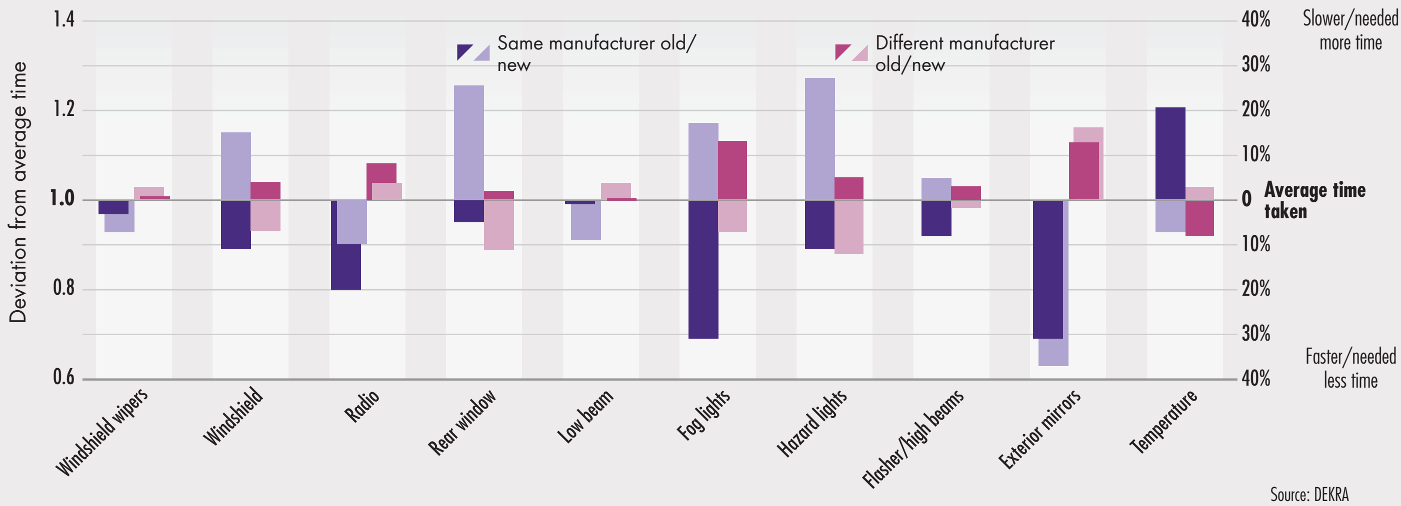
Time Required Depending on the Manufacturer of the Test Subjects' Own Private Vehicle

The 1 as the horizontal middle axis represents the average time taken. If the column is above 1, it means that this group took a longer amount of time to complete the respective task. So 1.2 means that this group took 20 percent longer compared to the average time it took for this task to be completed, and 0.8 means 20 percent less time.



Source: DEKRA

There is an urgent need to standardize operating functions across manufacturers, particularly with regard to safety-relevant settings.

itself on and then off again, or accidentally pressed other touch buttons in the vicinity. Buttons and controllers with haptic feedback proved to be the better options for safety-relevant functions or settings in particular. Due to the fact that touch buttons and touchscreens do not provide this feedback (such as when typing on a smartphone), they necessitate the user to look at them for longer, thus increasing the distraction time. They are also associated with more input errors, as the user's fingers can easily miss the small buttons, especially when driving. Regardless of these challenges during operation, the younger test subjects still preferred the newer vehicle and were more willing to familiarize themselves with the modern operating concept.

This finding corresponds to the results of the DEKRA-commissioned forsa survey mentioned in the introduction of this report. According to this survey, 90 percent of car drivers were in favor of standardizing the oper-

Superheroes in the Service of Vision Zero

Crash test dummies are indispensable for accident research and vehicle development, as they sacrifice their steely bones for us. To obtain the best possible results from the crash tests, these life-size dummies, officially known as "anthropomorphic test devices," have to be as life-like as possible. However, almost all of the models used today represent a typical man. The one that is used most often is the Hybrid III Dummy (HIII50M), developed in the 1970s and 1980s. It was based on the height and weight of the average man back then: 1.75 meters tall and 78 kilograms in weight.

The issue is – as it was back then – that accident statistics, and thus all of the people involved in accidents, cannot simply be assigned to this one category of person. The range of different body heights and body weights is tremendous and is subject to constant fluctuations. A person's bodily characteristics also change throughout the course of their life, which is a critical aspect, considering the demographic shift to an increasingly aging society in many parts of the world. The female body still remains almost completely disregarded. Women have a different physique to men: for example, they have a different hip shape, they generally have weaker neck muscles, and their arms, legs, wrists, ankles, and abdomen are more fragile. So, in the context of traffic accidents, women have a different accident risk level than men. Statistically, women are also more frequently affected by osteoporosis. The female dummy that has been used to date, the HIII5F, was directly derived from the male dummy, the HIII50M, and is more or less just a smaller version of it. These days, its height and weight are more representative of a 12 to 14-year-old girl rather than a grown woman. To address this problem, a completely new female dummy is currently being developed – one that actually reflects the female anatomy. Dubbed the THOR5F, its design incorporates women's lower muscle mass, more fragile joints, wider hips, and narrower shoulders.

Also in development is a dummy to represent senior female citizens. The Elderly

Dummies, containing highly sensitive measuring instruments, sacrifice their steely bones without compromise in the name of road safety.

ating principle of the various functions and systems across different vehicle types and manufacturers. Other interesting results from the survey are as follows: 86 percent of participants (representative of all age groups) did not immediately know how to operate or use certain functions or systems in a vehicle that was completely foreign or somewhat unfamiliar to them. This especially affected the cruise control function, the lighting system, the windshield wipers, and the navigation system. Almost 25 percent of participants who struggled with operating certain functions or systems said that this was a challenge they had already encountered and found distracting, and which had resulted in a critical situation on the road.

All in all, vehicle manufacturers and developers have a significant challenge ahead of them: designing the operating concept to be as intuitive as possible and reconciling this with the need to find space for an increasing number of functions and settings. Settings that have particular relevance to safety, such as those relating to sight and lighting, require prioritization and must be easy to identify. In general, operating functions and the manner in which the controls are arranged urgently require further standardization. This would help drivers to familiarize themselves more quickly in vehicles from different manufacturers. A voice command system as an alternative is fundamentally unable to replace a good operating concept, but can be a good addition – if the user is familiar with it.

