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Informatics

Autonomous driving

Rechtliche Fragen und Realisierungsprobleme des autonomen Fahrens in Europa

DIPLOMARBEIT

zur Erlangung des akademischen Grades

Diplom-Ingenieur

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Wirtschaftsinformatik

eingereicht von

Philipp Komar, BSc
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an der Fakultät für Informatik
der Technischen Universität Wien

Betreuung: Ao. Univ.-Prof. Mag. Dr. iur. Markus Haslinger

Wien, 12. März 2023

Philipp Komar

Markus Haslinger

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Informatics

Autonomous driving

Legal and feasibility issues of autonomous driving in Europe

DIPLOMA THESIS

submitted in partial fulfillment of the requirements for the degree of

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by

Philipp Komar, BSc
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at the TU Wien

Advisor: Ao. Univ.-Prof. Mag. Dr. iur. Markus Haslinger

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Philipp Komar, BSc

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Kurzfassung

Automatisierte Fortbewegung wird zu einem zunehmend diskutierten Thema. Ganze Industriezweige sind stark auf die Entwicklung neuer Technologien in diesem Bereich angewiesen. Neue Technologie erfordert oft neue Gesetze, aber der Gesetzgeber weiß oft nicht im Voraus wie diese formuliert werden sollen.[1] Bisher wurde immer davon ausgegangen, dass ein Fahrzeug von einem Menschen gefahren wird. Infolge dieses Grundsatzes wurden viele Anträge auf Gesetzesänderungen abgelehnt, da die Grundannahme eines menschlichen Fahrers nicht erfüllt wurde.[2] Neben der aktuellen Rechtslage soll diese Arbeit auch rechtliche Lücken und fehlende Gesetze aufzeigen. Der Datenschutz ist eines der Hauptthemen, da beim Reisen mit autonomen Fahrzeugen eine große Datenmenge generiert und gesammelt wird. Diese Daten bestehen nicht nur aus Benutzerdaten, sondern auch aus Maschinendaten.

Als eines der 4 Megathemen der Automobilindustrie, ergeben sich durch die enormen Ressourcen in kürzester Zeit viele neue Technologien und Anwendungen. Die Klassifizierung dieser und der Einsatz im automatisierten Fahrzeug bedarf genauen Analysen und Normierungen im Sinne der technischen Sicherheit, welche für eine erhöhte Gesamtsicherheit sorgen soll.

Die Probleme in diesem Bereich können daher wie folgt beschrieben werden: Die rechtliche Situation entwickelt sich viel langsamer als es für die neue Technologie notwendig wäre, dies schafft rechtliche Lücken und einige Gesetze müssen angepasst werden. Aufgrund des Fehlens von Gesetzen und Standards ist der Schutz personenbezogener Daten in vielerlei Hinsicht noch unklar, insbesondere in Bezug auf die künftige Verwendung. Darüber hinaus muss auch die verfügbare Infrastruktur geändert werden, um Fortschritte im Bereich des autonomen Fahrens zu ermöglichen.

Da sich sowohl der technische Wissensstand, als auch die rechtlichen Gegebenheiten in diesem Gebiet sehr schnell fortentwickeln, beschränkt sich die Recherche dieser Arbeit auf den Zeitraum bis März 2022.

[1] Ritz (2018d): Juristische Betrachtungen, p.1.
[2] Maracke (2017): Wirtschaftsinformatik & Management, Nr. 3, Bd. 9,, p.4.

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Abstract

Automated locomotion is becoming an increasingly discussed topic. Whole industries are strongly relying on the development of new technologies in this field. New technology often requires new laws, but the legislative authority often does not know how to formulate them in advance. [3] Until now, there was always the assumption, that a vehicle is driven by a human being. As a result of this principle, many requests for changes in legislation have been declined because the basic assumption of a human driver was not met.[4] In addition to the current legal situation, this thesis should also highlight legal gaps and missing laws. Besides the legal situation, data protection is one of the main topics, since a huge amount of data is generated and collected when traveling with autonomous vehicles. This data does not only consist of user data, but also of machine data.

As one of the 4 megatopics of the automotive industry, many new technologies and applications are emerging in a very short time due to the enormous resources available. The classification of these and their use in automated vehicles requires precise analyses and standardisation in terms of technical safety, which should ensure increased overall safety.

The problems in this field can thus be described as follows: The legal situation develops much slower than it would be necessary for the new technology, this creates legal gaps and some laws need to be adapted. Due to the lack of laws and standards, the protection of personal data is still unclear in many respects, especially the future use. In addition, the available infrastructure is also in need of change in order to make progress in the field of autonomous driving possible.

Since both the technical state of knowledge and the legal situation in this area are developing very rapidly, the research in this paper is limited to the period up to March 2022.

[3] Ritz (2018d): Juristische Betrachtungen, p.1.
[4] Maracke (2017): Wirtschaftsinformatik & Management, Nr. 3, Bd. 9,, p.4.

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List of abbreviations

5G NSA	5G Non-Standalone
5G SA	5G Standalone
5GAA	5G Automotive Association
ABGB	Allgemeines bürgerliches Gesetzbuch
ABS	Anti-lock Braking Systems
ACC	Active Cruise Control
ACSF	Automatically commanded steering function
ADS	Automated driving systems
AI	Artificial Intelligence
ASIL	Automovive Safety Integrity Levels
AutomatFahrV	Automatisiertes Fahren Verordnung
BASt	Bundesanstalt für Straßenwesen
BMVIT	Bundesministerium für Verkehr, Innovation und Technologie
CAM	Cooperative Awareness Message
capex	Capital Expenses
CBC	Cross-Border Corridor
CCAM	Connected Cooperative Automated transport
C-ITS	Cooperative Intelligent Transport Systems
C-V2X	Cellular - Vehicle-to-Everything
DARPA	Defence Advanced Research Projects Agency

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DDT	Dynamic Driving Task
DENM	distributed environment notification messages
DNN	Deep Neural Network
E2E	End to End
EC	European Commission
ECE	Economic Commission for Europe
ECU	Electronic Control Unit
EDPB	European Data Protection Board
EIF	European Interoperability Framework
EKHG	Eisenbahn- und Kraftfahrzeughaftpflichtgesetz
ENISA	European Union Agency for Network and Information Security
ESC	Electronic Stability Control
ETSI	European Telecommunications Standards Institute
FDIS	Final Draft International Standard
FIT	Failures In Time
FOV	Field of View
GDPR	General Data Protection Regulation
GLOSA	Green Light Optimised Speed Advisory
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
HMI	Human Machine Interface
IMSI	International Mobile Subscriber Identity
ITS-G5	Intelligent Transport Systems
ITU	International Telecommunication Union
KFG	Kraftfahrgesetz
KPI	Key Performance Indicator
LBO	local break-out

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LIN	Local Interconnect Network
LKA	Lane Keeping Assistant
LTC	Long-term Certificates
MaaS	Mobility as a Service
MEC	(Multi-Access/Mobile) Edge Computing/Cloud
MLR	Multi-linear Relationship Model
mMTC	massive Machine Type Communications
MNO	Mobile Network Operator
MRC	Minimal Risk Condition
MRM	Minimal Risk Manoeuvre
MUNIN	Maritime Unmanned Navigation through Intelligence in Network
NFR	Non-functional Requirement
NHTSA	National Highway Traffic Safety Administration
NR	New Radio
ODD	Operational Design Domain
OEDR	Object and event detection, recognition, classification and response
OICA	Organisation Internationale des Constructeurs d'Automobiles
opex	Operational Expenses
PDC	Park Distance Control
PHG	Produkthaftungsgesetz
PKI	Public Key Infrastructure
PLMN	Public Land Mobile Network
QoS	Quality of Service
RAN	Radio Access Networks
RAT	Radio Access Technologies
RSS	Responsibility-Sensitive Safety Model
RSU	Roadside Unit

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SAE	Society of Automotive Engineers
SaFAD	Safety First for Automated Driving
SDL	Security Development Lifecycle
SLA	Service Level Agreement
SoL	Self-organised logistics
SOTIF	safety of the intended functionality
SPA	Sence Plan Act
SSC	Session and Service Continuity).
StVO	Straßenverkehrsordnung
TARA	Threat Analysis and Risk Assessment
TC	Temporary Certificates
TCS	Traction Control System
totex	Total Expenses
TTC	Time-to-Collision
UCC	Use Case Classes
UE	User Equipment
UNECE	United Nations Economic Commission for Europe
URLLC	Ultra-Reliable Low Latency Communications
V2I	Vehicle to Infrastructure
V2N	Vehicle to Network
V2P	Vehicle to Pedestrian
V2V	Vehicle to Vehicle
VRU	Vulnerable Road User Protection
WRC	World Radiocommunication Conference

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CHAPTER 1

Introduction

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Automated locomotion is becoming an increasingly discussed topic and counts as one of the 4 megatopics of the automotive industry.[1] Whole industries are strongly relying on the development of new technologies in this field. For example, in early 2017, a cooperation between the German car manufacturer BMW and the US American semiconductor manufacturer Intel was announced. The goal was to bring production-ready autonomous vehicles on the market as soon as 2021.[2]

New technology often requires new laws, but the legislative authority often does not know how to formulate them in advance. A very vivid example is the theft of electricity. At the beginning of the electrification, this was not a crime because one did not know how to handle electricity, a non-material good. Similar, though perhaps not as extreme, is the legal situation surrounding autonomous driving, which also leaves many questions unanswered.[3] Until now, there was always the assumption, that a vehicle is driven by a human being. As a result of this principle, many requests for changes in legislation have been declined because the basic assumption of a human driver was not met.[4] In addition to the current legal situation, this thesis should also highlight legal gaps and missing laws. Besides the legal situation, data protection is one of the main topics, since a huge amount of data is generated and collected when traveling with autonomous vehicles. This data does not only consist of user data, but also of machine data. In June 2017, this topic was discussed on the Ethics Committee on Autonomous Driving.[5] Autonomous vehicles were depicted as machines which can independently collect and process private data. Furthermore, from

[1] Scheffels/Gelowicz (2018): Autonomes Fahren: Definition, Level & Grundlagen.
[2] Maracke (2017): Wirtschaftsinformatik & Management, Nr. 3, Bd. 9,, p.1.
[3] Ritz (2018d): Juristische Betrachtungen, p.1.
[4] Maracke (2017): Wirtschaftsinformatik & Management, Nr. 3, Bd. 9,, p.4.
[5] Bundesministerium für Verkehr und digitale Infrastruktur (2017): Ethik-Kommission - Automatisiertes und vernetztes Fahren.

today's point of view, it is still unclear to what extent this data will be used in the future.[6]

Autonomous vehicles are becoming more and more complex and now have better sensors than smartphones. They capture the environment, like public spaces, in high intensity.[7] With the realization of an autonomous traffic becoming ever closer, the topic of safety, both technically and digitally, becomes more and more important. To ensure the safety of people both inside and outside of the vehicle, cyber- and computer security have the highest priority in the discussion about autonomous connected vehicles. The best autopilot is of no use if someone manipulates the vehicle without authorization.[8]
Finally, but no less ambitious in the explanation, is the question of the success factors, or the necessary infrastructural changes and/or development that need to be made for the successful introduction of autonomous driving in the future. In order to make autonomous movement possible in the long term, it is necessary to create a solid basis for the technology. No matter if cloud-based systems (v2i) or interconnected vehicles (v2v), one challenge is certainly the large amount of data. Three-dimensional orientation and cartography, for example, is one cause for high data volumes, which makes a new fast data transmission standard necessary.[9] [10]

[6] Jakobi/Stevens/Seufert (2018): Datenschutz und Datensicherheit - DuD, Nr. 11, Bd. 42,, p.705.
[7] Ritz (2018a): Autonome Datenverarbeitung, p.175.
[8] Ritz (2018e): Die Schattenseiten des autonomen Fahrens, p.195-196.
[9] Clausen/Klingner IVI (2018): Automatisiertes Fahren, p.393-395.
[10] Dangschat (2018): Zeitschrift für Politikwissenschaft, Bd. 27,, p.499-502.

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CHAPTER 2

Automated driving

2.1 Historical access

In order to fully understand and comprehend the scope of autonomous driving, it is necessary to clear the field from the very back. A historical approach to the topic of autonomous driving gives you a good overview of the development of the last almost 100 years. One thing should be noted at the outset, the roots of autonomous driving are in the United States of America, the main factor being that the motorization of the masses began here a good 30 years earlier than in Europe.[1] A much earlier invention by the famous Leonardo da Vinci would also be worth mentioning at this point. From around the year 1478 there are sketches(2.1) of a vehicle that could have been moved by a pre-programmed mechanism.[2] The scetch shows an open top three-wheeler which would have been powered by a large coiled clockwork spring and so, would be able to move without beeing pushed.[3]

2.1.1 Early Years

At the beginning of the 1920s, after the end of the First World War, the high number of victims in traffic accidents quickly became a major problem. To understand the magnitude, let us give an example: after just four years, more people were killed in road accidents in the USA than were killed during the war in France.[4] In 1922, 14,859 people died in road accidents, numbers rising each year around 10%.[5] Overall, motorized

[1] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.43.

[2] Weber (2014): Where to? A History of Autonomous Vehicles.

[3] Ibid.

[4] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.43.

[5] Wikipedia (2020): Motor vehicle fatality rate in US by year.

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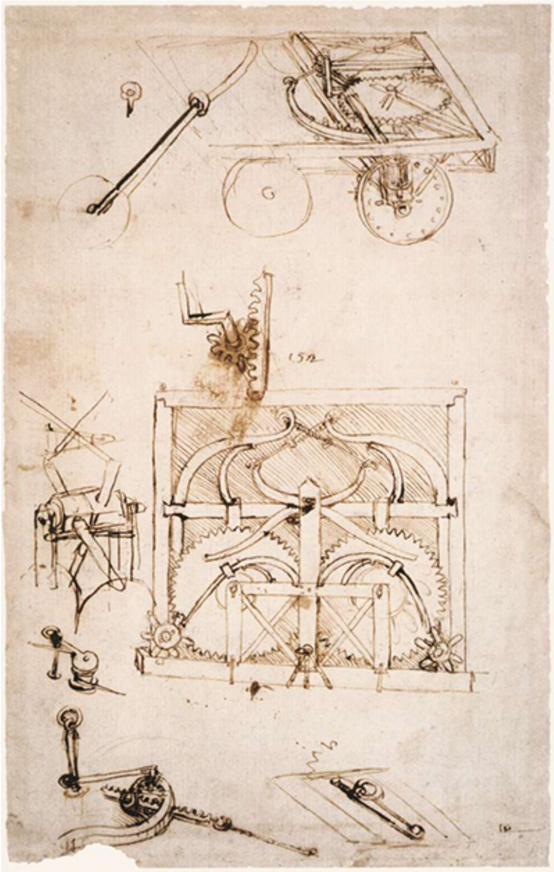

Figure 2.1: pre-programmed clockwork cart by Leonardo Da Vinci, original source from LeonardodaVinci.net: Automobile

traffic led to the death of around 200000 US citizens in the 1920s, the largest number of them were pedestrians.[6] The development of the next few years was largely driven by the premise that the human driver is primarily to blame for the accidents and not the technology or infrastructure, which was almost completely ignored at the beginning. [7] In order to leave out the human factor, two technical developments for automated driving were considered. First, a radio technology to control Torpedos called radioguidance, which was mainly developed and sponsored by the US military, was introduced. [8] Early precursors of autopilots had also been developed, based on a gyroscope. This system was called airplane stabilizer, which, as the name suggests, was developed to stabilize airplanes in their flight path, was impressively demonstrated in a field test by its developer

[6]Norton (2008): Fighting Traffic: The Dawn of the Motor Age in the American City, p.22.

