VDE Fact Check

Autonomous Driving

The vision of fully automated vehicles is being driven forward by the international competition among automotive manufacturers, suppliers, and software companies. However, before that vision can become reality, in addition to technical challenges, there are legal, ethical, and societal questions that must be clarified. This fact check offers an overview of autonomous systems (with a focus on road traffic), the existing regulations, national and international activities, and the role of DKE VDE in developing standards and specifications.

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The Future of Mobility is Autonomous

When talking about the future of mobility, the following keywords usually come up: electric, networked, shared and autonomous. Autonomous refers to the final stage of development of automated vehicles and refers to the fully automated and targeted driving of a vehicle without human intervention. People become passengers. The successive increase in automation is described by the Society of Automotive Engineers (SAE) based on levels. The benefits of autonomous and networked vehicles are diverse, as they make important contributions toward traffic safety and environmental conservation by reducing the risk of accidents and lowering CO_2 emissions. The comfort level is also increased because people no longer must continuously pay attention to the traffic and hazardous situations are detected early on by the networked vehicle. Autonomous vehicles would, for instance, only be used when they are needed (on-demand). Thus, traffic caused by searching for parking spaces can be prevented by means of intelligent networking with other vehicles (car-to-car communication) and the infrastructure (car-to-x communication), traffic jams and traffic density can be reduced, and the flow of traffic can be optimised. Current studies estimate an increase in efficiency of four to ten percent due to autonomous vehicles in 2050. However, until that time comes, further technical developments are required, and the legal framework must be revised and open questions in the fields of standards and specifications must be clarified.

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Current State of the Art in Technology

Automated driving is enabled by various driver assistance systems in the vehicle like braking, lane, turning or parking assistance systems which are already in use in current luxury class vehicle models. Autonomous driving also requires sensor systems for environmental detection like laser, ultrasound, radar and lidar sensors for distance measuring and detecting objects and persons.

- **Lidar Systems (Light Detection and Ranging):** Lidar sensors emit infrared laser beams and based on the back reflection of the environment, determine the distance to objects. Using a beam deflection unit, laser beams can be used to "probe" the entire environment and create a 3D point cloud of the surroundings. In the time-of-flight procedure, one or more laser pulses are emitted, and the time taken to detect the signal reflected by an object is measured and the distance calculated using the speed of light.
- **Radar (Radio Detection and Ranging):** Radar sensors emit bundled electromagnetic waves via antennae and analyse the echoes reflected from the environment. The electromagnetic waves are information carriers which are modulated upward on the transmitter side and demodulated on the receiver side by means of amplitude or frequency modulations. By analysing the signals based on various criteria like phase or Doppler shifting, the distance and speed can be determined.
- **Camera Systems:** Front-view camera systems can also depict the environment like the human eye and are usually located behind the windscreen at the height of the rear-view mirror. The video data are analysed using image processing algorithms and used to identify traffic signs, lane markings or objects in order to, e.g. make high-beam and lane change assistants or emergency braking systems available. IR cameras also work in fog and at night. They make detecting higher-risk situations easier.

The electronics systems in the vehicle ensure that the engine, brakes, and steering are electrically activated after processing the data and all active and passive systems are networked with each other. At the same time, progress in digitisation has produced powerful hardware and software by increasing computing power and further developing computer processors to process the massive amount of data in the vehicle and in the cloud using artificial intelligence (AI).

If there were around ten million lines of software code ten years ago, autonomous vehicles will have between 300-500 million lines of code. With these lines of code, machines are taught cognitive capabilities so they can take control of the vehicle. So, the (on-board) computer can orient itself, high-resolution map material (HD maps) are required to ensure the safe and targeted propulsion of autonomous vehicles in urban metropolitan areas. (Survey) vehicles that scan their environment are already in use worldwide. The collected data are further processed by the control unit in the vehicle and then transferred to the cloud. There, they are converted into simulations by engineers, situations are played through and the on-board computer is taught new behaviours. Continuous updates and virtual training thus continuously make the technology better and safer.