Female Dummy is being designed to represent a 70-year-old woman who is 1.61 meters tall and weighs 73 kg. This dummy also differs from current dummies in its body-mass distribution and in its heavier hips, for example. Initial DEKRA crash tests using a prototype have shown that this dummy behaves differently than the currently used HIII5F female dummy. Due to its heavier hips, the Elderly Female Dummy sinks lower into the seat, and the part of the seat belt that goes around the hips slips into the abdomen area, which can lead to severe injuries. The upper body also does not move quite as far forward, which leads to a different type of load on the lumbar spine area.

Another model currently in development is the "Obese Dummy," which represents an overweight vehicle occupant and weighs 124 kg. DEKRA has also already carried out initial crash tests with a prototype for this demographic. Although the results are still being evaluated, initial findings show that the restraint systems are reaching their limits. The seat belt is no longer able to adequately restrain the obese dummy driver, and the legs of the dummy impact hard with the dashboard, even deforming it.

The Facts at a Glance

- Even the best system cannot change the laws of physics.
- Many technological achievements of the 20th century, such as radial tires, the disc brake, servo brake, and power assisted steering, have provided the building blocks to enable us to develop the efficient systems for vehicle occupant and road user safety that we use today.
- Even just slightly misaligned sensors which neither the driver nor the vehicle systems detect can lead to a safety-jeopardizing malfunction.
- Although the various different truck automated emergency braking systems conform to legislation, the qualitative differences between them shows that there is still considerable potential for them to be improved.
- Conventional, standard turn signals on motor vehicles should be further refined in order to make their intended effect even more efficient.
- In future, technical vehicle inspections will increasingly rely on data saved in the vehicle or in a virtual vehicle file.
- Touchscreens in modern vehicles are associated with a longer distraction time due to their lack of haptic feedback and the subsequent need for users to look at them for longer.
- The fact that manufacturers can follow their own interpretation of an intuitive user experience when operating the vehicle via touchscreen results in considerable differences in menu navigation and menu naming conventions. If vehicles from different manufacturers are driven (rental cars, car sharing, etc.), problems are bound to occur.

Digital, Connected, and Rule-Compliant

When it comes to automated driving, there are all sorts of regulatory and infrastructure challenges that we have to overcome in the short term. These challenges relate not only to communication technology and cyber security, but also to statutory regulations, road construction, traffic sign detection, and the role of a "technical supervisor" for monitoring the operation of fully automated vehicles.

The previous chapters have made it clear that smart connectivity and digitalization inside and outside of vehicles is set to become increasingly important in the future. Vehicles will not only communicate with one another (vehicle to vehicle, V2V) but also with infrastructure (vehicle to infrastructure, V2I), such as traffic lights and traffic management systems. A major advantage of these systems (also known as "car-to-X" communication systems) is that they can inform and warn the driver about hazards along the route within split seconds, even if these hazards are not yet visible to the driver. In these cases, a highly or fully automated vehicle would even brake or change lanes independently in order to avoid the hazard area with sufficient clearance, without the need for the driver to intervene. The benefits of connected mobility for unprotected road users like pedestrians and two-wheeled vehicle riders are also likely to be high.

But in order to ensure this and to provide the necessary connectivity, we need corresponding communication technologies. In addition to standardized, general-purpose short distance technologies (Bluetooth, Wi-Fi, wireless power, Near Field Communication, etc.) and cellular technologies (GSM, UMTS, LTE, and all the associated variants), this also includes technologies developed specifically for vehicle connectivity, such as the WLAN standard IEEE 802.11p or the cellular standard C-V2X (Cellular-Vehicle-to-Everything) on the basis of 4G or 5G. IEEE 802.11p, a standard which was released by the Institute of Electrical and Electronics Engineers (IEEE) in 2010 uses WLAN technology, which

Connected Versus Human-Friendly Roads

Jacobo Díaz Pineda
General Director of the Asociación Española de la Carretera (AEC)

These days, everyone is talking about digitalization, connectivity, automation, and cyber security. In the context of road infrastructure, these terms are increasingly merging into one another and convey a reality that is striving for real transformation in the transportation of persons and goods.

Connected and autonomous mobility, as well as the digital transformation of infrastructure, are currently at the heart of this digital revolution. The introduction of 5G has opened the door to a whole range of new possibilities that center around connectivity between the vehicles themselves and between the vehicles and the infrastructure. This will generate enormous amounts of data that will enable traffic information and the road network to be managed dynamically.

Even though we still have a long road before us, there are already several projects that have had a successful pilot phase and are now taking initial steps to offer innovative new services. In this context, the interaction between technology and the user is paramount, which is why it is crucial that vehicles and infrastructure are further developed in parallel. This is the only way to fulfill mobility requirements in a way that takes sustainability and safety objectives into consideration.

Societal acceptance of driver assistance systems, trust in connected mobility solutions, and acceptance of autonomous mobility are just some of the areas where there is still work to be done to make all of the current technological developments a success.

It is also imperative that we do not forget about cyber security. It was only recently that, in its "Global Risks Report 2022," the World Economic Forum described the threat of cyber attacks as one of the greatest risks of the years ahead, and highlighted the need for governments to cooperate in the interest of coordinated and seamless management of these risks.

Mobility is becoming digital. That is a fact. However, it is imperative that the decision-makers in this sector ensure that humanization and maximum effectiveness are at the heart of this digital transformation. After all, the users are and will remain humans.

is suitable for real-time-capable communication over distances of a few hundred meters. C-V2X is a standard developed by the 3rd Generation Partnership Project (3GPP) and enables vehicles to interact with their surroundings. The technology enables both direct communications, which works independently of cellular networks, and network-based communications. The direct communications mode uses the 5.9 gigahertz frequency band. It remains to be seen which standard will ultimately prevail, but at the moment, the C-V2X looks like it has the edge. In the USA and China at least, the die has already been cast for this standard.

One important aspect in this context is reliable signal coverage, as most applications relating to connected cars are, after all, heavily dependent on fully functioning communications. For non-safety-related applications, a drop in signal coverage is not critical, as the user can easily determine whether there is connectivity or not. But when it comes to safety-relevant services or applications like eCall, warning displays should be triggered to inform the user about any communication outages. Furthermore, the system should be able to independently regain control of the relevant function once the signal is stable again.

Manipulation-Proof Connectivity and Data Transfer

Given the enormous volumes of data that vehicles and their many control devices and sensors generate, the communications standard 5G is an especially key technology for connected mobility. 5G allows data to be transferred considerably faster, more reliably, and in much greater volumes than 4G. While 4G (including LTE) enables data transfer rates of up to merely 100 megabits per second, the 5G standard allows up to 10 gigabits per second, with a maximum latency time of one millisecond. If vehicles are to continuously exchange data with one another and with their surroundings in real time, this type of ultrashort delay time is indispensable. However, it will probably take a while before this technology becomes

Information processing capability of current systems has plenty of room for expansion

more widespread, as it will only really make sense if used on a mass scale and if there is corresponding investment in (road) infrastructure.