[7]Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.43.

[8]Ibid., p.44.

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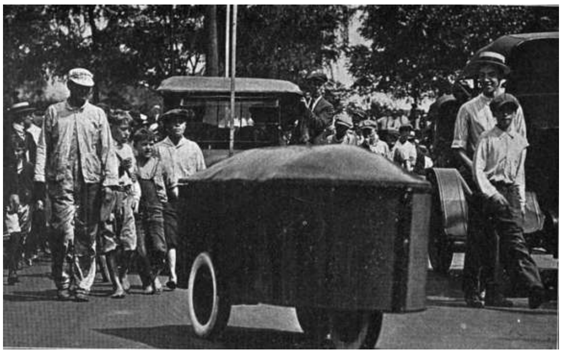

Figure 2.2: the first radio controlled car by Captain R. E. Vaughn, original source from Radio Corporation of America (1922): World Wide Wireless, p.19

Lawrence B. Sperry on June 18, 1914.[9,10,11]

Since the technology was of course not that advanced at the beginning of the 1920s, the first autonomous vehicles were not really autonomous, but remotely controlled. The first remote-controlled vehicle was unveiled to the public in 1921 and demonstrated at the McCook Air Force Test Site in Dayton, Ohio.[12] The radio controlled car was about two meters and 45cm long and had three wheels (see 2.2). Captain R.E. Vaugh, the builder of this car, was controlling it remotely over a wireless radio connection from a manned vehicle, driving shortly behind the unmanned car.[13] [14,15]

During the 1920s and 30s the development of autonomous vehicles under the guise of "safe means of transport" continued to advance.[16,17] There are many references to such driverless vehicles in the literature, often in connection with topics that are still current today. For example, the fear of losing control is a core problem then as it is now and that is why we are always working on increasing the security aspects.[18]

Over the years there have been many concepts and ideas for highways of tomorrow, to make autonomous driving a reality. For example, the May 1938 issue of Popular Science Monthly presented a number of concepts for "super highways".[19] This concept

[9] Scheck (2004): Lawrence Sperry: Genius on Autopilot.
[10] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.43.
[11] McRUER/ASHKENAS/GRAHAM (1973): Aircraft Dynamics and Automatic Control, p.27.
[12] Everett (2015): Unmanned Systems of World Wars I and II, p.429.
[13] Wikipedia contributors (2020b): Unmanned ground vehicle — Wikipedia, The Free Encyclopedia.
[14] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.44.
[15] Radio Corporation of America (1922): World Wide Wireless, p.18.
[16] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.45.
[17] Wünsche (2013): Geschichte des Automatischen Fahrens.
[18] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.46.
[19] Bonnier Corporation (1938): Popular Science, p.27-28.

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represented a cultural model until the 1970s and was created in collaboration with the US oil and automotive industries, architects, transport scientists, industry and urban planners.[20]

Since many people lost faith in technological progress as a result of the Great Depression, this concept also served to give people hope again and to promote the expansion of the American highway. [21] Conductor tracks were planned in the floor of these highways, which should control the vehicles and thus make them autonomous. This concept, F.Kröger translated it to "Leitdrahtvision" in "Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext"[22] , was not planned to be implemented immediately, rather, the design character was underlined by countless futuristic illustrations, such as those by Benjamin Goodwin Seielstad.[23]

A year later, at the 1939 world exhibition, which was fully committed to the motto "building the world of tomorrow", visionary aspects of autonomization were presented in the General Motors Pavilion under the exhibition title "Futurama".[24] General Motors wanted to show the audience what a future might look like in 1960 and therefore organized elaborate presentations. Visitors were guided through miniature landscapes on a 16-minute tour. On this tour interstate highways were shown, an impressive view for the people who at that time hardly owned their own vehicle. The visualization of 10,000 animated vehicles on 14-lane motorways gave the viewers new ideas about what was possible and brought breeding ground for visions for the next decades. However, some questions remained unanswered, for example how GM had envisioned automation not being discussed in detail. The only information given was that a driver would be at the wheel of the vehicles and that they would receive and carry out commands and instructions from experts in control towers.[25]

2.1.2 The heyday of the automobile

Between 1940 and 1950 the success of autonomous driving and the entire automotive industry stalled due to the Second World War. It was not until the early 1950s that people began to deal more intensively with the topic. Technologies that were developed for military purposes during the war served as the basic building block. Particularly noteworthy here are the further developed radar technology and magnetic detectors, which were used by the military mainly to track down mines.[26] With the help of the new technologies, the visions of the linked up super highways were no longer so hesitant

[20] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.46.

[21] Komar (2017): Autonomes Fahren - Aktueller Stand und Untersuchung rechtlicher Aspekte, p.4-5.

[22] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext.

[23] Ibid., p.48-49.

[24] Auer et al. (2016): History of intelligent transportation systems., p.1-2.

[25] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.50.

[26] Ibid., p.51.

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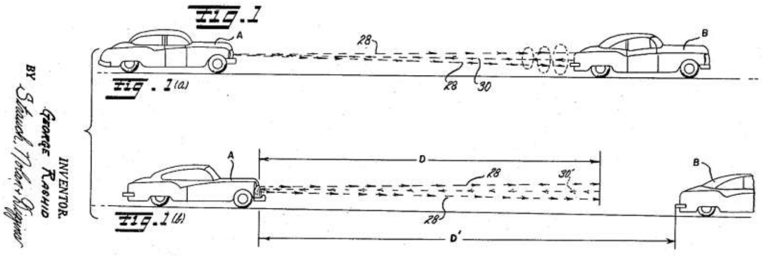

Figure 2.3: "Automatic vehicle control system" by George Rashid, original source from George (1957): Automatic vehicle control system

and so, for example, the first tests were carried out by RCA Labs, a large American electronics company, as early as 1953. Here, a small-scale model vehicle was guided over wires laid in the ground. This successful attempt resulted in repeating this setup on a 1:1 scale. In 1957 a field test was carried out, also by RCA Labs, on an approximately 120m long test track on a public highway in Nebraska.[27] The radar technology, or its intended applications in the automobile, which also has its origins in this time, is, as it turns out over time, a forerunner of the active cruise control that is frequently used today.[28][29] The first sketches and patents were already available in 1957[30], see figure 2.3.

Compared to the last few decades, the trend was more and more towards "what is feasible" instead of pursuing utopian fantasies. Theory quickly turned into practice, and so new assistants and techniques were constantly coming onto the market in the 1950s. The "speedostat" developed in 1948 by mechanical engineer Ralph R. Teetor[31] and available for the first time in 1958 (Chrysler Imperial) is the first variant of a cruise control, also called "Auto-pilot".[32] It was also the first system that we would call a driver assistance system today.

In order to understand why no expense or effort was spared in such early years and why a lot of money and time was invested in research, one has to understand what was one of the main driving forces behind the success of autonomization at that time. This will also be taken up in the later course of this work. In 1954, McCall's Magazine sponsored a publicity campaign aimed at encouraging families to spend more time together. This "togetherness" is also reflected in the development of the automobile future, as many contemporary illustrations prove.[33] So the basic idea was to spend more time with the family and less at the wheel of a car. This was illustrated very well by LIFE magazine in

[27] Hicks (2018): Nebraska tested driverless car technology 60 years ago.
[28] Komar (2017): Autonomes Fahren - Aktueller Stand und Untersuchung rechtlicher Aspekte, p.6.
[29] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.51.
[30] George (1957): Automatic vehicle control system.
[31] Teetor (1950): Speed control device for resisting operation of the accelerator.
[32] Chrysler (1958): 1958 Chrysler Auto Pilot Brochure.
[33] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.53.

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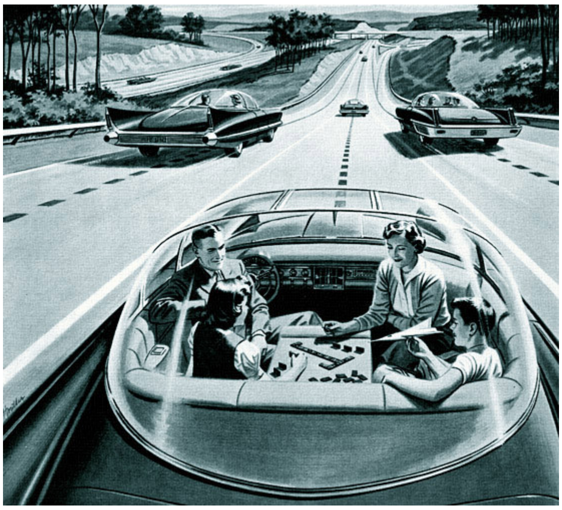

Figure 2.4: Illustration of "family togetherness", driving an autonomous car by the LIFE Magazine 1956, original source from U. (2016): The Road to Driverless Cars: 1925 - 2025

1956, as can be seen in Figure 2.4. The already mentioned guide wire concept, which is intended to keep the vehicle on track, can also be seen. Also in 56, the Firebird II concept was presented by General Motors, which contained such a system to follow circuits embedded in the ground and so could be remote controlled.[34]

The first real "automatically guided automobile" was tested 1958 on a one mile long test track in Michigan. The system was still the same here as it was at the end of the 1940s, with electronic sensors attached to the bumper that allowed the vehicle to follow cables laid in the ground.[35] Outside the United States, work was also being done to make autonomous vehicles a reality. For example, a driverless Citroen DS was tested in the UK by the Transport and Road Research Laboratory in 1960, which, similar to the concepts in the United States, was following magnetic cables buried in the ground.[36]

2.1.3 Years of Progress

It was not until the 1970s that it was realized that such a major change in the infrastructure, i.e. laying cables or something similar like that, was not feasible. In addition, due to the progress of technology during this time, there were now significantly more possibilities for the realization of autonomous locomotion.[37][38] The turning point came when, in the mid-1970s, research was carried out on the technology required and on the

[34] U. (2016): The Road to Driverless Cars: 1925 - 2025.

[35] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.55.

[36] Waugh (2013): How the first "driverless car"was invented in Britain in 1960, p.55.

[37] Komar (2017): Autonomes Fahren - Aktueller Stand und Untersuchung rechtlicher Aspekte, p.8.

[38] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.59.

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intelligent logic that was necessary for autonomous driving. Research was carried out at the Coordinated Science Laboratory of the University of Illinois[39], and in 1977 the Mechanical Engineering Laboratory in Tsukuba, Japan even succeeded in designing the first advanced autonomous vehicle. At that time, two cameras were used for the first time, filming the surroundings and allowing them to be processed. [40]

At the beginning of the 1980s, Daimler-Benz, in cooperation with several other European vehicle manufacturers, with the team led by Ernst Dickmanns, successfully tested a converted "semi-autonomous" Mercedes-Benz bus. They have chosen a Mercedes-Benz Vario because of the size of the equipment that had to be carried, e.g. the heavy high-tech computers and components.[41] It was possible to achieve a speed of 63km/h on streets without traffic, focusing on the usage of GPS systems and radar.[42] This success led EUREKA [43] to launch the "Prometheus" project, with a budget of the today's equivalent of 749 million Euros.[44] Many similar test vehicles and projects will follow in the next few years. For example, in the USA a project for an autonomous land vehicle (ALV [45]) was supported by DARPA [46] in 1986. The research carried out under DARPA in various universities is jointly responsible for the progress in this research area. In the ALV project, newly developed technologies such as LIDAR, computer vision and autonomous control were used. Several tests were carried out, both on and off the road.[47][48]

However, this development on a conceptual level also led to the fact that many technologies for assisting driving were also introduced to the broad masses in car production.[49] Over the next few years, new technologies often found their way into the automobile.

The influence that the film industry had on this development should also not be underestimated. Especially in the 70s and 80s there were some films and series that dealt with or with autonomous vehicles in some way. As an example, one could use well-known television series such as Knight Rider (1982-86), which is about the intelligent vehicle "KITT" and, in addition to many unrealistic functions, also had a number of technologies that can be implemented today. Earlier films such as Duell (1973) or Herbie, The Love Bug, which in 1968 was about a self-driving VW Beetle with its own character, were very memorable for viewers from this time and left room for the imagination. This depiction of autonomous vehicles in films was interesting until about the first half of the 2000s,

[39] Wikipedia contributors (2020a): History of self-driving cars — Wikipedia, The Free Encyclopedia.
[40] Russell (2015): How Autonomous Vehicles Will Profoundly Change The World.
[41] Oagana (2013): A Short History of Mercedes-Benz Autonomous Driving Technology.
[42] Bin Sulaiman (2018): SSRN Electronic Journal, p.1-2.
[43] an intergovernmental organization for funding and coordination of research and development
[44] Bimbraw (2015): Autonomous cars: Past, present and future a review of the developments in the last century, the present scenario and the expected future of autonomous vehicle technology, p.193.
[45] Autonomous Land driven Vehicle
[46] Defence Advanced Research Projects Agency
[47] Bin Sulaiman (2018): SSRN Electronic Journal, p.2.
[48] Bimbraw (2015): Autonomous cars: Past, present and future a review of the developments in the last century, the present scenario and the expected future of autonomous vehicle technology, p.193.
[49] Bin Sulaiman (2018): SSRN Electronic Journal, p.1.

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from then on there were hardly any self-driving vehicles in films that were supposed to represent an attraction, since such vehicles were already realistic.[50]

In addition to the cruise control (1958) already mentioned in chapter 2.1.2, the ABS anti-lock braking system was presented for the first time in 1971 (launched by Bosch in 1978). Variable steering assistant and crosswind Compensation were studied in 1990 by MacAdam et al.[51]. A year later, in 1991, ultrasonic parking sensors were introduced. With the introduction of the electronic stability program (ESP), attempts were made to counteract the susceptibility of the human-machine interface to errors. The BAS brake assistant followed a year later. A new introduction, which was already predicted in chapter 2.1.2, is the "Distronic" introduced by Mercedes-Benz in 1998, which was supposed to enable "semi-automated" driving at that time. The distance to the vehicle in front is constantly measured while driving and the speed is adjusted accordingly.[52][53]

The acceptance of people to pay attention to instructions from computers and to act accordingly has a lot to do with the use of navigation systems. Permanently installed systems were installed for the first time in 1994 in the then new 7 Series from the German car manufacturer BMW.[54] TomTom launched the first portable "all-in-one" solutions in 2004 (TomTom Go).[55]

2.1.4 Millenium

From the 2000s onwards, developments went in the direction of what we now understand by an autonomous vehicle. In the 00s, some projects were again supported by DARPA, such as the first to the third "Grand Challenge" (2004, 2005 and 2007).[56][57] Companies like Google also started research in this area in 2009, today known as Waymo.[58] BMW was one of the first major vehicle manufacturers to begin developing driverless systems around 2005, and by 2013 all major manufacturers, such as Ford, GM and Mercedes-Benz were intensively involved in the issue.[59] As it soon turned out, this challenge quickly became more complicated than expected, since at the beginning of the 2010s the technology was for the most part semi-autonomous and, above all, the legal conditions had not yet been adapted.[60]

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[50] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.57-61.
[51] MacAdam et al. (1990): Vehicle System Dynamics, Bd. 19,.
[52] industrie.de (2018): Mercedes-Benz/Bosch: 40 Jahre Anti-Blockier-System.
[53] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.61.
[54] BMW AG (1994): [Pressemappe (E38):] Der neue 7er BMW, p.56-57.
[55] BV (2021): Our story.
[56] Kaldewey (2018): Minerva, Nr. 2, Bd. 56,, p.175.
[57] Thrun (2010): Commun. ACM, Nr. 4, Bd. 53,, p.1.
[58] Glon/Edelstein (2020): The history of self-driving cars.
[59] Wikipedia contributors (2020a): History of self-driving cars — Wikipedia, The Free Encyclopedia.
[60] Glon/Edelstein (2020): The history of self-driving cars.