Technical Development and History

In 1968, the automotive supplier Continental had a Mercedes 250 (W11) complete a circuit on the Lüneburger Heide as the first driverless vehicle; the vehicle navigation was controlled by a guide wire and sensors. In the early 1980s, the test vehicle "VaMoRs", developed by the German pioneer Ernst Dickmann, drove on closed routes and was partially automated, whereby the driver had to intervene quite a bit.

It wasn't until after there was technological progress in the field of vehicle technology, computing power and progress in the field of AI those important milestones were reached in the early 2000s. For example, an autonomous vehicle covered a route of 150 miles for the first time as part of the DARPA challenge initiated by the United States Department of Defense. Shortly thereafter, in 2011, Google's subsidiary, Waymo, received the first patent for the technology to operate autonomous vehicles in the USA and introduced the first driverless car to the public in 2014. AUDI followed in 2015 and introduced an autonomous vehicle close to serial production at the CES (Consumer Electronics Show) based on the Audi A7, which had autonomously driven 900 kilometres to the trade show. The Future Truck prototype from Daimler also manoeuvred autonomously in a convoy (platooning). Since 2015, the Tesla Model S has a software function (full self-driving) to change lanes autonomously. The vehicles collect data under real operating conditions and send it over the air to technology centres where they are further processed in simulations which continuously improves the technology.

Initial tests with autonomous vehicles are already being conducted on public roads in the USA. In Germany, testing is limited to so-called digital test fields/routes on sections of motorways in Düsseldorf, Bavaria and Hesse and the testing of shuttles/people movers with a special permit to use the latter to supplement, e.g., public transport systems in urban areas.

While hardware was crucial with respect to purchasing a car in the past, the software is becoming increasingly important. This is directly related to the interface to the (end) customer and new business models. According to a Capgemini study, there is a potential for turnover amounting to USD 80-800 billion in 2030 through the monetisation of data or networked cars. This challenge is increasingly resulting in collaborations between automotive manufacturers, suppliers, information and communication technologies and ridesharing companies. The issue automotive manufacturers are facing has to do with their own development of the technology or licensing.

Areas of Application

The most well-known use of networked and autonomous vehicles is robot taxis/shuttles which, in the future, will autonomously navigate road traffic to bring their passengers to the desired destination. For ridesharing companies like Uber, Lyft or Didi Chuxing, this could significantly reduce the operating costs because human drivers would no longer be needed. In Germany, for instance, the ride-pooling company IOKI, a subsidiary of Deutsche Bahn (DB) and the Berliner Verkehrsgesellschaften (BVG) are currently testing the use of autonomous shuttles and minivans in real operation. There are also potential application opportunities for autonomous systems in rail, shipping, and air traffic.

Trains are also equipped with (driver) assistance systems and already run partially autonomously today, like the Serfaus funicular in Tirol and the subways in Nuremberg, Paris, London, Turin, Budapest or Lausanne. The French national railway SNF plans to use self-driving trains as prototypes in 2023. Further research projects, funded by the Bundesministerium für Verkehr und Digitale Infrastruktur (BMVI (Federal Ministry of Transport and Digital Infrastructure)) as part of the federal program "Zukunft Schienenverkehr" (Future of Rail Traffic) are being conducted in the Munich-North district. Here, automated, and digitised shunting and braking procedures are being tested in order to simplify the composition of freight trains.

The digital automatic coupling (DAC) is being tested in shunting operations of freight cars to drive automation and digitisation forward in the rail sector and take over physically strenuous work or make it easier for people to perform. The future basis of the complete automation of rail traffic will be the cross-border European Train Control System (ETCS) which is intended to provide a uniform standard without technical barriers by means of guidelines. The ATO (Automatic Train Operation) allows trains to be fully or partially controlled by a travel computer from a radio control centre. Analogue to road traffic, there is also a scale of levels which describes the grade of automation (GoA) based on four levels and was published by the International Association of Public Transport (UITP) in the IEC 62267 standard.