The increasing intensification of vehicle connectivity is simultaneously heightening the need to protect them against cyber crime. In order to protect vehicles against as many external attacks as possible, manufacturers must ensure that any new vehicle types are safe against connectivity and data transfer manipulation – a requirement that has been mandatory since July 2022. From July 2024, this regulation will apply to all new vehicles in the EU. The basis for this is the set of regulations formulated in 2020 by the UNECE World Forum for Harmonization of Vehicle Regulations (WP.29), which stipulates that manufacturers must run a certified management system for cyber security (UN-R 155) and software updates (UN-R 156) throughout the entire development period and life cycle of a vehicle.

Limited Ability to Interpret Complex Traffic Situations

Another major challenge facing IT developers concerns the basic principles which govern the various different statutory road traffic regulations in different countries around the world. This is because the respective regulations have to be operationalized using electronic "what-if" logic connections. This includes the requirement to exercise constant caution and show consideration for others road users, and to avoid endangering, disrupting, hindering, or causing damage to them. The (German) Road Traffic Act (StVO), for example, is aimed at conventional drivers, and given the various different case-by-case solutions, has proven to show a high level of attention to detail. The two following examples on the "line-of-sight" driving principle and the principle of trust will demonstrate the high requirements that the electronic decision logic has to meet.

The line-of-sight driving principle obliges the driver to ensure that they are able to bring their vehicle to a halt within the visible stretch of road. The principle of trust means that all road users must be able to trust that other road users are adhering to the applicable regulations. Translated into the world of fully automated driving, the line-of-sight driving principle means that a vehicle's sensors must be able to detect the relative minimum visual range at all times – despite design factors currently limiting vehicles in this capacity to around 250 meters. This is because this is the prerequisite for vehicles to be able to adapt their speed sufficiently in the respective traffic situation. The relevant visual range can be impaired by the layout of the road, weather conditions, vehicles in front, or situational restrictions like temporary roadworks or mobile roadworks.

Considering that the automated system takes around 0.2 seconds to react and factoring in a safety margin for poor conditions, experts in Germany suggest lowering the permissible driving speed by a significant degree – up to 20 percent – and increasing the safety distance. However, this would interfere with the "harmony of the traffic flow" and potentially induce drivers in conventional vehicles to overtake or maneuver into a gap between two vehicles.

For a vehicle to be able to adapt its speed in the respective traffic situation, its sensors must be able to detect a visual range of 250 meters at all times.

Several traffic experts have also criticized that the technology currently still lacks the ability to correctly process the information required to put the principle of trust into practice. In other words, the systems are currently unable to adequately decode and interpret a complex traffic situation. This would have fatal consequences. For, even though every road user can trust that all other road users are adhering to the relevant regulations, there remains a permissible exception to this rule – according to applicable law – for protecting more vulnerable road users, such as children, pedestrians, and cyclists. We also see unlawful deviations from the rules every single day.

Faults in Sensor Perception Critical to Safety

As a result, any sensors and downstream system technology must reliably identify any person to whom the principle of trust does not apply. The sensor technology must also be able to correctly register potential conflict situations and provide a correct prognosis of how the road users will behave next. Potential areas for conflict situations include the entrance and exit areas of car parks and service stations, domestic drives and gateways, bus and streetcar stop areas, and pedestrian crossings, among others. This is a problem that still requires a considerable amount of research and the solutions are still only in their infancy.

Another problem is that the current functionality of sensor technology and the programmed decision logic are still prone to faults. According to an analysis carried out by the University of London in 2021, in a fully automated vehicle, a safety-critical sensor percep-

It Is the Moment to Leverage Existing Cellular-Vehicle-To-Everything Developments

Johannes Springer
Director General, 5G Automotive Association

More than six years after its creation, the 5G Automotive Association (5GAA) keeps moving forward to make our roads safer, traffic more efficient, and to reduce CO2 emissions.

The journey ahead for the association is clearly defined in our 5GAA roadmap, positioning the Cellular-Vehicle-to-Everything (C-V2X) technology at the center of our activities and establishing several milestones on the 2030 horizon. This C-V2X roadmap – updated at the end of 2022 – is a key instrument that allows us at 5GAA to focus our efforts toward bringing a number of use cases, including safety applications, into reality. These efforts also comprise, of course, the investment that is required from different actors in the 5G ecosystem: automakers, telecommunications providers, and network operators, all of them brought together by the 5GAA to facilitate the conditions for deployment.

We are now standing at a crossroad where the technology has been ready for years, as cars have been equipped with mobile-network features for some time now, and a large fleet of connected vehicles is in the market, with new models equipped with 4G and 5G technologies coming out every day. Part of the investment has already been made. It is the moment to leverage existing C-V2X developments and keep expanding functionalities, building up the infrastructure, and improving the reliability of the use cases. Like our association, the ecosystem never stops. Innovations like 5G-V2X direct communication, edge computing, or the use of non-terrestrial networks are proof that the technology isn't standing still. In fact, the innovative range of initiatives such as 3GPP (of which the 5GAA is a proud partner) looks as promising as ever for automotive applications.

However, investment from the industry might not be enough without the right regulatory framework. We need regulators to ensure technology neutrality for the ecosystem to make its own decisions. On a level playing field, the rationale in favor of one solution or the other would be purely market-driven. Collaboration among public and private actors has always been the cornerstone of our association, as we have historically looked to provide a space for dialog with experts and decision-makers. At the same time, the 5GAA will continue to turn to road operators for best practices and recommendations. As challenging as consensus might be, it is from that exchange that we thrive.

tion fault occurs every 288 miles. The reasons for this lie in hardware defects (faults in components, wear, manipulation, damage), the detection of situational context conditions (for example, temporary or mobile roadworks), the reliable monitoring of environmental conditions despite hampered perception (due to weather conditions such as snow, fog, or rain), and damaged infrastructure (pot holes or gaps in road markings).

Beyond the need for reliable object detection capability, automation technology must also be able map anticipatory driving. Yet in order for the system to make adequate driving decisions, there needs to be a knowledge base that it can draw on to obtain information about interactions between individual objects in different traffic situations and the connections between motion sequences. The following example demonstrates the importance of this: if a ball were to roll onto the road from an obscured location, a human driver would be able to draw on their experience and expect a person to potentially run onto the road from the obscured location a short while later. In this particular traffic scenario, not only is there the need to avoid colliding with the ball, it is also necessary to consider that a person (for example, a child) might suddenly appear and run after the ball. An automated vehicle that lacks the ability or underlying knowledge to interpret this kind of traffic situation would merely try to avoid colliding with the ball, and most likely not factor in the possibility of a person suddenly appearing on the road.