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In the following years, various research teams and companies continuously presented and tested new developments. Autonomous driving was and is an omnipresent topic. Together with electromobility, this is a research area that serious vehicle manufacturers inevitably have to devote themselves to in order to remain competitive on the international market. As a result, for example, the 2014 model of the Mercedes-Benz S Class could be optionally equipped with assistants for autonomous steering, accelerating and braking, lane departure warning, parking assist and collision avoidance.[61] In the USA, it was also possible for manufacturers such as Tesla to present their first version of an autopilot at the end of 2014, which was activated in March 2015 with a software update. It should be noted here, that at that time, legally speaking, fully autonomous vehicles were not yet permitted in the USA either, so the driver still was legally required to be in control of the vehicle at all times.[62] Following statement from Elon Musk was recorded during a press conference regarding the Version 6.2 software update:

> "You're not supposed to turn on autopilot and go to sleep. There's certainly an expectation that when autopilot on the Model S is enabled, that you're paying attention. But it should also take care of you if you have moments of distraction"[63]

As Musk already says, Tesla's vehicles are therefore at the level of autonomy between 2 and 3 (NHTSA [64]) at this time.[65] Human intervention is therefore still necessary to intervene in emergency situations. A tragic example occurred in March 2018 when the death of Elaine Herzberg in Arizona was recorded as the first fatal accident involving a self-driving vehicle and a pedestrian. As it turned out later, the driver, who should have intervened in this situation, was at this point busy watching a television series.[66]

2.2 Definition of autonomous driving

In order to go into the definition of autonomous driving from today's perspective, one must first understand what is meant by "autonomous" and where the limits are drawn in autonomous driving. At the beginning, there is the definition of the word "automobil", which is basically composed of the Greek word "autós" - meaning "self, independent", and the Latin word "mobilis" - meaning "mobile". This definition has been in existence since the beginning of the automobile. However, this term originated from a time when horses were used for propulsion. At that time "self-mobile" meant something like being

[61] Daimler AG (2021): Pioneering achievement: Autonomous long-distance drive in rural and: Mercedes-Benz S-Class INTELLIGENT DRIVE drives autonomously in the tracks of Bertha Benz.

[62] Ackerman (2015): Tesla Model S: Summer Software Update Will Enable Autonomous Driving.

[63] Weintraub (2015): Audio Recording of the Tesla 6.2 Range Anxiety Press Conference, video-recording: 31:15-31:35.

[64] National Highway Traffic Safety Administration

[65] Golson (2016): Volvo autonomous car engineer calls Tesla's Autopilot a 'wannabe'.

[66] Kaplan et al. (2018): Deadly Uber crash was 'entirely avoidable' had the driver not been watching Hulu.

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mobile without being pulled by horses. The term "autonomy" ends with the Greek word "nómos" meaning "law (man-made)". A horse could therefore move autonomously to a certain extent, for example, to keep its lane independently, vehicles could not.[67] There is no exact definition in the literature, but over the course of time, classifications have been drawn up that classify and describe autonomy. When talking about "autonomy" in the context of autonomous driving, however, this is incorrectly defined as "self-determination". It is much more about the vehicle being able to move independently within a defined framework, described by Feil in "Antithetics of Modern Reason." Autonomy - Heteronomy "and" Rational - Irrational "" as "Kant's concept of autonomy". This predefined framework is given by the legislature, for example traffic regulations.[68]

Said classifications for the degree of autonomy of vehicles were drawn up by various institutes. In 2012, BASt [69] defined a list of level descriptions in a final report on the subject of "Legal Consequences of Increasing Vehicle Automation". This first version comprised levels from 0 to 4, the 5th level (fully autonomous) was still missing here.[70] In the USA, the NHTSA [71] was the first organization to compile a list of the individual levels of autonomy in 2013, which initially comprised 5 levels, starting at 0. There was no distinction made between high and full automation.[72][73] In 2014 the "SAE J3016" standard, which is the most widely used system for classifying autonomous vehicles, was defined. Basically, the classifications of the 2012 BASt classifications have been incorporated into the standard and have been extended by a level five (full automation / driverless driving). Together with the classification of the OICA [74], there are several different systems that coexist. The differences are very small, however, and in 2016 the system created by NHTSA was adapted to that of the SAE. The differences between the individual systems can be seen in Table 2.1.

2.2.1 Definition by SAE J3016

As already mentioned, the SAE J3016 standard is the most frequently used and is considered as the "standard" when it comes to classifications. It was adapted by the US American NHTSA and is an extension of the BASt system developed in 2012. It was issued by SAE International [75] and has been valid since January 2014.

First of all, SAE J3016 specifies the definition of some terms. The terms "**autonomous**"

[67] Maurer (2015): Einleitung, p.2.
[68] Ibid.
[69] Bundesanstalt für Straßenwesen
[70] Gasser (2012): Rechtsfolgen zunehmender Fahrzeugautomatisierung: gemeinsamer Schlussbericht der Projektgruppe, p.31.
[71] National Highway Traffic Safety Administration
[72] Schreurs/Steuwer (2015): Autonomous Driving - Political, Legal, Social, and Sustainability Dimensions, p.161-163.
[73] U.S. Department of Transportation (2013): Preliminary Statement of Policy Concerning Automated Vehicles.
[74] International Organization of Motor Vehicle Manufacturers
[75] formerly Society of Automotive Engineers

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Organisation	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
BASt, SAE, OICA	Driver Only	Assisted	Partial Automation	Conditional Automation	High Automation	Full Automation
NHTSA	No Automation	Function-spec. Aut.	Combined Function Aut.	Limited Self-Driving Aut.	Full Self-Driving Automation	

Table 2.1: Differences between the four major classification systems, original source from Zanchin et al. (2017): On the Instrumentation and Classification of Autonomous Cars, p.2632

or "**autonomy**" are not used because in legal science they are mostly seen as the ability for self-governance, which, as already described in 2.2, does not exist in this sense.[76]

Important definitions from the SAE J3016 are as follows:

Automated driving systems (ADS)

> The term "automated driving system" is used to describe driving automation systems from level 3, 4 and 5. It describes the hard- and software which together are able to carry out the dynamic driving task (DDT). However, this should happen regardless of whether the system is limited to a special operational design domain (ODD). [77]

Dynamic driving task (DDT)

> The expression "dynamic driving order" is used to describe all real-time functions (operational and tactical) that are required to operate a vehicle in traffic. This excludes strategic functions, which would be:
>
> - trip scheduling
> - selection of destinations and waypoints
>
> The following operational functions are also included:
>
> - steering (lateral vehicle motion control)
> - acceleration/deceleration (Longitudinal vehicle motion control)
>
> Tactical functions are as follows:
>
> - maneuver planning
> - Enhancing conspicuity (lights, signals, gesture)
>
> Combinations of operational and tactical functions:

[76] SAE international (2018): SAE International,(J3016), p.28.
[77] Ibid., p.3.

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- Monitoring the driving environment (object and event detection, recognition, classification, response preparation)
- Object and event response execution

The original source of this list is from SAE J3016[78]

Operational design domain (ODD)

The "operational design domain" describes a special environment or condition under which a certain moving automation system or one of its functions is designed to operate in. There are no geographical, environmental or time of day restrictions. There is still a special provision about the presence (or absence) of road users or road obstacles. [79]

Request to intervene

When a "fallback-ready" driver / user receives a "request to intervene", he is notified by an ADS that he should perform a "DDT fallback". This can mean, that the driver has to take over manual operation of the vehicle. If the vehicle is not in a drivable state, a "minimal risk condition" must be derived. [80]

From a summary, published in 2014 by SAE International, it can be seen that in addition to the classification into six levels, from "no automation" to "full automation", basic definitions of functional aspects of the technology are also included. Furthermore, uncertainties should be removed which spread over different areas of development (e.g. engineering, legal,..). This creates clarity as to which role the driver has at each of the individual levels.[81]

The standard divides the degree of autonomy into 6 levels, which are described in more detail in 2.2.1.1 to 2.2.1.6. The available technology in each category is also briefly described.

2.2.1.1 Level 0, No Driving Automation

At level 0 there is no automation, which means that the driver takes over the DDT at any time. The lowest level according to SAE J3016 does not, as one would assume, contain any automated driving systems. However, this does not mean that vehicles in this category do not have auxiliary systems. Systems that can support the driver in this

[78] SAE international (2018): SAE International,(J3016), p.6.
[79] Ibid., p.14.
[80] Ibid., p.15.
[81] SAE International (2014): Automated driving - Levels of driving automation are defined in new SAE International standard J3016.

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category are called "active safety systems" and are defined in SAE J3063. These are vehicle systems that sense and monitor the conditions inside and outside of the vehicle. This serves the purpose of identifying the current conditions and predicting potential hazards for the vehicle and its occupants.[82][83] Examples of technologies available at active safety systems can be divided into two different sets. On the one hand, the so-called "**warning systems**" fall into level 0, and on the other hand "**emergency systems**". Warning systems, as the name suggests, warn the driver in dangerous situations, e.g. Lane Departure Warning, Lane Change Assistant, PDC [84] or Rear-End Collision Warning. The second set, the emergency systems, includes driving aids such as ABS [85], ESP / ESC [86], TCS / ASR [87] or Emergency Brake Assistants. Even if at first glance one would think that these systems would belong to higher automation categories, they actually belong to level 0. The reason for this is that these systems intervene on a longitudinal level (prevention of wheel-locking (ABS), reduction of engine power (TCS)) or on a lateral level (targeted braking of individual wheels, reduction of engine power and thus intervention in the lateral dynamics of the vehicle (ESC)), but only for a very short time and not for a permanent state.[88] These systems, if available, are therefore never intended to perform any part of the DDT in any situation.[89]

2.2.1.2 Level 1, Driver Assistance

Level 1 already includes assistance systems that can take over specific tasks such as steering or acceleration/deceleration. Parts of the DDT are therefore taken over by advanced driving assistance systems. Either the lateral or the longitudinal vehicle movement can be taken over and executed, not both at the same time. However, the driver is still responsible for the perception of objects and driving situations and for execution of rest of the driving task, which is not carried out by an assistance system at that time. In addition, the driver is expected to be in control of the automated DDT at all times, to monitor it at all times, and to intervene immediately when the situation requires it. The system must respond immediately to the driver's deactivation command.[90] [91] Driver assistance systems that fall under this category would be, for example, the parking assistant (PA), which automatically manoeuvres the vehicle into a parking space. The vehicle or its PA system measures the distances to the parked

[82] SAE international (2018): SAE International,(J3016), p.3 and 24.

[83] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.23.

[84] Park Distance Control

[85] Anti-lock Braking Systems

[86] Electronic Stability Control

[87] Traction Control System

[88] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.20, 23.

[89] SAE international (2018): SAE International,(J3016), p.21.

[90] Ibid.

[91] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.20, 23-24.

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vehicles and turns the steering wheel accordingly. All that remains for the driver is to operate the accelerator and the brake. The ACC [92]is an extension of the normal cruise control, which has been in use since the 1960s. Sensors actively measure the distance to the vehicle in front while driving and the System automatically brakes or accelerates the vehicle according to given threshold values. On motorways, a so-called Lane Keeping Assistant (LKA) is also often used, which is an extension of the Level 0 Lane Departure Warning System. Camera systems detect lane markings and, when the assistance system is activated, steer the vehicle accordingly to keep it within the marked lanes. If this is not possible, the driver must intervene accordingly with level 1.[93] An adapted function of ACC, which will be discussed in more detail later, is **cooperative ACC platooning**, which is based on conventional ACC, but extended to include communication between the individual vehicles.[94]

2.2.1.3 Level 2, Partial Driving Automation

In contrast to level 1 automation, with level 2 both the lateral (steering movement) and longitudinal (acceleration, braking) movement of the vehicle can be executed simultaneously. Apart from this, the same conditions are expected of the driver at level 2 as at level 1. The driver must continue to carry out the rest of the DDT, which is not carried out by a system. In addition, the driver must continuously monitor the driving automation system and intervene if necessary. The OEDR [95] subtask, as well as switching the system on and off depending on the situation, is also part of the driver's area of responsibility.[96] As with level 0 and 1, the driver monitors the driving area, but it may be possible with level 2 that the driver can be completely disengaged, i.e. does not have to operate/touch the steering wheel and pedals.

Technologies that make this possible would be, for example, the further development of the Automated Parking Assistant, the so-called Parking Assistant Level 2. Basically, the old system is extended by the acceleration and braking function that was missing in Level 1. The driver does not even have to be in the vehicle, but can stand outside the vehicle. However, monitoring is still the responsibility of the driver, as is the need to intervene in dangerous situations.[97] To give an example, BMW introduced the first parking assistant in 2006 and in 2010 introduced a concept that allowed the driver to park his vehicle in a garage, for example, without sitting in the vehicle itself. These systems are now common optional features in the medium and luxury class. The driver must continuously press a button on the vehicle's key for the time of the parking process, during which the vehicle travels at a maximum speed of 2km/h. The driver is then able

[92] Active Cruise Control

[93] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.24.

[94] Ibid.

[95] Object and event detection, recognition, classification and response

[96] SAE international (2018): SAE International,(J3016), p.21, 24.

[97] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.25.

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to park the vehicle without sitting in the vehicle, which stops immediately when the button is released.[98] In addition to the enhanced Parking Assist, Traffic Jam Assist, which is also a further development, is also worth mentioning at this point. The Active Cruise Control, which is already used in Level 1, is extended by a function that allows the Traffic Jam Assist to also carry out lateral movements.[99]

2.2.1.4 Level 3, Conditional Driving Automation

With level 3, the monitoring obligation changes for the coming levels. The driver's area of responsibility covers the following points. First of all, he is expected to always be aware of the functional condition of the ADS-equipped vehicle and therefore decides when the ADS can be used. The driver's remaining task when the ADS is activated is to be fallback-ready for the DDT, i.e. to be able to intervene quickly in an emergency situation. Level 3 systems have the ability to perform one or more DDTs at once. In contrast to level 2, level 3 can also monitor the surroundings under certain conditions, so the driver is not obliged to pay constant attention to the surroundings. However, the driver must be alert to the request to intervene at any time and must do so within a suitable period of time.[100]

At the time the SAE standard was written (current version June 2018), Level 3 features in vehicles were still a thing of the future. Today, some manufacturers were pursuing the goal of bringing the first Level 3-capable vehicles onto the market in 2021; Mercedes Benz, for example, planned to introduce the "Drive Pilot" in the S-Class in the second half of 2021.[101] Other manufacturers, such as BMW, are also pursued the goal of bringing a Level 3 system to market in 2021. A similar system is to be used in the "iNext EV" research vehicle.[102] These highway chauffeur systems or traffic jam chauffeurs are advanced forms of the traffic jam assistants already used in Level 2. These two systems differ in the speed of their application. Congestion Chauffeurs are mainly intended for narrow traffic up to 50kmh, including multi-lane motorways. Motorway Chauffeurs are designed to cover long distances and relieve the driver of the driving task. The navigation and route planning is done via precise GPS data and sensors attached to the vehicle (more on this in the chapter 3.4.1.1).[103]

2.2.1.5 Level 4, High Driving Automation

High automation takes Level 3 one step further. The ADS executes the entire DDT permanently. Even the DDT fallback, which is still carried out/expected by the driver at

[98] Boeriu (2010): BMW Remote Controlled Parking.

[99] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.21, 25.

[100] SAE international (2018): SAE International,(J3016), p.22.

[101] Jordan (2020): DER DRIVE PILOT DER NEUEN S-KLASSE KANN LEVEL 3.

[102] Slovick (2020): BMW Takes Self-Driving to Level 3 Automation.

[103] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.25.