Ships can also be controlled from a great distance using a joystick in the command centre. In addition to an offshore supply vessel, the Yara Birkeland will also be the first autonomous container vessel to transport goods to the Norwegian coast without emissions. Autonomous and networked agricultural machinery and tractors in agriculture can be autonomously controlled and fuelled via integrated GPS tracking and camera controls. Smart farming reduces the financial expenditures and allows for the machines to be controlled and monitored by the computer with centimetre precision. Autonomous, electrical flight systems like drones or air taxis are being developed for the third dimension: the air. Originally developed for military purposes like reconnaissance flights, they could revolutionise urban and regional transport. On the road, however, autonomous delivery vehicles offer major potential for rapid delivery or last-mile transport, especially in the logistics sector. Driverless transport systems like industrial trucks are now essential components of large warehouses and will be used for load carrier handling in the intralogistics segment. They are networked with each other by means of artificial intelligence and networking with the cloud and can be optimally navigated by computers using cloud/edge computing and machine learning based on a dynamic route planning. Only the operations and maintenance are still monitored by humans.

Uniform standards are needed for the various forms of autonomous systems due to the networked communication and interaction between hardware and software. Statutory framework conditions and legal, ethical, and normative matters also need to be clarified which is considered more closely in the following based on the case study on vehicles in road traffic in Germany.

Legal Aspects

An ethics commission, consisting of 14 scientists, has been dedicated to examining the liability and safety-related matters pertaining to autonomous driving systems since 2016. The results were the final report "Guidelines for Programming Automated Driving Systems" and 20 ethical rules that created an initial legal basis for the law on "Amending the Road Traffic Act" in 2017. The obligation of the driver during the trip was defined therein, according to which they must be able to take control of the steering wheel at any time. A black box that records the relevant data, stores it for six months and then automatically deletes it, must also be installed in the vehicle.

With the recently passed "Law on Amending the Road Traffic Act and Mandatory Insurance Act - Law on Autonomous Driving" (version: May 2021), driverless operation for fully automated driving starting in 2022 in defined operating zones was allowed for the first time in Germany. The computer has complete control of the vehicle and the computer is monitored by a technical supervisor, i.e., a human, who can initiate or deactivate driving manoeuvres in individual cases. Technical requirements for the construction, quality and equipping of autonomous vehicles and handling data will be revised in the framework of the law. According to the BMVI, Germany is therefore the first country that can put autonomous vehicles into regular operation.

While initial legislative initiatives can be found in individual countries and US-American states, there are no international, harmonised legislation. The basis for this is still the "Vienna Convention on Road Traffic" from 1968 which was most recently revised in 2015. It dictates that vehicle must be steered by drivers but does not include any basis for autonomous driving systems. A final revision and approval of the participating countries is still pending. The United Nations Economic Commission for Europe (UNECE) which is responsible for technical rules for international road traffic, would like to allow for highly automated driving at up to 60 kph starting this year and (further) open higher speed limits.

In addition, the (German) manufacturers still require a type-approval from the Kraftfahrtbundesamt (Federal Motor Transport Authority) in accordance with the (EU) Ordinance 2018/858, which contains specifications for the introduction of new vehicles, systems, components, and autonomous technical units for vehicles to the market, without, however, taking autonomous driving systems into account. This gap is now to be closed by the newly enacted national law on autonomous driving, whereby the authorisation only has (national) validity.

Ethical Aspects

The thought experiment or dilemma in the event of a pending accident with an older and younger person was already discussed in detail at another point. In autonomous vehicles, which were programmed by people, this question should be clarified before the actual accident. Thus, the ethics commission suggested that the selection of actions based on human qualification characteristics in the event of an accident is impermissible and a restrained and defensive manner of driving must be programmed. Autonomous driving also offers the opportunity for positive societal developments because mobility can be rethought and people without a driver's licence can gain access to individual mobility.

Data Protection & Safety

Questions regarding the safety of the passengers and pedestrians are of particular importance, after reports of fatal accidents involving autonomous vehicles in the USA, however, the two legal frameworks are not comparable in this case. The manufacturers and suppliers are working at full speed on the further development of the safety and technology to build trust in the new technologies. In the future, accidents are to be avoided via regular updates of the safety and assistance systems as well as improved communication between hardware and software.