Clear Communication Between Road Users

To be able to deliver on the promise of greater safety through fully automated vehicles, we also need to address how these vehicles will be able to interact in mixed traffic, for example, with unprotected road users or conventionally operated vehicles. The interaction between road users is one of the biggest challenges of fully automated driving. There is still very little knowledge about how they communicate in situations that require cooperative behavior, for example, when merging with a freeway from an on-ramp or negotiating ambiguous priorities at junctions. Gestures, particular eye-contact signals, and careful, defensive driving can help to resolve these kinds of stalemate situations.

Just like people do in day-to-day communication, road users interact using a combination of explicit and implicit communication. "Explicit" communication is when someone sends a clear and unequivocally formulated message. "Implicit" communication describes aspects that cannot be understood in and of themselves, but rather have to be logically deduced. It is very rare for explicit communication to occur in road traffic, in fact, it is more or less non-existent. Implicit communication, such

Cyber Security Is a Key Component in Road Safety

Prof. Giuseppe De Rita
President of the Centro Studi Investimenti Sociali (Censis)

One of the problems facing Italy and the Italian population relates to the quality of inner-city and intercity roads. This makes road safety a very worrying topic that has to be given more attention.

Against this backdrop, it is clear that more digitalization is guaranteed to improve the Italian road network. It is therefore imperative to remember that cyber security is a key component in road safety, and ensure that this topic is not neglected in further developments in the automotive industry. This is the major challenge facing all car manufacturers, who are aware that increasingly connected vehicles will be a potential target of cyber attacks.

Institutions and private individuals must understand that the "road" is a danger to the health and safety of the population, and it would be logical to take all practical measures to try to curb the risks associated with motor vehicle usage. In a competitive world in which cyber threats have become a weapon for illegal purposes and a tool for harming others, cyber security will be decisive for the defense and advancement of freedom and prosperity.

This is a critical realization, as only effective and united protection against cyber risks can restore the necessary calm required to move unimpeded through the digital world. Digital security, which is closely associated with road safety, must no longer be regarded as a cost factor, but rather as a social investment for the mutual benefit of all: it means making citizens, companies, and institutions less prone to malicious attacks and reducing the resulting, potentially very high, social and economic costs, and maximizing the advantages and opportunities of the Internet.

as vehicle motion patterns and dynamics, on the other hand, is essential for facilitating efficient traffic behavior, especially for pedestrians. This has been proven by a Dutch study in which merely 2.7 percent of pedestrians said they made gestures to indicate when they wanted to cross the road at pedestrian crossings. Pedestrians and car drivers said that they very rarely used explicit forms of communication, and instead relied on "clues," such as distance, speed, and braking behavior.

A field study that recorded and analyzed interactions between drivers and pedestrians in different European cities (n = 701 interactions) found that just four percent of drivers use gestures to communicate with pedestrians, and less than one percent do so using the flashers or sounding the horn (explicit). Only six percent of pedestrians used gestures to show when they wanted to cross the road. This means that recognizing a pedestrian's intention to cross a road is a difficult perception process to map, especially for fully automated vehicles, and is an area that requires further research.

Various human–machine interfaces are currently being further developed and optimized in a bid to improve communication with road users. These human-machine interfaces (HMI) fulfill different functions, depending on with whom they are meant to communicate. There are HMIs that send messages to other vehicles with information about their own behavior or status (called external HMIs or eHMIs). Brake lights and turn signals are two types of eHMIs, for example. Also being explored and tested are prototypes for on-road projection systems, light strips, and display screens. However, as there are currently no standards or minimum requirements for most of these types of eHMIs, there are several questions that have to be clarified. For example, what are the best colors to use? Where are the eHMIs to be placed? And which medium is actually most suitable? It is also not yet clear whether the eHMIs should inform other road users about their own intentions, or even request an action from them. Equally essential is the need for a universal design, one that functions across modalities that also address people with visual or hearing impairments.

Interaction between road users increases safety

Strengths and Weaknesses of Traffic Sign Recognition

Essential to a smart information system is that it must be able to recognize traffic signs reliably. These days, this is generally carried out using imaging or video-based techniques. However, this image-based pattern detection method cannot be guaranteed to be one hundred percent reliable in its classification. A key reason for this is the many factors that might prevent traffic signs from being reliably recognized by the system: weather conditions (snow, fog, or blinding sunlight), objects blocking road signs (for example, the branch of a tree), vandalism, or motion blur. However, studies with four European datasets, such as the "German Traffic Sign Recognition Benchmark," show that current classification meth-

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Head-up displays show important information such as traffic signs on the windshield.

Legal Considerations on Core Elements of Section 1d of the German Road Traffic Act

Prof. Dieter Müller, J.D.

Head of the Traffic Sciences study area at the Saxony University of Applied Police Sciences in Rothenburg/Oberlausitz and Chairman of the Legal Advisory Group of the German Road Safety Council (DVR).

People say that automated and autonomous driving are the future of automotive mobility, but what real opportunities do these new, revolutionary forms of travel offer, and what are their limits? The legislature and the regulator have already done a lot of work in terms of legislation and setting out the (preliminary) statutory traffic framework conditions. But in what scope and depth? The following discussions will attempt to contextualize these questions.

"Consulting the law simplifies the search for justice," is a familiar dictum among lawyers in Germany. But this is only half the truth, as legal texts are often written in convoluted legalese, which makes them difficult to understand. This also applies to the recently added section 1d of the German Road Traffic Act (StVG), which came into effect on July 28, 2021, and concerns "motor vehicles with autonomous driving function in specific Operational Design Domains." The first paragraph sets out the legal definition of a "motor vehicle with autonomous driving function" – i.e., a Level 4 motor vehicle. The law states that a motor vehicle with autonomous driving function must be able to independently carry out the driving task in a specified Operational Design Domain purely on the basis of the vehicle technology, without the need for a driver.

The term "driving task" means the various different driving situations that have to be negotiated during a drive, such as turning off, overtaking, and parking.