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level 3, is already carried out independently by the ADS at level 4, so that the driver never has to intervene. Likewise, the user does not have to monitor the vehicle and the surroundings; this task is carried out by the ADS-enabled vehicle itself. In the event of an emergency, or when the design conditions are no longer met, the driver is not expected to intervene or be ready to intervene. The driver becomes a passenger when driving in a vehicle with an activated Level 4 system.[104]

Depending on the design, Level 4 ADS features can be designed differently. Depending on the application, this results in different driving modes which are ODD-specific. The system boundaries are defined more widely than with Level 3, so use is possible over entire sections of a journey. However, the use is domain-specific, i.e. for a specific area of application.[105][106]

The following technologies are used at Level 4 Automation. Technologies already exist today that belong to this category, for example the "Intelligent Park Pilot" from Mercedes-Benz, which allows the current S-Class to park without a driver and fully automatically.[107] This so-called automatic valet parking function, or Parking Garage Pilot, is offered by several premium vehicle manufacturers. The driver no longer even has to sit in the vehicle. An extension of the Highway Chauffeur, the "Highway Pilot" allows, as already mentioned, to completely hand over entire sections of a journey, for example a longer journey on a motorway, to the ADS.[108]

2.2.1.6 Level 5, Full Driving Automation

With level 5, you have arrived at the highest category of automated driving. Level 5, or full driving automation, describes the permanent and unconditional takeover of the DDT by the ADS. As with level 4, the fallback of the DDT is completely taken over by the system. At the start of the journey, the driver only has to determine the operational state of the vehicle and decide when the ADS should be activated. The factors under which the active ADS performs a DDT fallback are: if a relevant system failure occurs, the driver does not react, or the driver wants the system to reach a minimum risk state. [109]

Level 5 differs from Level 4 in the following areas, Fully autonomous driving enables DDT in all possible circumstances, on different surfaces and roadways.[110] So fully autonomous driving is **not ODD specific**! Conversely, this means that, in contrast to level 4, there are no design-related limits. However, this does not mean that there are no circumstances

[104] SAE international (2018): SAE International,(J3016), p.25.
[105] Leicht (2019): Automatisiertes Fahren - Die Stufen des autonomen Fahrens.
[106] SAE international (2018): SAE International,(J3016), p.27.
[107] Jordan (2020): DER DRIVE PILOT DER NEUEN S-KLASSE KANN LEVEL 3.
[108] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.26.
[109] SAE international (2018): SAE International,(J3016), p.23.
[110] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.21.

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under which it would not be possible to continue driving. Like the driver himself, the system is subject to certain system limits, such as black ice, high water or heavy snow storms. Thus, a journey may have to be interrupted as the ADS performs a DDT fallback to put the vehicle in a minimum risk state.[111] As with Level 4, the driver does not need to monitor the Level 5 ADS or be ready to receive a request to intervene. The driver is no longer referred to as such, but becomes a passenger.

Finally, it should be noted that this highest level of automation is mainly intended for private vehicles that operate in non-urban areas. In urban areas, at least from today's point of view, it is planned and generally agreed that vehicles (cars, buses, lorries, etc.) should "only" run Level 4 systems, which means that the ADS may only be used up to a certain speed or in certain areas.[112]

2.2.1.7 Noteworthy Opinions

In addition to the generally recognised SAE J3016, there are other approaches that are worth mentioning here. According to expert opinions of the ADAC, only 3 operating modes would be sufficient instead of the described 5 (or 6) stages. The described levels would therefore range from level 1, assisted driving, to 2. automated driving and 3. autonomous driving. Starting with level 1, the vehicle is driven by a driver at all times, who must also maintain control of the car and keep an eye on the traffic. Similar to the first two levels of SAE, the vehicle is able to provide certain assistance, such as lane keeping. The driver is liable in any case.

Level 2 (Automated Driving) in this case, would be similar to level 3 or level 4 SAE, where the driver is allowed to hand over the driving task to the system and engage in other activities. However, a predefined domain is also necessary here, which the manufacturer specifies within which the vehicle is allowed to operate in, for example traffic jam assistants. As soon as the system requests the driver to take over the vehicle, this request must be followed, otherwise the driver is liable for any accidents that may occur.

Finally, at level 3, the driving task is completely handed over to the system and the driver becomes a passenger. This is between level 4 and 5, as the autonomous mode can be limited to defined routes. Level 5 according to SAE, however, does not know any specific ODD. Apart from that, DDT fallbacks are handled by the system itself and the driver does not have to monitor anything. It is interesting that the provider is assigned a supervisory role, which he must perform in order to react to malfunctions. The driver, who is also a passenger at level 3, is not liable for anything.[113]

[111] SAE international (2018): SAE International,(J3016), p.25.

[112] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.26.

[113] ADAC (2018): Autonomes Fahren: Die 5 Stufen zum selbstfahrenden Auto.

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SAE level	Name	Narrative Definition	Execution of Steering and Accel./Decel.	Monitoring of Driving Environment	Fallback Performance of DDT	System Capability (Driving Modes)
Human driver monitors the driving environment						
0	**No Automation**	the full-time performance by the human driver of all aspects of the DDT, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the DDT	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration /deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the DDT	System	Human driver	Human driver	Some driving modes
ADS ("system") monitors the driving environment						
3	**Conditional Automation**	the driving mode-specific performance by an ADS of all aspects of the DDT with the expectation that the human driver will respond appropriately to a request to intervene	System	System	Human driver	Some driving modes
4	**High Automation**	the driving mode-specific performance by an ADS of all aspects of the DDT, even if a human driver does not respond appropriately to a request to intervene	System	System	System	Some driving modes
5	**Full Automation**	the full-time performance by an ADS of all aspects of the DDT under all roadway and environmental conditions that can be managed by a human driver	System	System	System	All driving modes

Table 2.2: Overview of SAE levels for automated driving for on-road vehicles, original source from SAE International (2014): Automated driving - Levels of driving automation are defined in new SAE International standard J3016

2.2.1.8 Overview

The 6 levels (0-6) or categories according to SAE J3016 become more and more complex in terms of the degree of autonomisation as the level increases. In order to better visualise the sometimes subtle differences, table 2.2 serves as a summary.

2.3 Impact and Benefits of automation

2.3.1 Fewer Accidents

The benefits that arise from the consistent introduction of automated vehicles are very far-reaching. Above all, an improvement in the safety aspect is expected in order to reduce the number of the current 1.2 million road deaths per year. According to statistics of the European Parliament, about 95% - 98% of all traffic accidents are caused by

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human error.[114] Obviously, there is a huge potential for improvement here. One of the most important benefits of automated driving is therefore the reduction in the number of accidents and thus also in the number of fatalities. This is realised by the simple fact that an autonomous system is not aware of fatigue or inattention and, provided the programming is correct, accidents will also decrease as the degree of autonomy increases. The more complex the systems are and the higher the resolutions that the respective sensors and cameras can achieve, the more accurate and better such a system can work and the lower the risk that an accident could occur. To give a few figures, which have been compiled by insurance companies, the following are reductions in accidents as a percentage of systems already available on the market.[115] For example, the high improvement of 38% achieved by an automatic emergency brake assistant is remarkable. Lane Keeping Assist with an improvement of 4.4% and Lane Change Assist with 1.7% also offer a plus in safety.

It can be assumed that systems of higher SAE categories still have much more potential for improvement. In urban environments, such scenarios have already been simulated by the Institute for Motor Vehicles (ika) in cooperation with the Institute for Road Systems (isac) at RWTH Aachen University using extrapolation logic within the framework of a research project of the "Bundesanstalt für Straßenwesen" (BASt). Especially in urban areas, considerable improvement potentials of up to 26% were found through the use of so-called robot taxis alone, and this already with a market penetration of 50%.[116] In general, five different automated driving functions of SAE levels 3 and 4 were analysed. However, the working environment differs; for example, the traffic jam assistant, motorway assistant and commuter chauffeur are only active outside towns and the robot taxi systems already mentioned are only active in urban areas. Only the universal chauffeur, as the name suggests, can be used in and out of town.

Since the introduction of new systems cannot automatically be expected to result in 100% market penetration, a gradation of 5, 25, 50 and 100% was chosen for this extrapolation in order to get an overview of the potential for improvement. It is noteworthy that in summary it can be shown, that depending on the domain, between 46% and 54% of the total number of accidents can be prevented with 100% market penetration (apart from the traffic jam chauffeur).[117]

2.3.2 Better utilisation of time

In addition to increased safety and reduced accident potential, there are other advantages that should not be neglected. Another advantage, for example, is that the vehicle occupants, especially the driver, are not preoccupied with the driving task as they used to be, but can devote their time to other things. This, of course, offers a far more efficient

[114] Europäisches Parlament (2020): Verkehrsunfallstatistiken in der EU (Infografik).
[115] Brenner/Herrmann (2018): Digital Marketplaces Unleashed, p.431.
[116] Rösener et al. (2019): Potenzieller gesellschaftlicher Nutzen durch zunehmende Fahrzeugautomatisierung, p.5.
[117] Ibid., p.88.

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use of driving or travelling time. Of course, the use of this freed-up time still leaves a lot of room for manoeuvre, so this time can be used for recreation, entertainment or getting together with friends and family. Apart from that, it can also be used productively in the form of valuable working time.[118] According to a study by Horváth & Partners and the Fraunhofer IAO, the diverse needs can be divided into "communication, productivity, entertainment, information, well-being and basic needs".[119]. The true potential can be understood by looking at the time spent in a vehicle every day. According to the BMVI's event report "Mobility in Germany 2017", average journey times of 46 minutes per day were determined.[120] Of course, this figure varies greatly depending on age, gender and place of residence, but nevertheless offers an approximate idea.[121] Finally, if we consider only the time spent in traffic jams each year, we find that between 154 hours (Berlin) and 100 hours (Düsseldorf) are lost each year. This results in an average of 120 lost hours per year across Germany, which could be used more sensibly.[122] By way of comparison, in Vienna people are stuck in traffic jams for around 109 hours a year.[123]

Not only is it advantageous to make better use of the time spent in traffic jams, but the use of automated driving systems such as the motorway chauffeur can also reduce the time spent in traffic jams. A further analysis by RWTH Aachen University showed that the potential for avoiding traffic jams by reducing the number of accidents is between 1 and 11%, depending on market penetration. This can save not only time, but also money and energy.[124] The annual costs for every individual caused by standing in traffic jams are between 900 and 1340 Euro (Berlin), depending on the city/extent of the congestion.[125] Particularly nowadays, environmental considerations are also relevant in terms of climate protection; an investment in such systems is also indirectly an investment in climate protection. Shorter congestion times mean less exhaust gas pollution, regardless of whether it is emitted from the vehicle by a combustion engine or generated during the generation of electricity.

2.3.3 Social justice and a chance for the elderly

Another point that makes autonomous driving a forward-looking technology is that it redefines/interprets the opportunity for mobility. In the case of conventional forms of automobile mobility without automated functions, older people, the sick or physically disadvantaged, for example, are often excluded from using vehicles. This means that they are denied something that is taken for granted by the majority of the population. If these

[118] Brenner/Herrmann (2018): Digital Marketplaces Unleashed, p.431.
[119] Dungs et al. (2016): Fraunhofer-Institut für Arbeitswirtschaft und Organisation IAO, Horváth & Partners: Stuttgart, Germany, p.8.
[120] Nobis/Kuhnimhof (2018): Mobilität in Deutschland- MiD: Ergebnisbericht, p.76.
[121] Ibid., p.45-54.
[122] INRIX (2019): Berlin ist Deutschlands Stauhauptstadt.
[123] Die Presse (2019): Wiener stehen 109 Stunden pro Jahr im Stau.
[124] Rösener et al. (2019): Potenzieller gesellschaftlicher Nutzen durch zunehmende Fahrzeugautomatisierung, p.88.
[125] INRIX (2019): Berlin ist Deutschlands Stauhauptstadt.

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people are not allowed to drive vehicles anyway, it is often physically impossible due to limited mobility or other reasons.[126] Especially older people have a higher inhibition threshold when using new, modern technology, but the benefits are tempting. It is not without reason that senior citizens, who sometimes have declining sensory abilities, are seen as a target group when it comes to autonomous driving. The risk of being involved in traffic accidents increases significantly for people over 75 years of age, 75% of which are caused by themselves.[127]

2.3.4 Financial benefits

As already mentioned, the use of automated driving functions offers, among other things, the possibility of making better and more productive use of time while driving or riding in the car. However, this is only one of many key points that can lead to a financial advantage or additional benefit of autonomous driving. Of course, all figures that can be quantified are pure speculation or extrapolations. [128] In addition, one must also understand that there can be some overlap between the individual areas. For example, the use of an ADS leads to a more productive use of travel time, but also to a reduction in travel time of up to 40%, which alone can lead to large savings.To give some figures here; a saving through increased productivity of £20 billion in the UK, in the US potentially 1.3 trillion US dollars due to an expected 80 billion hours saved which previously had to be spent on commuting. [129] [130] Many factors mean that a realistic scenario is relatively difficult to predict accurately. Nevertheless, studies are being carried out in many countries, for example, KPMG International had made a projection in 2015 which said that a cumulative saving to the consumer in the UK of £5 billion was possible. This is due to the reduced costs of insurance, running costs or parking costs. The more productive travel time conceivably offers a high potential. Depending on the source, however, the spread of the calculated sums is relatively large here. KPMG estimates an impact of £15 billion for the UK alone by 2030.[131] A 2019 article on "How cities can benefit from automated driving" by Andreas Tschiesner, a McKinsey senior partner, suggests that an EU-wide 1 billion Euro in additional income can be generated if only half of the time gained through ADS is used for productive purposes.[132]

Other financial benefits can also be found in the lower number of accidents. Of course, it is an advantage in itself that the number of accidents decreases, but this can also be expressed in economic terms. Even if it is macabre, the statistical life in the calculations of the Department of Transportation (US) has an official value of 9.2 million dollars. Forbes Magazine made the following calculation with figures from 2012, but the accident

[126] Brenner/Herrmann (2018): Digital Marketplaces Unleashed, p.431.
[127] Losch (2021): Selbstfahrende Autos: Senioren als lukrative Zielgruppe.
[128] Brenner/Herrmann (2018): Digital Marketplaces Unleashed, p.431.
[129] Thales Group (2021): 7 BENEFITS OF AUTONOMOUS CARS.
[130] Leech et al. (2015): KPGM, p.21.
[131] Ibid.
[132] Tschiesner (2019): How cities can benefit from automated driving.