The on-board computer sends large quantities of data to the cloud every second which requires higher bandwidths, lower latency times and fault-free data transmission to the digital infrastructure. Only powerful and secure (wireless) transmission networks can allow for a secure connection to the cloud and protect against hacker attacks by "unknown third parties". Due to the variety of existing interfaces in the vehicle to the outside world and, for instance, to external service providers, there are countless potential points of attack. Guidelines and standards can help here to ensure a secure exchange of data. Which wireless technology, whether 5G or WLAN standard, will assert itself in the end with respect to networking vehicles in real time, remains to be seen.

Standards & Specifications – VDE's Role

VDE advocates for the interests of German industry in committees on the national, European, and international level. DKE focuses on all electrotechnical safety aspects and consumer protection. These activities include, for instance, the work of the DKE/GK 717 Intelligente Verkehrssysteme (IVS (Intelligent Transport Systems)) committee as a mirror committee to the CEN/TC 278 "Intelligent Transport Systems (ITS)", the ISO/TC 204 "Intelligent Transport Systems" and the ETSI TC ITS "Intelligent Transport Systems (ITS)" committees. The complexity is in the variety of individual systems and the smooth interaction across various interfaces and the most unfavourable environmental and EMC conditions. This includes electrical safety, data security, cyber security, functional safety and interoperability, whose work is certified, for instance, by testing institutes.

Road traffic signal systems also ensure secure communication between the vehicle and infrastructure – car-to-infrastructure (C2I). Relevant standards pertaining to traffic management, routing and warning signals are handled by the DKE/K 355 committee. Autonomous industrial trucks are a component of the committee work conducted by DKE/K 352 "Elektrische Ausrüstung von Flurförderzeugen" (Electrical Equipment of Industrial Trucks) as a mirror committee to CEN/TC 150. The members of the DKE/AK 801.0.8 "Spezifikation und Entwurf autonomer / kognitiver Systeme" (Specification and Design of Autonomous/Cognitive Systems)" committee developed the first AI standard in the form of the VDE-AR-E 2842-61-1 standard. This creates an international path for the structured and demonstrably safer development of AI-based systems and provides a reference standard which can ultimately result in an AI test certificate. In the DKE/K 351 "Elektrische Ausrüstungen für Bahnen" (Electrical Equipment for Railways) committee, VDE is focusing on the digital automatic coupling (DAK/ DAC) and the first standardisation and specification of power and data lines in freight cars. The topic of networking is a component of the DKE/K 717 and DKE/K 201 "System Komitee Elektrotechnische Aspekte von Smart Cities" (System Committee for Electrotechnical Aspects of Smart Cities).

This short list shows how important standards and specifications are so AI systems can work safely and reliably for people. In addition, DKE and DIN published the "Normungsroadmap Künstliche Intelligenz" (Standardisation Roadmap for Artificial Intelligence) (Version: November 2020). It defines criteria for trustworthy AI which will contribute toward the safety of and ability to explain AI applications, for instance, in the event of regular updates. The correlations between AI and ethics are discussed in the white paper "Ethik und Künstliche Intelligenz" (Ethics and Artificial Intelligence) (Version: October 2020). In addition to standardisation roadmaps and recommendations for action, an open dialogue, a technical exchange of information and a network of experts are important. To this end, VDE and the largest professional association in the world for electrical engineers, the IEEE, founded the international initiative "OCEANIS" in order to anchor ethics in the standardisation of autonomous and intelligent systems. In the "Praxisnetz Digitale Technologien" (Practical Network of Digital Technologies), VDE invites experts and decision-makers to collaborate in subject matter workshops, engage in an interdisciplinary dialogue and network.

Forecast & Conclusion

The open questions regarding the safety and reliability of autonomous systems are counterbalanced by countless potential opportunities. In the future, how these opportunities and challenges are viewed by the populace will be crucial. The existence of standards and specifications can be an important measure for promoting trust. After all, the assertion of autonomous systems is inevitable. The question is only when and how. Politics and the economy have shown that they are inclined to take this path and autonomous vehicles could be a reality very soon.