The technology must be able to perform the driving tasks without a person driving the vehicle. Instead, after entering the Operational Design Domain, the driver can temporarily retire into the role of a passenger (who is not generally considered to be a road user because they are not an active participant in the traffic) during the autonomous driving process. In this situation, it is only the autonomous driving motor vehicle that is an active participant in the traffic, which is reflected in the term "independently." The concept of independence is not to be understood in a human sense here, because this independence is always based on human programming and controlled by technology. In this Level 4 "autonomous mode" of driving, motor vehicles can drive independently without their drivers having to take over, meaning the functions act quasi autonomously when performing the respective driving task. The driving is only "quasi" autonomous because the vehicles' software was programmed by humans for almost all conceivable, known driving tasks, and it is only humans who have free will and are able to act with real autonomy. So the term "autonomous" is not really entirely suitable for programmed motor vehicles, and is instead more a reflection of traffic policy wishful thinking.

A motor vehicle with an autonomous driving function must also have technical features in accordance with section 1e, paragraph 2 of the German Road Traffic Act. This provision contains no fewer than ten clauses dedicated to technical requirements, all of which the motor vehicle must fulfill. One of the central features is the newly created concept of a "technical supervisor," which is explained further in section 1d, paragraph 3 of the German Road Traffic Act.

Provisions With Lots of Gaps

The content of section 1e, paragraph 2 of the German Road Traffic Act is straightforward enough to explain, as it is merely a more detailed description of the area of application of motor vehicles with autonomous driving function. The concretized provision in section 7, para. 2 of the AFGBV (German Act on Autonomous Driving), which entered into force on June 24, 2022, stipulates that it is the responsibility of the motor vehicle holder to determine the Operational Design Domain. However, no such Operational Design Domain has yet been approved by the "responsible authority" (as defined by state law) pursuant to section 7, paragraph 2, sentence 2 of the AFGBV, meaning there is currently no practical experience to draw on.

The new provisions shall apply to shuttle vehicles (among others), facilitate the driverless deployment of people movers, and allow driverless vehicles, for example dual-mode motor vehicles, to perform tasks such as "automated valet parking." So, the new legislation is predominantly applicable for commercial passenger transportation in a public transport context. Based on the current outlook, it would seem that autonomous driving is (still) wholly unsuitable for private use and not actually conceived for this purpose, as private vehicle owners would be considerably overwhelmed by the technical requirements that have to be met and the imposed responsibilities, especially those set out in section 13 of the AFGBV.

There are always gaps in new provisions, of course, some of which are quite alarming in the context of road safety. For example, in terms of the "technical supervisor" model (envisaged in section 1d, paragraph 3 and further defined in section 1f, paragraph 2) which requires a real person to fulfill the function, it is still largely unclear how successful this vision will be. After all, their task would be to monitor the safety of the autonomous driving process at all times in order to be able to intervene if the technology fails. It remains unclear why this remotely located person would even be thought to be in a better position to react than a supervisor inside the actual vehicle with the passengers. There may also be the risk of cyber attacks occurring at any time, as the vehicles are constantly monitored and accompanied by means of cloud-based applications, meaning they have to be online all the time. This creates the potential for attacks, for example by individuals blackmailing the companies that provide this service on the road.

Section 14 of the AFGBV provides greater detail on the requirements for the function of technical supervisor, setting out personal and professional suitability requirements, which, in fact, also describe an entirely new occupational profile for which there is currently no suitable pool of applicants. Against this backdrop of these very detailed occupational requirements, it seems inevitable that a new study program or equivalent professional qualification will be created.

Unclear Framework Conditions

The conclusive definition in section 1d, paragraph 4 of the "risk-minimized state" of a motor vehicle with an autonomous driving function is, metaphorically speaking, no less than an attempt to square the circle by using in an assortment of vague legal terms to try to solve an occurring dangerous driving situation. Already the legislature's phrasing of the task "the vehicle must react appropriately" is one such deliberately vague description, as the notion of appropriateness – a concept borrowed from constitutional law – is as multifaceted as life itself and leaves more open to interpretation than practitioners of law will welcome. With the phrases "at its own instigation" and "at the instigation of the technical supervisor," the regulation itself describes two of several possible starting points for bringing the motor vehicle into a risk-minimized state.

It goes on to stipulate that this responsibility-laden task must be carried out "in the safest possible place" in the traffic environment, which, considering the complexity of the public traffic sphere, could be everywhere and nowhere, but de facto would mean that the motor vehicle would be decelerated until it came to a standstill. The fact that this process has to be implemented while "taking due account of the traffic situation" and ensuring "the greatest possible safety for the vehicle occupants, other road users, and third parties" sets the bar deliberately high and, ultimately, merely serves as legal protection for the legislature.

It is virtually impossible to interpret new legal provisions in the required scope of application and technical depth if the determining factors are not put in the necessary concrete terms. The new legislation concerning autonomous driving is certainly a step in the right direction and could be a groundbreaking component for improving road safety. However, it remains to be seen what the institutions and authorities mentioned in the legislation and the act will put into practice, especially as vehicle manufacturers are making constant progress and advances in their technical innovations.

Legislative PR Exercise Attempt

It is unclear, for example, how the performance of automated and autonomous motor vehicles on the road over the years is to be validated, so that specific risks and areas for improvement can be detected at an early stage and interventions made for safety reasons, if necessary. It is questionable whether, from a technical point of view, the Federal Motor Transport Authority (KBA) would be the best institution to be in charge of continuously monitoring the performance of the autonomous driving function as part of a field monitoring process. Probably more appropriate would be organizations who have been entrusted by the state to carry out technical vehicle inspections and therefore already have decades of experience in this area.

If potentially safety-critical faults are detected within what should be ongoing quality control in real time, the KBA must immediately withdraw the operating license until it can be proven that the fault has been rectified through a hardware or software update. Furthermore, on the basis of present-day technologies, the notion of autonomous driving currently seems an impossibility for inner-city areas in Germany due to the complexity of interactions with "analogue" road users, such as pedestrians and cyclists. For the moment, the computing power required for this and the fact that vehicle sensors are still frequently designed to operate in good weather conditions remain insurmountable obstacles. In my view, so far this has all just been a legislative PR exercise attempt that has failed to properly explain the framework conditions and has no clear starting point.

Controlling a vehicle remotely gives rise to new challenges

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ods achieve recognition rates of between 95 and 98 percent, which is almost the same as that of a human – close to 99 percent.

A Chinese study conducted in 2022 investigated the effects of extreme weather conditions on traffic sign recognition. In sunny or overcast conditions and in a bright wintry landscape without precipitation, the precision and call-up rates of the recognition algorithms were relatively high, even reaching 82 to 97 percent respectively in sunny conditions. During rain or fog and at night, on the other hand, the rates were relatively low. In rainy conditions, the precision rate of correct traffic sign recognition fluctuated between 22 and 91 percent depending on the light and contrast levels as well as the type and intensity of the rain.