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figures are not much different today.[133] If one now assumes that 30000 accidental deaths can be avoided annually through the use of ADS, this alone results in cost savings of 276 billion dollars. Added to this are savings from non-fatal accidents and accidents without personal injury.[134] Bertonello (McKinsey & Company) assumes a not quite as large but no less insignificant figure of $212 billion in costs caused to the US economy. Assuming 90% potential improvement through the use of automated driving systems, there would be financial savings of $190 billion in addition to lives saved through accidental deaths.[135]

A study by Morgan Stanley (2013) estimated the total savings for the US economy at $1.3 trillion in a realistic scenario. In this study, the savings due to accident avoidance are estimated at 488 billion dollars. Globally, up to $5.6 trillion in savings are possible. Shorter travel times and congestion will also reduce fuel consumption and energy use. According to Morgan Stanley, the savings potential is 169 billion dollars. [136][137] It should also be noted that not all jobs will benefit from autonomous vehicles. It can be assumed, for example, that the use of ADS will greatly reduce penalties for traffic violations and parking violations. [138] For many cities and municipalities, revenue from fines is a firmly calculated part of the budget; in Hamburg alone, up to 30 million Euros are collected annually just from parking fines. In Stuttgart, 11 million Euros are earned annually through strategically placed speed cameras. As these revenues will fall drastically, other ways of raising money, for example city tolls instead of parking tickets, will have to be considered.[139]

2.3.5 Traffic and parking management of urban areas

For decades, more and more people have been drawn to cities. In the first decade of the 21st century, more than 50% of the population lived in cities and it is predicted that up to 70% of the world's people will live in cities by 2050. [140] Due to this fact, the impact, especially in a positive sense, of autonomous driving is also crucial. Driving with ADS can have a positive effect on the development of inner city traffic and urban planning. In the future, when a vehicle is used to drive in the city, the journeys before and after the actual journey will be handled by the vehicle itself. This means, in theory, the automated vehicle will park itself and pick up the vehicle occupant(s). After completing the actual driving task, the vehicle drops the occupant(s) off at the desired destination and then drives to an assigned parking position. This leads to a correspondingly far more effective and efficient parking system. automated vehicles can manoeuvre at the assigned parking space in a much more space-saving manner, as no people have to get in or out. Depending on the area, parking zones or collective garages for autonomous

[133] Kords (2020): Verkehrstote in den USA bis 2019.
[134] Ozimek (2014): The Massive Economic Benefits Of Self-Driving Cars.
[135] Bertoncello/Wee (2015): Ten ways autonomous driving could redefine the automotive world.
[136] Shanker et al. (2013): Morgan Stanley blue paper, p.1-9.
[137] Brenner/Herrmann (2018): Digital Marketplaces Unleashed, p.431, wrong scale.
[138] Tschiesner (2019): How cities can benefit from automated driving.
[139] Ibid.
[140] zukunftsInstitut (2021): Urbanisierung: Die Stadt von morgen.

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vehicles would be conceivable. Car parks specifically designed for driverless vehicles could be made much more efficient by replacing ramps with lifts, reducing the overall ceiling height and, as mentioned, implementing a higher density of parked vehicles. According to the developers, such facilities could park up to 60% more vehicles in the same space. [141] Even in conventional parking garages that have already been built, an improvement in parking space of up to 30% could be achieved. [142] The more efficient use of parking space is accordingly also reflected in a financial advantage, since it can be assumed, that parking costs might decrease as vehicles could choose their parking spot according their cost-efficiency.[143]

In addition to parking spaces, driving with activated ADS also affects space requirements in flowing traffic. Coordinated platooning, i.e. coordinated acceleration and braking, can thus reduce the amount of road space used.This circumstance leads to a significant increase in capacity for the same area, depending on the source, projections vary here from 180% (Brownell[144]) in the inner city area to 500% (Fernandes[145]) over all.[146] The increased efficiency could now serve to reduce the space built up by roads in order to generate more space for quality of life.

Finally, there is a third effect that is worth mentioning, namely the changed attractiveness of residential areas. Many users will presumably accept a longer commute as a result of automated driving, since the time spent in the vehicle itself, as already described, can be used elsewhere or more sensibly. A trip into town will be easier to plan and there will be less uncertainty in terms of traffic congestion. [147] According to various authors, however, some of the advantages described only come into play with SAE Level 5. [148] All the effects mentioned are conceivably difficult to predict; much will depend on the market penetration of autonomous vehicles. The trend in the total number of vehicles is also not clear-cut, even though the arguments would tend to favour an increase in private vehicles.[149]

[141] Heinrichs (2016): Autonomous Driving and Urban Land Use, p.222.
[142] Linnhoff-Popien/Schneider/Zaddach (2017): Digital Marketplaces Unleashed, p.431.
[143] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.73.
[144] Brownell (2013): Princeton University, April.
[145] Fernandes/Nunes (2012): IEEE Trans. Intell. Transp. Syst., Nr. 1, Bd. 13,.
[146] Heinrichs (2016): Autonomous Driving and Urban Land Use, p.224.
[147] Ibid., p.223.
[148] Ibid., p.224.
[149] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.74.

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CHAPTER 3

Technology and Safety

In addition to increased comfort, increasing safety and thus reducing the risk of accidents is the main focus when it comes to the development of and motivation for autonomous driving.[1] A current statistic of the European Parliament shows that in 2019 about 120,000 people were seriously injured in a traffic accident, 22,800 were fatally injured. Even though the number of traffic fatalities is steadily decreasing, it is assumed that between 95% and 98% of all traffic accidents are due to human error.[2][3] It is therefore understandable why there is a great potential for improvement in this area. This potential increases with the degree of automation, so that it can be assumed that the number of accidents will decrease with increasing autonomisation.[4]

Safety and security are often grouped together, even though these two topics are not necessarily the same and their focus is characterised by various differences. Nevertheless, due to various overlaps and the general understanding of safety, safety in the security aspect will also be addressed here.[5] With increasing complexity on the digital side, more and more possibilities and incentives to misuse these capabilities arise with more advanced degrees of autonomisation. The following chapter looks at how security is currently guaranteed, both on the technical side, e.g. technical design, and on the digital side. Why is cyber security important for the safety of autonomous driving, both today and in the future?

[1] Linnhoff-Popien/Schneider/Zaddach (2017): Digital Marketplaces Unleashed, p.430.
[2] Europäisches Parlament (2020): Verkehrsunfallstatistiken in der EU (Infografik).
[3] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.6.
[4] Linnhoff-Popien/Schneider/Zaddach (2017): Digital Marketplaces Unleashed, p.431.
[5] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.21.

3.1 State of the Art

For many years autonomous driving has been an ever-growing field of research whose introduction to daily life in the future is approaching ever closer. However, the definition of autonomous vehicles can be differentiated, the levels of automation defined in the norm SAE J3016by the engineering association are as follows. Starting at level 0, which does not include any automation, lower levels of autonomy begin at level 1, Driver Assistance. At this stage, the driver is assisted in longitudinal or transverse guidance, for example ESP or ACC. Level 2 (partial automation), on the other hand, offers assistance with both longitudinal and transverse guidance. Here, for example, Tesla has pioneered the Model S, which already masters simple driving situations on the freeway. For most research, however, what you mean by "autonomous driving" does not start until level 3 and above. "Conditional automation" is understood to mean that the vehicle drives automatically, but the driver must always be ready to intervene actively in the system, in the case of an error. Level 4 is high automation, here the vehicle drives independently and does not expect any intervention of the vehicle occupants.[6] At level 5, the full automation, there are different views, the Bundesanstalt für Straßenwesen (BASt) for example assumes a driverless vehicle. [7]

Autonomous driving has long ceased to be in the test stadium, the first tests of university research groups were a long time ago. Today, almost every vehicle manufacturer is researching in this direction.[8][9] Google operates as one of the trailblazers about 53 test vehicles which have already driven more than 3.5 million test kilometers by the end of 2015, 75% fully automatic.[10] J.Ritz predicts in his book "Mobilitätswende – autonome Autos erobern unsere Straßen" (2018), that the first high automated cars could already be on sale in 2021, and by the year 2039 self-driving vehicles could have become established in the market.[11] This prognosis coincides with the goal of the german car manufacturer BMW, to bring an autonomous vehicle, the BMW i5 on the market as soon as 2021.[12] This vehicle would potentially be considered to be classified as level 5, but due to legal requirements in different countries, BMW limits itself by the use of a steering wheel to level 4.[13]

Autonomous driving does not stop with the conventional car. In many cities around the world autonomous vehicles of all kinds are already being used today.[14] For example, driverless cabins are used at London's Heathrow Airport for shuttle services between the parking garage and the terminal. Subways in Tokyo or Dubai operate partly without

[6] Ritz (2018b): Autonome Fahrzeuge, p.28-37.
[7] Wikipedia (2018): SAE J3016 — Wikipedia, Die freie Enzyklopädie.
[8] Ritz (2018b): Autonome Fahrzeuge, p.37.
[9] Maracke (2017): Wirtschaftsinformatik & Management, Nr. 3, Bd. 9,, p.1.
[10] Clausen/Klingner IVI (2018): Automatisiertes Fahren, p.387.
[11] Ritz (2018b): Autonome Fahrzeuge, p.37.
[12] BMW AG (2018): BMW PressClub Österreich.
[13] Flehmer (2018): BMW fährt mit Vision iNext Richtung Level 4.
[14] Ritz (2018b): Autonome Fahrzeuge, p.27.

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staff.[15] Driverless transport systems in logistics have been used since the 1960s. Off-site use by trucks will require a few more years of development, but in-house such systems are already state of the art.[16] Autonomous vehicles are also being researched in agriculture, such as autonomous feudal swarm units for soil tillage at the TU Dresden.[17] Furthermore, an EU-funded project on unmanned merchant vessels, the MUNIN (Maritime Unmanned Navigation through Intelligence in Network) was implemented at the Fraunhofer Institute.[18] [19]
Autonomous city traffic can mean even more. A more efficient use of parking space would be conceivable through networked communication between parked and parkingspace-searching vehicles. A relief through fewer parkingspace-searching paths can have a positive effect on the traffic situation and air quality. According to a calculation by J.Ritz (2018), autonomous parkingspace search and parking assistants can save space by about 30%, if autonomous vehicles park in compact formations up to additional 50%.[20]

In order to make safe autonomous driving possible today different technologies are developed and used. These include above all high-performance communication techniques, for example 5G radio, a combination of different sensors that perceive the environment (camera, radar, LIDAR or ultrasound) and should lead to a robust ad-hoc identification and situation detection. The machine learning of vehicles in a real environment also has a major influence. [21]

3.2 Safety Approach

In July 2019, "'Safety First for Automated Driving"', a major white paper on safety for automated driving (for Level 3/4 SAE) was published in collaboration between the largest manufacturers in the automotive sector and other big players related to autonomisation (Aptiv, Audi, Baidu, BMW, Continental, Fiat Chrysler Automobiles, HERE, Infineon, Intel and Volkswagen). The basis for the statements made in the paper are **12 guiding principles**, which have been summarised or compiled from publications and recommendations of public authorities and consumer associations.[22]

The main general goal is for the automated vehicle to provide safer transportation than would be possible for the average driver. The aim is to achieve a positive risk balance across all situations, even if a negative safety balance arises in the unlikely situation of an accident. In order to achieve a positive risk balance, the 12 principles, according to the SaFAD white paper, described below can provide an approach to derive safety

[15] Ritz (2018b): Autonome Fahrzeuge, p.37.
[16] Clausen/Klingner IVI (2018): Automatisiertes Fahren, p.403-404.
[17] Ibid., p.404.
[18] Ibid.
[19] Jahn (2017): Maritime autonomous navigation technology.
[20] Ritz (2018c): Folgeinnovationen, p.68-75.
[21] Clausen/Klingner IVI (2018): Automatisiertes Fahren, p.387-393.
[22] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.10.

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requirements and activities necessary for the automated driving functions, down to individual safety objectives of the various components.[23][24]

Safe Operation The principle of safe operation deals with the circumstances of **how degradation is dealt with**, i.e. it describes how the system has to behave when system failures of critical components occur. According to this, the vehicle should on the one hand be able to compensate for the failure and on the other hand be able to put itself/and the passengers in a safe position. On the other hand, it is expected to find an appropriate time window to hand over the driving task to the human driver. Furthermore, it is assumed that a failure of a safety-related component/function should never lead to a safety-related situation (described as "**fail-operation**").[25]

Safety Layer The safety Layer ensures that the automated driving vehicle recognises its system limits reliably and in time. It is expected to act accordingly, for example to hand over the driving task to the driver at the appropriate time. Foreseeing critical situations or recognising system limits is particularly important in situations in which it would no longer be possible to safely hand over the driving task to the driver.[26]

Operational Design Domain (ODD) The ODD, short for Operational Design Domain, is dealt with in a separate principle, which includes **ODD determination** on the one hand and the **management of typical situations** on the other. As described on page 14, the ODD describes a specific environment or condition under which an automated vehicle operates.[27] If the predefined system limits are exceeded, this must be perceived by the vehicle. Finally, the system should react in a compensatory manner or communicate a request to the driver to take over the driving task in a suitable time window. When driving in a certain environment/ODD, the vehicle is expected to recognise situations typical for that ODD and to consider and manage possible risks accordingly.[28]

Behaviour in Traffic When the autonomous vehicle moves on public roads, the principle of "behaviour in traffic" comes into play. This defines how the vehicle behaves in road traffic and how it should be perceived by other road users. The "SaFAD" white paper calls this "**Manners on the Road**". The behaviour of the autonomous vehicle or even the automated function itself should therefore be easily understandable, predictable and manageable for outsiders. Of course, every road user must obey the traffic rules, and an automated driving system is no different. Under the point "**Conforming to Rules**", it is assumed that this self-evident fact is also implemented by the system.[29]

[23] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.10.
[24] Daimler AG (2019): “Safety First for Automated Driving” (SaFAD).
[25] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.7.
[26] Ibid., p.10.
[27] SAE international (2018): SAE International,(J3016), p.14.
[28] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.7.
[29] Ibid., p.9.

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User Responsibility When driving vehicles that have functions that are SAE levels 3 and 4, a certain responsibility remains with the user. The so-called user responsibility serves to promote safety. The condition of the vehicle user plays a central role, so the user must be in a receptive position at all times, for example in the event of a request to take over the driving task. The system constantly monitors the driver's condition and must regularly inform the driver about his area of **responsibility** as well as about any safety-relevant information that could have an influence on the situation of the vehicle in scenarios of unmanned driving. The driver must therefore be aware at all times of the tasks for which he is responsible at any given moment. In order to ensure a safe driving condition and not to create any ambiguity in the operation, it is assumed that the vehicle user must be aware of the active driving mode at all times. "**Mode awareness**" therefore means that the currently active mode should be unambiguously apparent to the driver, and any changes of driving modes should also be clearly recognisable. [30] Depending on the state of the vehicle's driving mode, responsibility for compliance with traffic regulations is left either to the automated driving system or to the driver himself. This is addressed in the Behaviour in Traffic principle.[31]

Vehicle-Initiated Handover In dangerous situations, the automated driving system must request the driver to take over the driving task in order to bring the vehicle into a minimal risk state. The **take-over requests**, which are directed from the vehicle to the driver, must be unambiguous and realisable for the driver. If the driver does not comply with this request, for whatever reason, the vehicle must independently perform a manoeuvre that results in the vehicle and its occupants being in a **minimum risk condition**. For this purpose, the vehicle itself must decide which measures are necessary. These depend on the respective conditions and must be selected proportionally to the situation.[32]

Driver-Initiated Handover The principle of driver or vehicle operator-initiated handover means that the activation or deactivation of the automated driving system and its functions is always based on an explicit request from the driver. The safety aspect is that the system must not be activated unintentionally or autonomously, but always represents an intended action by the driver.[33]

Effects of Automation Another point in the overall evaluation of system safety is the impact or dependencies between the driver and the Automated Driving System (ADS). Driving with activated functions in an ADS may well have an impact on the driver's attention. Other effects could include increased fatigue due to reduced cognitive demand.

[30] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.8.
[31] Ibid., p.9.
[32] Ibid., p.8.
[33] Ibid., p.7.

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It is therefore important to include all these effects on the driver in the overall evaluation, including the time periods immediately after the end of the autonomous driving process.[34]

Safety Assessment The assessment and evaluation of safety is particularly important in the case of autonomous driving, as the use of such systems entails a high level of responsibility. Wherever people and their safety are at stake, it is important to ensure safety. For this purpose, a verification of the results already achieved and a validation of the safety objectives should be carried out on an ongoing basis. This serves to continuously improve overall safety.[35]

Data Recording An important topic in automated driving systems is the recording of data. Due to the large number of complex sensors and camera systems, it is possible to record a large number of areas in varying degrees of detail. Data recording is of course a sensitive issue when it comes to the Data Protection law (GDPR). This is dealt with in more detail in chapter 4.3.3. The principle of data recording is that automated vehicles should record the relevant data that would be crucial to determining the circumstances in the event of an accident or incident, in order to make data recording a positive benefit.[36]

Security Safety and security are often mentioned together in the same sentence, even though they deal with different topics. Nevertheless, security is an important component and one of the 12 principles of autonomous driving. It is assumed that if an automated driving function is implemented in a vehicle, all necessary steps are taken to protect the automated system from security-related attacks and threats. Chapter Cybersecurity 3.7.5 goes into more detail on this.[37]

Passive Safety The use of autonomous driving technologies creates completely new opportunities to increase the passive safety of vehicles. For example, the **layout of the seating positions** can be reworked, as there are sometimes more possibilities due to the autonomous driving functions. On the other hand, it must of course be ensured that the vehicle is modified and retrofitted for **accident scenarios** that are caused or facilitated by automated driving.[38]

3.3 Technical Infrastructure

In order to enable automated driving, a number of changes are conceivably necessary. There are different approaches to how an autonomous vehicle can communicate with the infrastructure. The communication of the automated system and the transport infrastructure is one of the key issues when it comes to realising autonomous driving. The

[34] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.8.
[35] Ibid., p.9.
[36] Ibid.
[37] Ibid., p.7.
[38] Ibid., p.9.

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interaction of automated vehicles with the environment is done through a combination of a physical product and an underlying computer-aided information processor, due to which automated vehicles are also seen as cyber physical systems.[39]

To ensure safe and efficient interaction in all possible driving situations, two main approaches are currently being investigated. The first approach is based on sensor-based vehicles. Here it is assumed that a vehicle equipped with sensors operates in an environment that has not been subject to any major modification or already exists. Technologies such as GPS for positioning would continue to be used. The second approach is based on cooperation and communication between the automated vehicles. Here, it is assumed that the infrastructure would have to be changed or expanded to make communication between the individual vehicles possible.[40]

These types are currently being investigated, among other things to enable safe interaction of the technology with different user types and unpredictable obstacles. In order to create an infrastructure that is independent of external influences, a combination of these two approaches will probably be used. [41]

As new technologies become available all the time, there are more and more possible applications. In addition to sensor-based vehicles using systems that monitor/perceive their environment (smart sensors), technologies such as C-V2X [42] or 5G are also becoming relevant when it comes to communication between vehicles or between vehicles and infrastructure (or "everything"). Furthermore, aggregated technologies such as big data also play a role, as very large amounts of data become available and need to be analysed in large quantities. According to experts, blockchain, digital platforms, artificial intelligence and the Internet of Things will also be decisive for the development of the autonomous transport sector.[43]

The following diagram 3.1 gives an overview of how the technologies interact and should provide more clarity for the further descriptions. Furthermore, commonalities with the "Sense - Plan - Act" design paradigm can be recognised, which is described in more detail in the chapter 3.7.[44]

Based on the graph shown, the following assumptions can now be understood. EU officials, stakeholders and selected literature come to the conclusion that this technology will have the biggest impact on the transport sector by 2030. This assumption is based on the following key points.

[39] Linnhoff-Popien/Schneider/Zaddach (2017): Digital Marketplaces Unleashed, p.432.

[40] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.77.

[41] Ibid.

[42] Cellular - Vehicle-to-everything

[43] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.21-22.

[44] Ibid., p.22.

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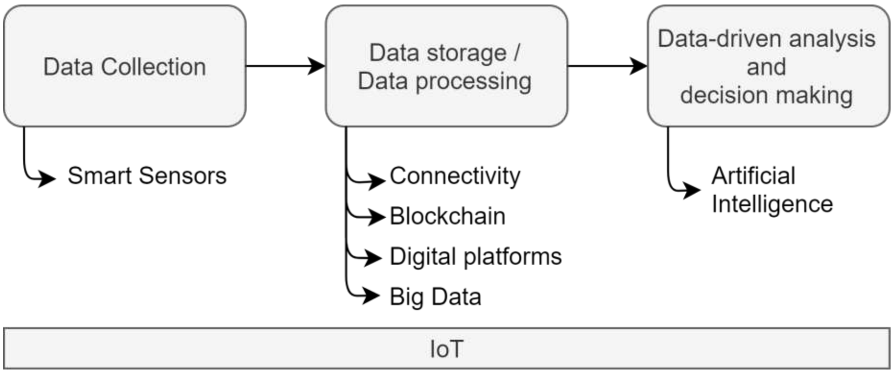

Figure 3.1: Overview of relevant key technologies, original source from Schroten et al. (2020): The impact of emerging technologies on the transport system, p.22

1. progress in the individual fields in the past years.
2. expected future developments
3. the versatility of the technologies, which will create new applications to make the transport sector intelligent.

In the following chapter 3.6, the possible applications of the technologies mentioned will be discussed in more detail: Self-organised logistics (SoL), Mobility as a Service (MaaS), Connected Cooperative Automated transport (CCAM) and Cooperative Intelligent Transport Systems (C-ITS).[45]

3.4 Technological concepts

As described, there are a handful of new technologies which, according to selected experts, will play a significant role in the development of autonomous driving and the transport system in the period up to 2030. In the following, a brief overview of the selected technologies will be given, as well as a report on possible challenges and potential problems.

3.4.1 Sensor-based automated vehicles

With the use of sensor-based vehicles, it is possible to realise a relatively quick implementation, as the environment is not subject to too much change. There are already some manufacturers testing and building vehicles that find their way in certain environments by using sensors in combination with already existing infrastructure such as map navigation and GPS. Examples of this would be vehicles from Tesla or Google, which are already relatively advanced today and would be able to operate on existing roads. As

[45]Ibid.

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already mentioned, sensor-based vehicles should manage without an externally modified environment and adapt to it.[46]

With the emergence of more complex applications (CCAM) of sensors, these also became increasingly intelligent. So-called "smart sensors" are divided into three main categories: camera, radar and lidar. These systems all have different areas of application and corresponding advantages and disadvantages in their use. In order to get the maximum effectiveness out of the individual sensors and to make the system as a whole "smarter", a number of approaches are being specified.[47]

- As precise as possible detection of road edges/banking and road markings and a prediction of the behaviour of other road users (few seconds).
- Data protection: Stored data of other road users must be anonymised, for example number plates or faces of humans.
- Differentiation between static objects such as a tree next to the road and objects that would pose a safety risk to the vehicle, such as obstacles on the road, concrete pillars or road work objects and the filtering out of artefacts (ghost objects).
- A combination of several sensor types or an array of several identical sensors (e.g. for redundancy), which, using neural networks and AI, are also used to draw an accurate model of the environment (World Model).
- An indication of the level of certainty of correct measurement/recording of certain parameters (e.g. speed).

(original source from Schroten et al. (2020): The impact of emerging technologies on the transport system, p.24-25)

3.4.1.1 Complex sensors and elements

Sensors are used to record the environment as accurately as possible and in real time. Since it is currently not possible for a single sensor to record all relevant information, a large number of different sensors are usually used in real and test operations. The information required for the operation of automated vehicles is composed of the following entities: Traffic signs, acoustic signals, other road users and the infrastructure defining the driving operation.

Due to fail-safety, special attention is also paid to redundancy for important sensors.[48]

[46] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.77.
[47] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.24-25.
[48] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.47.

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Radar: Radar systems (FOV [49]: 4°-60°) are very well suited for measuring speeds and can be operated under certain restrictions in most weather conditions. However, the detection of people in traffic is relatively poor and the classification of objects is difficult.[50][51]

Lidar: Lidar (FOV: 90°-360°) is used for object classification because it has very high precision in measuring structured and unstructured elements. It also has a very large effective range and resolution. Similar to the camera, its performance also depends on the weather situation.[52] Another disadvantage, which will probably change fundamentally in the course of time with increasing market penetration, is the currently still relatively high price for individual components (2000-15000 Euros). It can be assumed that this will drop significantly when OEMs introduce them to the market.[53]

Camera: The camera (FOV: 54°-190°) can provide a great deal of information and serves as the main sensor when it comes to classifying objects. Furthermore, it is possible to recognise traffic and brake lights as well as road markings.Similar to human perception, the camera is also subject to the disadvantage of great sensitivity to weather influences and is relatively poor at perceiving distances and speeds.[54][55]

Microphones: Microphones are used to record acoustic signals, such as those used by public transport to attract the attention of passers-by or other road users (e.g. tram bells or train horns at level crossings). Of course, automated vehicles must also be able to react to such signals.[56]

Ultrasonic: Sensors, which have already been used for a long time in technologies with a low degree of autonomy, will also play a role in the future. While ultrasonic sensors have so far mainly been used for parking sensors, these well-established near-field sensors can be used to detect obstacles at shorter distances.[57]

3.4.1.2 Challenges

Sensor-based vehicles monitor and analyse their environment and react according to the data available to them. If one were now to assume that there would be no change in the environment with this concept in its pure form, various problems would arise sooner or later. Like humans, the environment created by humans is not always perfect. It

[49] Field of View
[50] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.23.
[51] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.47.
[52] Ibid.
[53] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.23.
[54] Ibid.
[55] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.47.
[56] Ibid.
[57] Ibid.

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becomes problematic for sensor-based vehicles when important references such as traffic signs and signals are missing or the road surface is not ideal (potholes, etc.). Accordingly, an almost perfect infrastructure would be a basic prerequisite for the functioning of this concept. [58]

The fact that the vehicles react to changes in the street scene and thus adjust their function also results in various weak points that offer possible points of attack for unlawful manipulation. There have already been various studies on how sensor-based automated vehicles can be misled with deliberately misplaced road signs or incorrect road markings.[59] More on this in the chapter 3.7.5.

Since the large amount of data processed inevitably involves a lot of data protection-relevant data, it is a challenge to handle this data in a data protection-compliant manner. The stored data must be anonymised in order to make, for example, licence plates recorded by cameras or the faces of passers-by and other road users unrecognisable. [60]

3.4.2 Vehicle cooperation and communication

In the concept of connected infrastructure, it is necessary to adapt the transport infrastructure in such a way that networking is created and communication with automated vehicles is possible. A distinction is made between communication between two vehicles, also called vehicle-to-vehicle (V2V) communication, and communication between the vehicle and the infrastructure, vehicle-to-infrastructure (V2I). Originally, this technology was mainly used in truck platooning, but nowadays more and more applications are emerging in the consumer sector, such as route guidance based on real-time data in map navigation. In any case, the management of traffic in inner-city areas is also being considered, always with the primary goal of improving the traffic safety and efficiency.[61]

Communication itself can be divided into two broad areas. These differ on the one hand in their purpose and on the other hand in the technology that is required and necessary for their implementation. According to their range, the communication types are divided into **low-distance communication** and **high-distance communication**. These types are described in more detail below.[62] In Figure 3.2, the graphic created by the 5GAA gives a very good overview of the individual dependencies and communication paths in V2X communication.

3.4.2.1 Low-distance vehicle communication

Low-distance or short-range communication is mainly used for communication between vehicles (V2V). However, communication technologies based on ITS-G5 or C-V2X are

[58] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.77.

[59] Sitawarin et al. (2018): CoRR, Bd. abs/1802.06430,.

[60] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.25.

[61] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.77.

[62] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.25.

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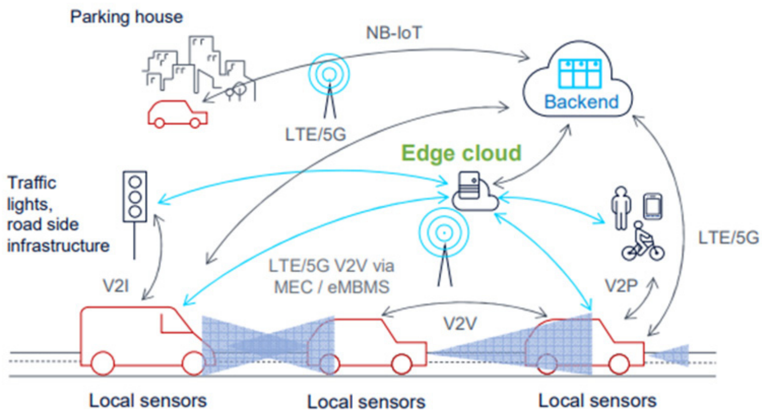

Figure 3.2: Overview of V2X Communication, from Schroten et al. (2020): The impact of emerging technologies on the transport system, p.25, original source Sabella et al. (2017): White Paper

also used for V2I or communication of vehicles with pedestrians (V2P). The underlying technology is the core issue that makes a connection possible. The standard, called ITS-G5 by the European Telecommunications Standards Institute (ETSI), is a technology that was introduced in Europe in 2010 and until recently was the only short-range technology available. It is an extension of the IEEE 802.11 WLAN standard and uses the IEEE 802.11p amendment as an access layer basis.[63] This introduced an ad-hoc technology required for V2X communication and allowed communication over a few 100 metres using the WLAN standard. The ITS-G5 standard has latency times of a few milliseconds and uses the 5.9 GHz frequency band, which is divided into different channels depending on their use (service functions, control functions and security functions). The connection time is usually very short, which is why authentication mechanisms of the IEEE 802.11 WLAN standard are not used. The maximum range is 1000 metres and enables a vehicle speed of up to 200km/h.[64] ITS-G5 or also called pWLAN therefore offers various application areas in safety systems, such as collision warning systems, assistants for right of way or traffic lights, monitoring of blind spots or warning of danger spots. The platooning function, originally popular in the truck sector, is also being used in the passenger car sector.[65]

With Cellular Vehicle-to-Everything (C-V2X), an alternative communication standard was designed, which is using the 3GPP PC5 interface. C-V2X differs from conventional technology, which is based on the WLAN standard, in that it uses different mobile network variants. This relatively new standard has been tested for some time, but the LTE-V2X protocol, which was to be used for low-distance communication, was only defined in a

[63] Ibid., p.26.
[64] Luber/Donner (2020): Was ist 802.11p (pWLAN / ITS-G5)?.
[65] Ibid.

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standard by the Third Generation Partnership Project (3GPP) in 2017.[66]This alternative, defined in the 3GPP standard, uses the same 5.9GHz frequency band as ITS-G5, but utilizes a completely different technology and is not compatible with systems using the original ITS-G5 technology. In fact, parallel use causes additional interference and leads to problems.

Over time, amendments to the standard were continuously published, so-called releases. Starting with Release 14, which was introduced for the first time especially for use in automated vehicles (V2V, V2I), the standard has been continuously expanded with functions with consecutive release numbers. As of Release 16, the 5G mobile radio infrastructure has been integrated into the standard and the designation will henceforth be 5G-V2X. As of Release 16, the 5G mobile radio infrastructure has been integrated into the standard and the designation will henceforth be 5G-V2X or New Radio (NR)-V2X.[67] By using the new 5G standard, the higher bandwidths and lower latency times (URLLC) also make highly and fully autonomous driving systems possible. Even if the first operational developments are not expected before 2023, the faster data throughput will make it possible, for example, to realise situational decision-making in real time, platooning, teleoperated driving or the rapid sharing of sensor data.[68] Since backward compatibility has not yet been clearly determined, the implementation of Release 16 of the 5G-V2X standard is intended to enable the integration of both LTE-V2X and 5G-V2X radio technologies in chipsets in order to ensure backward compatibility.[69]

Since the two systems, ITS-G5 and C-V2X are fundamentally different, it is still unclear which of the two will prevail. However, many vehicle manufacturers are currently leaning towards C-V2X for vehicle networking.[70][71]

3.4.2.2 High-distance and hybrid vehicle communication

To overcome long distances, network technologies such as the LTE network or, more recently, the 5G network are predominantly used. Over long distances (Uu interface [72]), data is mainly exchanged between vehicles and servers located in a network (cloud backend), also called vehicle-to-network (V2N). As with low distance communication, the trend is towards the newer 5G standard, as its advantages (higher transmission speeds, lower latency) are tempting.[73]

The increasing networking of vehicles and the ever-growing amount of data transmitted make it essential to adapt the infrastructure to the given conditions. Many vehicles

[66] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.26.
[67] Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.21.
[68] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.26-27.
[69] Ibid., p.26.
[70] Luber/Donner (2020): Was ist 802.11p (pWLAN / ITS-G5)?.
[71] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.27.
[72] links 5G User-Equipment to 5G Radio Access Network, RAN
[73] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.27.