This shows that traffic sign recognition algorithms are more effective when there are no extreme weather conditions. Researchers have already developed various different systems that combine different recognition methods in order to minimize the effects of typical sources of error, such as motion blur or damaged signs. The 3D reconstruction method, for example, can detect damaged and partially concealed traffic signs in real time, as the algorithm is based on the automatic recognition of vertical traffic signs from point clouds and images that are captured by a mobile mapping system. This 3D reconstruction method achieves an overall success rate of almost 98 percent.

Remote Control via Teleoperation

Thanks to the automation of automotive road traffic and the expanding digital transformation of our various areas of life, we are seeing the emergence of new visions for how mobility in urban centers should be designed. Here is one potential scenario: people who live on the outskirts of a metropolitan area park their electric vehicles in car parks at the edge of the city and then change over to ready-to-depart "people movers" – small driverless buses that operate along a network, just like subway trains. Another scenario: for private-vehicle traffic, these "people movers" could function in the same manner as taxis or rental vehicles. For instance, an entire family could easily and conveniently hire a fully automated vehicle to transport them to the airport. As well as fully automated shuttles designed for transporting people, developers are also working on and testing different vehicles for fully automated goods transport ("delivery robots" and trucks), including the interlinking of existing fully automated trucks with other modes of transport.

Fully automated vehicles will differ significantly in terms of their sensory equipment, their weight and speed range, as well as their envisaged uses in traffic. Inside the actual vehicle, there are usually no devices for steering and operation. So it is, in effect, a motor vehicle without a steering wheel, and it is neither intended nor possible for passengers to intervene. In Germany, the legislature has already created a legal framework for this vehicle development: in July 2021, the Act on Autonomous Driving agreed by the Bundestag and the Bundesrat entered into force.

The act is being supplemented by implementing provisions and proposed specifications for codes of practice concerning the granting of operating licenses for motor vehicles with an autonomous driving function, concerning the approval of specified Operational Design Domains, and concerning the requirements and diligence provisions for persons involved in the operation of motor vehicles with an autonomous driving function. This extensive set of regulations is designed to ensure safe operation of fully automated vehicles, even if the technical system controlling the vehicle does not know what to do, for example because an obstacle or temporary roadworks are blocking the road. In these cases, the problem has to be solved remotely via "teleoperation."

In the future, we will see an increasing number of driverless minibuses, called "people movers," on our roads.

Making Towns and Cities Fit for More Mobility

Michael Kadow
CEO of House of Logistics and Mobility (HOLM) GmbH

To make towns and cities livable, we have to rethink our entire transport concept. This is exactly what "Campus FreeCity" has set out to do: led by HOLM GmbH as the consortium leader and funded by the Federal Ministry for Digital and Transport, the project involves researching a complete ecosystem for mobility and logistics on the basis of autonomous vehicles on a laboratory scale. The eight project partners from science and industry will ensure that all of the essential questions from a technical, economic, ecological, and social perspective are addressed as part of the holistic, sustainable approach.

In the project, logistics, mobility, and robotics are addressed in combination in order to develop new opportunities for urban transport. Passenger transport, goods transport, and municipal services in urban areas will be realized by means of a connected fleet of autonomous robotic vehicles that are modular in design so that they can be equipped and deployed for different purposes. Through optimized route planning and fleet utilization, the number of vehicles in towns and cities can be massively reduced, making parking space available for other uses.

To enable this vision of a new type of city to become reality, the preparations for the living lab are running at full steam. The testing of a wide range of use cases, including passenger transport, goods transport, and municipal work such as landscaping and path clearing, will begin from fall 2023 on the grounds of the Deutsche Bank Park in Frankfurt am Main. The living lab will function as a simplified city center that can then be scaled up and transferred to an urban context.

With "Campus FreeCity," we are pursuing an approach in order to make towns and cities fit for more mobility and logistics, while at the same time reducing traffic, congestion, and emissions. Our aim? To create livable cities for a sustainable and mobile society.

Teleoperation is when a person assists and intervenes in the operation and control of a vehicle from a remote location. Particularly in the context of fully automated driving, current safeguarding concepts envisage the deployment of a (human) teleoperator in a special work environment (the teleoperator workplace or driver's station). There are different types of teleoperation: "remote assistance" and "remote driving." "Remote assistance" is when a teleoperator assesses the situation and provides recommendations on the best course of action, or releases or initiates (alternative) driving maneuvers for the vehicle to perform. "Remote driving," on the other hand, is when the teleoperator takes full (remote) control of the vehicle, including navigation, road guidance, and vehicle stabilization.

The Role of "Technical Supervisor"

As a result, the role of human teleoperator will involve navigating a whole new array of tasks that are very different to those associated with the (more familiar) activity of driving of a vehicle in person. In Germany, this new function is referred to as "technical supervisor," as per the recently enforced Act on Autonomous Driving. At present, it is not yet clear how the driver's station for technical supervisors should be designed. In each case, the technical supervisor must receive traffic information from the (direct) environment of the vehicle, but will initially only have access to devices allowing indirect view (camera images on monitors). The data transfer technology will generally cause a delay in taking over control of the vehicle, which could significantly impair the level of perceived control and control performance. In the aviation sector, 100 milliseconds is the maximum acceptable delay for time-critical scenarios that require accurate control of the airplane. If the delay is more than 240 milliseconds, control of the airplane can no longer be guaranteed. Such fast information transfer rates – especially given the expected complexity of the required sensory data – requires suitable and malfunction-free infrastructure, for example, fast and secure cellular networks, including in rural areas.

To ensure that the technical supervisor has access to all of the information they require in order to steer the vehicle safely within an appropriate time frame, there is also a need for extensive knowledge on the principles of human perception and the specific behavior in the newly created human–machine interaction. The technical supervisor will only have limited, time-delayed information about the vehicle's environment, the traffic situation, and the actions of the road users, so there is still the need for significant research in this area. Given that the technical supervisor will have no initial involvement in the driver-vehicle-environment control loop, it is to be expected that there will be a severe delay in their ability to establish a realistic awareness of the situation. According to certain studies, it takes between 29 and more than 162 seconds for a "remote operator" to establish an awareness of the situation, depending on the problem.

In addition to the issue of delayed situational awareness and its impact on the ability of a technical supervisor to act, it is also unclear to what extent the legislature will allow or intend for technical supervisors to monitor and or assist several vehicles simultaneously. This lack of clarity calls for regulations governing how technical supervisors are to monitor other vehicles in the event of a takeover situation.