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already available on the market are supplied with updates by the manufacturer over long distances or receive important environmental variables, for example about traffic volume or the condition of the infrastructure, in part almost in real time.[74]

To ensure seamless interaction between high-distance and short-distance communication, a C-V2X technology set was introduced in 3GPP Release 16. This should enable a combination of short and high distance communication, which is referred to as "hybrid communication". In contrast to pure high-distance communication, which is mainly used for the connection to central servers, this combination of communication concepts also enables a particularly fast and low-latency connection to so-called "edge servers". These are physically much closer to the actual events and enable the supply of data that require a particularly low latency, such as up-to-date traffic information.[75]

For 5G-V2X vehicles, a combination of LTE-V2X (3GPP Rel. 14 or 15) and 5G-V2X/NR-V2X (3GPP Rel. 16 upwards) can also be used for low-distance communication or as so-called "side-links". Here, for example, the LTE-V2X side-link (PC5) is used for the transmission of safety messages, for example Cooperative Awareness Message (CAM) or distributed environment notification messages (DENM) and NR-V2X side-link (PC5) is used for advanced driving functions.[76]

3.4.2.3 Challenges

Of course, when it comes to autonomous vehicle communication, the introduction of C-V2X poses a number of challenges and problems that need to be overcome. First of all, there are some technical challenges, mainly due to low coverage and insufficient infrastructure, which is urgently needed. The technical difficulties are particularly complicated in the case of cross-border applications, where cross-border continuity of service must be ensured, see chapter 3.5.2. In addition to technical obstacles, there are conceivably many difficulties with legislation in Europe. This is currently dealt with in Directive 010/40/EU, which is the "Framework for the deployment of Intelligent Transport Systems in the field of road transport and for their interfaces with other transport modes".[77] The legal problems, especially in relation to automated driving in Europe, are described in more detail in Chapter 4.

As already described, the problem of incompatible technologies is particularly relevant in short-distance communication. ITS-G5 and C-V2X are fundamentally different and are not compatible, but much more precarious is the fact that both operate in the same 5.9GHz frequency band and even get in each other's way and interfere. A clear solution to this problem has yet to be found, either there will be coexistence or one of the two standards will prevail. Currently, manufacturers are leaning towards C-V2X for vehicle

[74] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.28.
[75] Ibid.
[76] Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.21.
[77] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.28.

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networks.[78][79] By 2025, it is expected that the 5G standard (3GPP Rel. 15 and upwards) will be accessible to at least one third of the world's population. The exact coverage rates vary by region and continent, but it is expected that coverage will be best in urban areas (North America 46%; Japan, China, South Korea 40% and in Europe 30%).[80]

3.4.3 Artificial Intelligence

Artificial Intelligence is a topic that forms an important part of computer science today. In order to understand why AI could also be important for the automotive transport sector, we will first briefly discuss the definition and scope of functions. An updated definition of the term was published in a study by the European Commission at the end of 2018 and describes AI systems as human-made systems (software and hardware) that perceive the environment with the help of collected data. This data, which can be structured or unstructured, is interpreted and knowledge derived from this data is inferred. The information is processed and the best actions are determined which are useful for achieving the given goal, which can be physical or digital. The decisions chosen by AI systems are influenced by the reactions of the environment to their previous decisions. AI systems use either numerical models or symbolic rules. AI is described as a scientific discipline that includes various techniques that can be applied to reasoning and decision making, learning and robotics.[81] [82]

In general, it can be assumed that systems equipped with AI are able to perceive their environment, analyse the perceived data and make decisions on the basis of this data. This sensing-thinking-acting process characterises AI systems and makes it possible to use such functions in logistical and mobility applications. Examples include automated vehicles, predictive maintenance, cooperative mobility or self-organised logistics. There is particular potential in the use of autonomous vehicles. Sensing", for example, involves collecting data on road conditions, road users or the weather, which are then classified and categorised to obtain a clear picture of the environment (world model). Afterwards, the collected data is analysed in "thinking" and possible reasons for the situations that have arisen, as well as possible future effects of any actions, are developed. Finally, in the "Acting" step, the developed solution is either executed by the system, or by an AI-assisted human, or no action is performed. The decision still has to be made by a human.[83]

This cycle can be used to establish techniques such as learning or reasoning and decision making, which could also be used in autonomous vehicles. Learning includes neural networks, deep learning, machine learning, decision trees or other techniques that allow

[78] Luber/Donner (2020): Was ist 802.11p (pWLAN / ITS-G5)?.

[79] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.27-28.

[80] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.43.

[81] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.33.

[82] European Commission (2018b): A definition of Artificial Intelligence: main capabilities and scientific disciplines, p.6.

[83] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.33-34.

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the system to continuously make "better" decisions. Reasoning and decision making are basically about building a body of knowledge. If the AI is now able to build a model that represents knowledge, it can start to make decisions based on that knowledge. However, the algorithms behind this are very complex and would require a more detailed description. [84]

If you look at Artificial Intelligence in the context of the transport sector, you can always see its applications in the focus of either people and objects, or processes and systems. People or objects can therefore be all possible road users, vehicles such as cars, trucks, ships, aircraft, etc., their infrastructure such as roads, traffic lights, rails, etc., or their freight. If the focus is on processes and systems, this includes processes that make transport possible in the first place, such as regulations, planning and implementation of infrastructure, logistics or passenger transport. Systems are subsequently the sum of all those people/objects and processes and the resulting developments. [85][86] As systems become more complex today, it can be assumed that over time it will no longer be possible to find the optimal decisions based only on manual planning or simple data analysis, which will give AI implementations a special importance in the future, especially in real-time applications. In order for Artificial Intelligence to become established and to be used efficiently, there must be consistent cooperation in the development of the required technologies, and it must also be clarified how domain-specific knowledge, which is important for the interaction between object and system, is acquired. This becomes a challenge especially in cross-border operations.[87]

3.4.3.1 Challenges

As mentioned, the cross-border operation of AI assisted vehicles, among other things, is also problematic and raises some challenges. Ideally, one would build on the same definitions internationally in order to make data sharing possible in a uniform infrastructure. In reality, however, it is often different, and there are many separate data sharing ecosystems with their own implementations. Furthermore, the interoperability between separate data sharing systems is often very complex and is addressed with the help of the new "European Interoperability Framework, EIF (2017)" presented by the European Commission[88]. This defines four levels where interoperability must be realised: legal, organisational, technical and semantic interoperability. Especially when it comes to interoperability of agreements between organisations, possibly in different legal jurisdictions or data sharing environments, it is suggested to clarify this in separate negotiations (mentioned in the International Data Spaces (IDS) initiative). However, the exact form of these negotiations has not yet been defined. [89] A vehicle equipped with artificial intelligence systems must necessarily process a large amount of data in order to

[84] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.34.
[85] van Ommeren et al. (2020): Artificiële intelligentie in mobiliteit en transport: position paper, p.7-8.
[86] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.34.
[87] Ibid.
[88] European Commission (2017): European Interoperability Framework – Implementation Strategy.
[89] Bastiaansen et al. (2020): The Logistics Data Sharing Infrastructure, p.20-21.

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make accurate decisions. One challenge is that a lot of shared data is not available, and if it is, it is often not clear who has sovereignty over the data and how privacy should be handled. Basically, one of the main tasks is to handle the privacy of the data owner responsibly. Furthermore, the processing of large amounts of data may also offer concerns about cybersecurity, as high dependencies arise here. Finally, AI must be explainable and controllable, i.e. it must be comprehensible and understandable for humans why the system proposes the decision and must also give humans the possibility to intervene.[90]

3.4.4 Blockchain

The term blockchain is one that is often mentioned in connection with cryptocurrencies. In terms of autonomous driving, the purpose of the blockchain is also similar, because basically a blockchain is supposed to be a shared ledger that is trusted by everyone and is valid and accurate "forever". The main point why the concept of a blockchain is being considered is that unlike databases, which are centrally organised, trust is maintained at all times and the fear of a central organisation becoming too dominant is eliminated. Apart from that, in principle all the functions that a blockchain offers could also be solved with conventional database technologies, but with the blockchain there is no need for a central administrator to synchronise the database. Currently, a lot of research is being done on various technologies that could make the use of blockchain even more interesting. Among other things, the reduction of fraud and administrative costs, higher supply chain transparency, and the linking and indexing of data stored by traditional database systems are to be investigated.[91]

Blockchain is particularly interesting in connection with the cross-border operation of autonomous vehicles, and the first blockchain technologies are already being used today to connect cross-border trade and transport. In China, the first cross-border platform using blockchain technology was realised in Chengdu in October 2019. This should lead to more efficiency in connecting carriers and provide precise data on logistics.[92][93]

3.4.4.1 Challenges

The challenges of using a blockchain in the context of automated vehicles are mainly composed of the following key points. First of all, it should be said that this technology is a relatively new development, which in turn means that it brings with it a number of challenges. On the one hand, existing solutions are not standardised, which can lead to incompatibilities, and on the other hand, when introducing new infrastructures, usually only the interests of large corporations are taken into account; due to the closed and non-neutral nature of the infrastructure providers, small and medium-sized enterprises are usually left out. From a data perspective, the main issues to be clarified here are data regulation and data sovereignty. Control over data and sharing has not yet been

[90]Schroten et al. (2020): The impact of emerging technologies on the transport system, p.35.
[91]Ibid., p.28-29.
[92]Cision PR Newswire (2020): OneConnect Launches "Linked Portïn China's Greater Bay Area.
[93]Schroten et al. (2020): The impact of emerging technologies on the transport system, p.30.

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fully clarified due to the state of development, and many companies do not yet want to relinquish control due to a lack of trust. Data regulation also comes into consideration in cross-border operations, where it must be clarified how and where data access can or must be granted. In summary, it can be said that problems can be solved by new infrastructures and proprietary solutions through standardisation, as well as by creating interoperability between the individual solutions. The problems on the data side require precise regulation.[94]

3.5 Technological challenges and impact of 5G network

The use of new data transmission technologies such as 5G mobile communications is of great importance for the future success of Automated Transport. Higher bandwidth and lower latency compared to 4G or LTE networks, which are still widely used today, offer great potential. The EU's Horizon 2020 research and innovation program is currently funding many projects to explore the benefits of 5G for an automotive future.[95] Just last summer (2020), another 11 projects were funded with a high investment of 70 million Euros.[96]

Of particular interest in the scope of this work are the projects 5G-MOBIX, 5G-CARMEN or 5G-CROCO, which were already launched in 2018 as Phase 3 (Part 2; Automotive Projects) of the European Commissions 5G PPP Projects and should explore the **cross-border** use of the 5G network in Europe in terms of automated mobility.[97] In phase 2 of the 5G PPP projects, the project "5GCAR"[98] was carried out, which had the research task of investigating the V2X roadmap in Europe and finding the architecture necessary for V2X communication and any gaps.[99]

3.5.1 Use Cases according to 5GCAR

Taking into account the operational processes of automated vehicles, 5 different "Use Case Classes (UCC)" were defined. For each class there are different specific use cases. In the course of the 5GCAR project, a predominant use case was filtered out for each class based on various characteristics (safety aspects, social and economic benefits, etc.) and their future importance or challenges for the communication system.

The individual classes, together with their use cases, are as follows: **Cooperative Manoeuvre** (use case: lane merge), **Cooperative Perception** (use case: see-through),

[94] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.30.
[95] Ibid., p.28.
[96] European Commission (2020): Europe boosts investment with 70 million Euro in 5G with strong focus on connected transport by launching 11 new projects.
[97] European Commission (2018a): Connected and automated mobility: three 5G Corridor trial projects to be launched at ICT 2018 event.
[98] Fallgren et al. (2019): 5GCAR Final Project Report.
[99] Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.21.

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Cooperative Safety (use case: network assisted vulnerable pedestrian/road-user protection), **Autonomous Navigation** (use case: high definition local map acquisition) and **Remote Driving** (use case: remote driving for automated parking).[100]

These use cases were then examined on the basis of requirements, which were divided into automotive, network or qualitative/non-functional requirements. Each requirement definition has its own set of KPIs [101] which, in summary, were evaluated based on their latency, reliability, capacity or positioning accuracy.[102]

In addition to some approaches to solving occurring problems, the "enablers" for V2X communication were described. In order to make 5G operational for automated vehicles, the following requirements must be met. As often mentioned, a **very low end-to-end latency** (below 5ms) must be achieved, as well as an **extremely high reliability** of nearly 10^{-5}, which means that on average a maximum of 1 error may occur per 100000 successfully delivered data packets (or 99,999% success rate). Furthermore, despite the ability to **handle a very large density of connected vehicles**, a **positioning accuracy** of at least 30 cm must still be achieved.[103]

3.5.2 Cross-border use

Furthermore, there were three other 5G PPP projects (phase 3), which had the research objective of investigating and examining the cross-border use of 5G mobile radio for autonomous and automated traffic on a large scale at various locations. The projects present the technical, organisational, business and administrative challenges of deploying CCAM over 5G around motorways and national borders (corridors). 5G-MOBIX conducted trials at 2 main locations, the so-called "Cross-Border Corridors (CBCs)", at the border of Spain and Portugal (between Vigo and Porto) and at the Greek-Turkish border.[104] 5GCroCo used the French-German and German-Luxembourg borders for trials in summer 2020 and autumn 2021.[105] For the 5G-CARMEN project, 5 sites were selected along the Munich-Bologna corridor, which include borders at Kufstein (Austria-Germany) and Brennero (Italy-Austria).[106] In all 3 projects, in addition to these main points, a number of other test sites are available.

Each of the 3 projects had a different focus, 5GCroCo focused the trials on **Tele-Operated Driving** (remote control of a vehicle), **High Resolution Mapping** (exchange of information regarding maps, dynamic generation of high-resolution maps

[100] Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.21.
[101] Key Performance Indicator
[102] Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.21.
[103] Fernandez et al. (2019): 5GCAR Scenarios, Use Cases, Requirements and KPIs, p.9,57.
[104] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.17-18.
[105] Ibid., p.11-12.
[106] Ibid., p.14-15.

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for high-level automated driving) and **Anticipated Cooperative Collision Avoidance** (exchange of information between vehicles to reduce the likelihood of accidents; in case of congestion, obstacles, sudden braking). The focus of the 5G-CARMEN project is as follows: **Cooperative manoeuvring** (coordinated driving lines within a small group), **video streaming for infotainment**, **green driving** (more sustainable mobility achieved through collected information) and **situation awareness** (detecting dangerous situations and sharing them with surrounding vehicles via 5G). Finally, the 5G MOBIX focus also differs, which will be briefly mentioned below: **Remote Driving** (taking over vehicle control in dangerous situations or if the driver cannot drive himself by a remote driver or by V2X applications), **Extended Sensors** (exchange of raw data from sensors), **Platooning** (dynamic forming of travel groups, sharing of data information), **Advanced Driving** (information exchange of all sensor data from vehicles and RSUs (Roadside Units)) and **Quality of Service support** (V2X application is informed about an expected/possible change before a change in QoS and can adapt accordingly).[107]

3.5.3 Conclusion

The investigation of these use cases has shown that the potential of 5G networks is very high and is of great advantage for the realisation of highly automated driving. In contrast to the conventional 4G-LTE data connection, which fulfils some but not all of the requirements of the automotive industry, the use of 5G offers considerable advantages over 4G-LTE, which is primarily explained by the **significantly higher bandwidth** and the **wider coverage** made possible by the use of different parts of the frequency spectrum. The V2X communication made possible by this allows a better all-round view (up to 360 degrees) and a wide view of up to several kilometres through the exchange of information with surrounding vehicles etc. The concept of collective group intelligence and group awareness is thus promoted, as well as the support of URLLC [108] and mMTC [109] communications. [110] Road safety for drivers and bystanders can be significantly improved by the assistance of 5G data networks and edge computing, as unexpected hazardous situations can be partially anticipated and avoided by increasing the range of perception.[111]

Taking into account the findings from other 5G PPP projects, the following 5 KPIs can be formulated for the application of 5G in the automotive sector:

1. **high data throughput**: Very important for functions that share large amounts of data such as sharing real-time information like video images between vehicles.