Autonomous Driving in the Future: Considerations on the Role of Technical Supervisor

Prof. Sebastian Pannasch
Professor for Engineering Psychology and Applied Cognitive Research, Faculty of Psychology, Dresden University of Technology

There is currently intensive discussion around what mobility will look like in the future. The development of autonomous driving plays a central role in this respect, but there are still a lot of issues to be resolved. In 2021, the German government approved the Act on Autonomous Driving. According to this act, autonomous vehicles are allowed to use public roads in specified, pre-approved Operational Design Domains without a physical driver present, but their operation must be constantly monitored by a technical supervisor. From an engineering psychology perspective, the tasks of the technical supervisor present interesting challenges, as they raise key questions on how humans interact with machines in complex situations: the technical supervisor would have to make decisions and take safety-relevant actions within a very short space of time. Against this backdrop, aspects such as hazard perception, task complexity, and how the function of technical supervisor should be designed from an occupational psychological perspective are particularly important.

The fact is that the ability to understand and interpret the objective conditions of a driving task significantly depends on the actual perception, the feedback during driving, on the experience and expectations of the driver, and on the context. One of the potential risks and negative side effects that has to be considered is that the technical supervisor might not feel the significance of their actions, similar to when playing a computer game. This could generate a reduced sense of responsibility and, in particular, result in misunderstandings due to misjudging the significance of certain information, such as the speed of the vehicle. The consequences of this could be fatal.

This is what the future workplace of a "technical supervisor" could look like.

Hazard perception requires recognition of the relevant information in a situation, comprehension of the difficulties at hand, and the ability to derive potential options for a course of action. This means that a technical supervisor must be able to understand the significance of individual elements in order to understand the situation and, from this, derive future actions and potential consequences. For this to reliably succeed, active task processing is of key importance. However, the status of the technical supervisor is more one of a passive observer with access to only selective information. So, compared with an active driver, their hazard perception is quantitatively and qualitatively different, and develops in a different temporal dynamic. While the role of active driver requires continuous information processing concerning the traffic situation, a technical supervisor would suddenly be confronted with a problem in which they previously had no involvement. They would then have to orient themselves on relatively abstract parameters and use these to extrapolate missing information and events. This makes the hazard perception ability of the technical supervisor prone to errors. It appears that this is something the legislature is well aware of and has taken into consideration, because technical supervisors are required to have liability insurance with limitations of liability that are twice the limits for conventional vehicles (ten million euros for personal injury and two million euros for material damage).

In terms of task complexity, this aspect has, so far, been insufficiently detailed in the Act on Autonomous Driving. For example, it is unclear which tasks exactly the technical supervisor has to take over. Potential simple scenarios, such as driving through a red light are illustrated in the act, and it is assumed that the vehicle will know the limits of its own system and be able to independently bring itself into a risk-minimized state. Vehicles are likely to vary considerably in their performance limits, and, due to the complexity of the tasks and situations, it will not be possible to achieve 100 percent reliability. In other words, what is doable will be automated, and elements of tasks that are too complex are to be performed by the technical supervisor in future. This contradiction was already described as the "irony of automation" back in the 1980s. Introducing automation to unburden a human operator leads to changes in their mental load: long periods of being mentally under-challenged are interrupted by short periods of overload. This means there will still be fundamental risks in road traffic during autonomous driving. The vision of fewer traffic accidents is thus rendered absurd, as the causes of accidents will simply shift from human failing on the part of the driver in the car to human failing on the part of the designer.

The occupational psychological design of the function of technical supervisor should be one that is fit for humans to perform. For this, it must fulfill the following four human criteria: feasibility, exclusion of the potential for harm to mental and physical health, freedom of impairment, and opportunities for personal development. The first three criteria are in the interest of health protection and, thus, help to ensure performance, and the fourth ensures continuous personal development. A person's work should be organized in a manner characterized by complete, transparent, meaningful, and health-promoting tasks with plenty of freedom to act. Work design has a direct impact on safety, as the tasks have a decisive influence on subjective work performance and commitment to work. Technical developments and solution approaches in the area of virtual or augmented reality might help to provide the technical supervisor with as complete a picture of the traffic situation as possible, making it easier for the responsible person to put themselves in the respective traffic situation.

The Facts at a Glance

- Most applications relating to "connected cars" are heavily dependent on fully functioning communications and good signal coverage.
- The increasing intensification of vehicle connectivity is simultaneously heightening the need to protect them against cyber crime.
- The systems that are necessary for fully automated driving are currently unable to adequately decode and interpret a complex traffic situation.
- The interaction between road users is one of the biggest challenges of fully automated driving.
- Various studies have shown that algorithms for traffic sign recognition are more effective when there are no extreme weather conditions.
- To ensure that a technical supervisor has access to all of the information they require in order to steer the vehicle safely within an appropriate time frame, there is a need for extensive knowledge on the principles of human perception and the specific behavior in the newly created human–machine interaction.

Technology in the Service of Humans

As shown time and time again by statistics and extensively covered in the previous chapters of this report, humans are responsible for over 90 percent of accidents. It is therefore for good reason that, for years now, the automotive industry has been increasingly focusing on the use of driver assistance systems that can detect critical driving and traffic situations early on, warn against hazards, and even actively intervene in the situation, if necessary.

The key technologies of mobility 4.0 also have an important role to play. Using smart infrastructure and vehicle connectivity, such as communication between the vehicles themselves (car-to-car) and between vehicles and centralized or decentralized systems (car-to-infrastructure), they can also help to further reduce the number of accident-critical situations and, thus, the number of serious accidents with fatalities and severe injuries. Automated mobility also promises the additional benefit of enabling people with reduced physical or mental capacities and people with age-related reduced abilities to take part in society.

So a win-win situation for everyone? That is just one side of the coin. In addition to the huge expectations with respect to digital evolution and the use of technology to leverage untapped safety potential, in the same breath, there are also doubts being expressed about their possible risks. It is essential to take the entire mobility system and the interrelated dynamics and effects into consideration, especially the redesigned role of the driver within the human–machine-environment control loop.

We must also consider that, so far, no technical system has been able to understand the respective situational circumstances and draw the right conclusions as well a human. The classic example of a ball rolling onto the road is a particularly clear illustration of this. The vehicle systems will detect the ball and calculate that, by the time the vehicle reaches that point, the ball will no longer be in the way of the vehicle. But a human behind the wheel will know that a child is likely to appear and run to pick up the ball from the road. Even communication between road users just works better when it is from one human to another. The smiling senior citizen waiting at the pedestrian crossing who indicates with a hand signal for the car to keep driving will be waving to no avail if the vehicle is highly automated.

For all the technical progress made in the motor vehicle sector, it is also important not to forget that acceptance of, and adherence to, the respective traffic regulations are crucial safety factors for any type of road user. Using the roads requires constant care and mutual consideration at all times. Last but not least, it is and always will be humans who, through their actions, make the most important contribution to safety in road traffic.

DEKRA's Demands

The Human Factor

- To leverage the full benefits of assistance systems, drivers must be better informed about their design domains, their limitations, and how to operate them. This information must be available not only to primary users of a vehicle, but also to secondary and further users.
- The prioritized approach should be one of cooperative assistance, where the technology assists the human driver and compensates for their weaknesses, rather than one of technology-heavy solutions that only require the human to intervene in a troubleshooting capacity.
- Every driver must understand that it is them who is responsible for the vehicle and for the driving – regardless of how many assistance systems are used and what manufacturers suggest in their marketing campaigns.
- The cockpit must be ergonomic and effective in design and display the respective information in a manner that is timely, relevant, situation-specific, and easy to understand.
- When developing crash test dummies and implementing them in the regulations, differences in gender, height, weight and weight distribution, age, and posture must be taken into adequate consideration.
- Future studies on the road safety of automated driving functions should take greater account of the fact that, in many situations (especially in adverse weather conditions), humans can keep driving "without errors," while technical systems may "bow out" purely due to dirty sensors.
- Providers of car sharing services, rental scooters, and similar services should design their offerings in a manner that does not make usage time a central cost factor. This will give users sufficient time to familiarize themselves with the vehicle's equipment and operation before departure. Even during the journey, a "time-is-money" approach is counter-productive to road safety.
- In concepts where fully automated vehicles are monitored by a control center and the personnel are able to remotely take over control of the vehicle in certain situations (technical supervisor), the demands placed on the personnel are high. The job profile must, therefore, be analyzed in order to derive the necessary qualifications and training and support measures.

Technology

- Even with today's systems of active and passive safety, we need to thoroughly tap into the unrealized potential for preventing accidents or mitigating their consequences. Automation is not a silver bullet.

- The functional capability of any mechanical and electronic vehicle safety components must be ensured throughout the entire service life of the vehicle and systematically tested as part of the technical vehicle inspection, and the required information for this must be provided.

- Highly automated systems in motor vehicles must also be able to adequately decode, interpret, and draw conclusions about complex traffic situations, including interactions with other road users (including cyclists, pedestrians, and children). The focus of future research should therefore also include communication between road users.

- If a system has taken over or handed back control of the driving, this must be clearly indicated to the person behind the wheel.

- There is an urgent need for manufacturer-independent standardization of safety-relevant operating functions with regard to arrangement, location, and operation of the controls in the vehicle cockpit. The driver must be able to easily adjust these operating functions using conventional controls with haptic feedback – one reason for this being the potential for touchscreens to malfunction.

- Modern large-scale displays should differentiate between the respective modes for assisted or automated driving (Level 2 versus Level 3) in terms of the scope of usable safety and comfort operating functions.

- As carrying out non-driving-related activities in an automated vehicle is associated with high risk potential if the driver is required to take over control, this handover process must be assisted through unequivocal and consistent design solutions, adequate takeover times, timely takeover requests, and accompanying warning functions (for example, through activation of the belt tensioner). Such takeover requests by the vehicle must be recorded or suitably documented for later analysis.

- Further research is needed to understand how new seating concepts might change mechanisms of injury and how they could be utilized in highly automated vehicles to continue providing the best possible protection for the vehicle occupants.

Infrastructure and Statutory Regulations

- There must be clear regulations governing the minimum requirements for the automated vehicle Operational Design Domains defined by the manufacturers. These regulations must include clearly defined parameters such as speed, road category, and weather conditions, among others.

- To be able to fulfill the requirements of the mobility revolution through safety and user-oriented infrastructure design, it is important to record the estimated number of unreported cases of cyclists and pedestrians fatally injured in single-vehicle accidents, including the accident locations.

- The traffic accident statistics system, which in many places is based exclusively on police accident reports, has to be fundamentally rethought. Insurance statistics (for example, vehicle and health) could also be used. Furthermore, the criteria and processes for recording accidents should regularly be adapted to current requirements and technical possibilities.

- Accident statistics should use consistent definitions that align with international standards as much as possible.

- In the context of Vision Zero, it is important to actively look for hazardous areas, in order to mitigate these as quickly as possible using structural and/or meaningful traffic-regulatory measures. In this respect, it is essential to ensure the requirements of modern assistance systems are taken into consideration.

Any Questions?

Your Contacts at DEKRA

Vehicle Inspections
Florian von Glasner
Tel.: +49 711 78 61-23 28
florian.von.glasner@dekra.com

DEKRA SE
Handwerkstrasse 15
70565 Stuttgart, Germany

Accident Research
Markus Egelhaaf
Tel.: +49 711 78 61-26 10
markus.egelhaaf@dekra.com

Andreas Schäuble
Tel.: +49 711 78 61-25 39
andreas.schaeuble@dekra.com

Luigi Ancona
Tel.: +49 711 78 61-23 55
luigi.ancona@dekra.com

DEKRA Automobil GmbH
Handwerkstrasse 15
70565 Stuttgart, Germany

Analytical Expertise on Accidents
Michael Krieg
Tel.: +49 711 78 61-23 19
michael.krieg@dekra.com

DEKRA Automobil GmbH
Handwerkstrasse 15
70565 Stuttgart, Germany

Basic Principles/Processes
André Skupin
Tel.: +49 357 54 73 44-257
andre.skupin@dekra.com

Hans-Peter David
Tel.: +49 357 54 73 44-0
hans-peter.david@dekra.com

DEKRA Automobil GmbH
Senftenberger Strasse 30
01998 Klettwitz, Germany

Traffic Psychology
Dr. Thomas Wagner
Tel.: +49 357 54 73 44-230
thomas.wagner@dekra.com

DEKRA e.V. Dresden
Senftenberger Strasse 30
01998 Klettwitz, Germany

International Committees
Walter Niewöhner
Tel.: +49 711 78 61-26 08
walter.niewoehner@dekra.com

DEKRA e.V.
Handwerkstrasse 15
70565 Stuttgart, Germany

Corporate Communications
Wolfgang Sigloch
Tel.: +49 711 78 61-23 86
wolfgang.sigloch@dekra.com

DEKRA e.V.
Handwerkstrasse 15
70565 Stuttgart, Germany

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DEKRA
Handwerkstrasse 15
70565 Stuttgart
Germany
Tel. +49 711 7861 0
Fax +49 711 7861 2240
www.dekra.com

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