[107] Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.22-24.
[108] Ultra-Reliable Low Latency Communications
[109] massive Machine Type Communications
[110] Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.25.
[111] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.9.

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2. **low latency**: A low latency is particularly important in safety applications that require a fast response time from the communication network.

3. **reliability and availability**: Depending on the area of application, different demands are placed on reliability and availability. For safety-relevant functions such as tele-operated driving or situation awareness, 99% is expected in each case. For less sensitive functions like Green Driving between 90% and 95%.

4. **seamless connectivity**: Especially due to the use of security functionalities, high demands are placed on seamless connectivity. Uninterrupted end-to-end (E2E) communication must be ensured, with high reliability and low latency.

5. **real-time communication**: For functions that work in real time, it is necessary that the data required for the correct function is also transferred in real time.

(original source from Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.25-26)

During the implementation of the projects, the following conclusions could be drawn. One of the key benefits of the 5G standard, when applied to automated vehicles, has been found to be an improved understanding of **guaranteed QoS** (Quality of Service), which in turn leads to improved reliability and service continuity.[112]

The versatile advantages of so-called "**network slicing**" were described, which enables the support of multiple logical networks over the same physical infrastructure.[113] This makes it possible to serve different services at the same time, such as providing an eMBB (enhanced mobile broadband) service in combination with network function virtualization.[114] Network slices in combination with enhanced caching make it possible to meet the requirements of the automotive sector due to the guaranteed high data transfer rate and low latency.

The higher bandwidth will improve existing LTE-V2X solutions, enabling direct communication between vehicles or infrastructure. Furthermore, precise positioning in combination with correction data from the GNSS (Global Navigation Satellite Systems) makes it possible to create high-resolution and precise localization. Finally, the introduction of 5G data transmission offers the possibility of introducing so-called "MEC [115]". This forms a computing infrastructure next to the road and enables computational and distributed outsourcing, as well as reduced response times. In this way, functions with a high demand on resources can be distributed, for example in the case of high data volume during video

[112] Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.25.

[113] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.8.

[114] Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.25.

[115] (Multi-Access/Mobile) Edge Computing/Cloud

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conferences while driving or streaming 4K video content.[116] This is also beneficial for an analysis of cyber security threats, which will be described in more detail in chapter 3.7.5. With Release 16 of the 3GPP standard, a combination of protocols for short-distance and high-distance communication should be possible with C-V2X, thus enabling higher network capacity, increased reliability and availability, as well as lower latency times.[117]

3.5.4 Challenges and possible solutions

The problems and challenges of cross-border use are similar to the challenges of vehicle communication, because it is above all the existing infrastructure and its area coverage that need to be worked on. In the cross-border use of automated vehicles, five main categories of obstacles were defined on the basis of the projects 5G-MOBIX, 5G-CARMEN and 5G-CROCO, which stand in the way of the introduction of CCAM (in the sense of cross-border use).

Especially when using advanced CCAM for cross-regional and cross-border applications, as investigated in the projects described, it is very important for a stable network connection to ensure continuity of service and session, even when roaming from one MNO to another. Data routing (HR) and local break-out (LBO), which allows the MNO [118] to break out internet sessions to the home network, also play an important role.[119] MNO offers incoming roamers the possibility of obtaining the data directly from the network and offers the advantage of shorter paths and thus reduced latency times or more performant cloud applications.[120]

In the following, the challenges resulting from the three 5G PPP projects are listed and the associated use cases are explained. Furthermore, a short summary in tabular form should provide a better overview and present individual possible solutions for the challenges mentioned.

3.5.4.1 Network coverage/access

In the first challenge, see 3.1, which concerns the coverage of network services and access aspects, the following problem areas were defined. **Inter-PLMN [121] handover**, which describes the change from one cell of a mobile network to an other one, is considered to be of particular importance, as well as **network reselection** and **cross-border network coverage**.

[116]Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.25.
[117]Schroten et al. (2020): The impact of emerging technologies on the transport system, p.28.
[118]Mobile Network Operator
[119]Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.8.
[120]MPC (2018): Lokaler Internet Breakout im WAN.
[121]Public Land Mobile Networks

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Inter-PLMN Handover: Many challenges arise when switching network services from one country to a neighbouring one, especially when it comes to ensuring a consistent connection with low latency. During the handover itself, either holes in the coverage or spill-overs near the border can occur. Both scenarios have conceivable consequences for a CCAM application, for example, which needs a continuous radio connection. In the case of overlaps, it can lead to mutual interference of radio transmitters and thus to a reduction in QoS. Another factor to consider is the handover between different technologies (hybrid handover), for example when combining 5G NR and conventional 4G LTE networks. In this case, the advantages of a 5G connection can of course no longer be used and one has to live with the disadvantages of the inferior connection (delay, lower throughput, potential disconnection).[122]

Cross-border network coverage and radio planning: When it comes to the overlapping of networks near the border, the planning of radio frequencies and area coverage near the border also comes into play. Legally, the permitted or regulated frequencies are determined by EU regulation of the Electronic Communications Committee, which is then implemented by the respective national authority (implementation by the individual MNOs). The problem, however, is that currently only the legal aspects of frequency bands and radio emission control are taken into account, and only on national territory. Since national law may not be applied abroad, the overlaps should be as small as possible, but the interpretation varies from country to country and there is no uniform regulation. Apart from the European "Harmonised Coordination Model" agreement[123], which, however, does not include all member states or MNOs, no agreements favourable to the continuity of network services are made, which, for example, represent the locations of antennas or a coordination of frequency bands.[124]

Network reselection: The problem with "network reselection" is that a connection gap is created when switching between foreign networks. Closing this hole is not as easy as it may seem, because apart from the costs, the legal requirements and security aspects, as well as the economic side, it is mainly non-technical problems that stand in the way of implementation. ePLMNs, for example, would reduce the mentioned connection gaps by making a collaboration with other MNOs in areas where the "home network" MNO does not have much coverage, thus giving the subscriber the impression that he is operating in his home network by means of a seamless handover.[125] Unfortunately, this technology

[122]Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.23-24.

[123]HCM Agreement (2020): AGREEMENT between the Administrations of Austria, Belgium, the Czech Republic, Germany, France, Hungary, the Netherlands, Croatia, Italy, Liechtenstein, Lithuania, Luxembourg, Poland, Romania, the Slovak Republic, Slovenia and Switzerland on the co-ordination of frequencies between 29.7 MHz and 43.5 GHz for the fixed service and the land mobile service..

[124]Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.22-23.

[125]CsPsProtocol (2021): WHAT ARE UPLMN, OPLMN, FPLMN,IPLMN, HPLMN, VPLMN AND EPLMN/EHPLMN?.

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Network coverage/access	
Challenge	**Possible solutions**
Inter-PLMN handover	regulations, standardization, QoS prediction, MEC utilization
Network reselection	regulations, standardization, QoS prediction, MNO collaboration
Cross-border network coverage and radio planning	regulations, standardization, MNO collaboration framework, V2X sidelink, 5G-CCAM business models

Table 3.1: Challenges and possible solutions of using 5G in cross-border applications, category "Network coverage/access", original source from Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities

is hardly established in European networks. There seems to be a lack of standards and regulations, especially in border areas where the 5G standard will not be introduced as quickly as in larger (prioritised) cities, there may be an overlap of different radio access technologies (RAT). Since the data on the individual radio access networks (RAN) is not shared via an infrastructure, the individual vehicles or users are dependent on their own scans in this case. [126]

3.5.4.2 MNO collaboration and Data Plane routing

The problems that roaming entails, and which necessitate cooperation between the individual MNOs, are cited here as a challenge (Table 3.2). The EU regulation "EU 2015/2120"[127], which was introduced in November 2015 (changed in 2020) and describes measures regarding access to public internet and roaming within the Union, regulated roaming charges within the European Economic Area, but did not specify the individual agreements between the MNOs. The agreements, which contain, for example, technical aspects, security aspects or legal framework conditions, can be presented differently depending on the network technology.

In the case of cross-border data transmission, roaming may occur in different cases depending on the penetration rate of the 5G infrastructure. In the early stages or in the near future, **roaming between MNOs with 5G NSA network solution support** will increase. The non-standalone mode describes the option of 5G NR deployment, which initially uses the existing control plane of the 4G LTE network structure for control functions.[128] This means that existing LTE roaming agreements are utilised and the 4G LTE technology is still used. This of course brings various performance

[126] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.24.

[127] European Union (2020): REGULATION (EU) 2015/2120 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 November 2015 laying down measures concerning open internet access and amending Directive 2002/22/EC on universal service and users' rights relating to electronic communications networks and services and Regulation (EU) No 531/2012 on roaming on public mobile communications networks within the Union.

[128] RF Wireless World (2021): 5G NR Deployment Scenarios or modes-NSA, SA, Homogeneous, Heterogeneous.

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MNO collaboration and Data Plane routing	
Challenge	**Possible solutions**
Isolated MNO planning	MNO collaboration framework, cross-border regulatory framework
Roaming/Data routing	MNO collaboration framework, standardization, security

Table 3.2: Challenges and possible solutions of using 5G in cross-border applications, category "MNO collaboration and Data Plane routing", original source from Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities

disadvantages in terms of bandwidth and end-to-end latency with it. In later phases of 5G rollout, **roaming between MNOs with 5G SA core network solutions support** will become more common. Standalone mode in 5G NR data transmission means that 5G cells are used for the transmission of signals and information at both the control level and the user level, and LTE RAT is no longer required.[129] However, as this requires relatively high penetration, the inter-PLMN handovers described in 3.5.4.1 will always be part of the 5G core specifications. There are still some developments to be made, such as standardisation, in order to be able to make use of new features (end-to-end slicing, SSC mode 3).Finally, a mixture of **roaming between 5G NSA and 5G SA networks** would be possible, which would again pose new challenges. This stage, seen as an intermediate step between 5G NSA and a complete introduction of 5G SA networks, requires its own consideration in terms of the use of new roaming interfaces.[130]

Since for V2X communication, especially in the context of CCAM functionalities, Europe-wide cross-border coverage must be guaranteed, roaming agreements between MNOs are a basic requirement. In terms of data routing, local breakouts via different MNO domains will sometimes be necessary for NSA networks, as otherwise all user traffic will be routed home during roaming, thus generating additional high latency. A local breakout would remedy this, as it would mean that the user traffic is not routed to the home network, but the traffic is routed directly via the roamed network. This in turn would bring a number of other difficulties with it, it would have to be ensured that the same conditions in terms of security, legal interpretation or traffic control etc. would apply to the user in the visited network. In addition, it must be ensured that all technical requirements are met, depending on the mode used. For example, in (Session/service Continuity) SSC mode 3, it is important that MNOs share information regarding UEs [131] and their associated services, as well as ongoing data sessions.[132]

[129] RF Wireless World (2021): 5G NR Deployment Scenarios or modes-NSA, SA, Homogeneous, Heterogeneous.

[130] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.26-27.

[131] User Equipment

[132] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.27.

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3.5.4.3 Continuity of service/session

The continuity of service and session is of great importance when using the connected driving functions of automated vehicles. This is especially true for technologies such as edge computing, which is used for end-to-end communication, typically between individual vehicles, and is particularly dependent on low latency and therefore flawless continuity of service. A complicating factor here is certainly the ability to ensure continuity across borders, which is clearly a challenge. A solution must be found to minimise the end-to-end routes during the journey.[133]

Data session continuity: When routing data or messages, the most decisive factor today is the change of gateway defined as "**session continuity**" in the 5G Core specification, as well as "**service continuity**" in the case of an additional change of application server (SSC, Session and Service Continuity).[134][135] The challenge here is to carry out a dynamic change in a moving vehicle. Depending on various factors, such as latency, the route should be optimally selected. As a vehicle moves dynamically, new optimal routes are created depending on the distance to the nearest gateway. If a new gateway is connected, this almost always leads to a change of the IP address, in the NAT [136] case the gateway address changes relative to the edge server. This results in conflicts regarding the addressing of the data sent by the edge server. Since IP addresses are no longer correct, a new connection must be established via the TCP protocol and a new IP address must be used as a result. Alternatively, a connectionless transport protocol could be used and the Edge service IP address could be used as the connection end point. Due to the continuity of the service IP address across different networks, however, the new problem arises that the network topology in the new network may no longer be correct and thus the standard routes no longer apply. For this, special routes would have to be created via own policies, which apply between the gateways to which the vehicle is connected and the new, relocated edge server. In order to be able to execute the applications correctly on a new edge server, a transfer of client-specific context may also be necessary.[137]

Cross-border message routing: The challenges of session continuity and service continuity described above are of course exacerbated when the individual routes cross national borders. Typically, so-called home routing is used in roaming scenarios where the vehicle moves in foreign networks. This sometimes results in extremely long communication paths that should ideally be kept short. The problem with cross-border data routing

[133] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.24.

[134] Ibid., p.25.

[135] Cisco (2020): Ultra Cloud Core 5G Session Management Function, Release 2020.02 - Configuration and Administration Guide.

[136] Network Address Translation

[137] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.25-26.

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Continuity of service/session	
Challenge	**Possible solutions**
Cross-border message routing	MEC utilization, cross-border message broker, V2X sidelink
Data session continuity	MEC utilization, QoS prediction, Service Orchestration

Table 3.3: Challenges and possible solutions of using 5G in cross-border applications, category "Continuity of service/session" original source from Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities

in terms of continuity is mainly due to missing or unattainable SLA guarantees, which are a basic requirement for the introduction of MEC. In cross-border communication, MEC hosts represent the servers, which would then have to execute the applications expected by the respective vehicle/user. Above all, communication on hosts of different MNOs, especially using NAT, represents a particular obstacle.[138]

Particularly for applications that permanently exchange data, even a short failure, as is possible in the situations mentioned, is a problem. However, this does not affect all functions; among other things, applications that only send and receive data from time to time may not be affected by temporary communication interruptions.[139]

3.5.4.4 Business enablers and non-functional aspects

Further challenges arise from non-functional aspects and economic issues. Non-functional challenges include regulatory and standardisation issues in the use of communication protocols and spectrum, as well as the need to strengthen transport- and data-specific regulations.[140] A precise, but also not overly restrictive elaboration of the individual problems in the sense of the NFR [141] is essential here. Too lax a definition would lead to inefficiencies and an over-specified NFR would probably exceed the cost framework.[142]

Non-functional aspects: A challenging and non-functional aspect here would be the **harmonisation of the frequency spectrum** or frequency band. First attempts to create a standardisation were already made by the Radio Spectrum Policy Group at the end of 2016. More recent developments in this direction were recorded at the ITU [143] World Radiocommunication Conference in November 2019 (WRC-19). Here, a spectrum of more than 17 GHz was defined, which is intended for future 5G use. This spectrum, which is composed of different frequency bands such as 4.25-27.5 GHz, 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 GHz and 66-71 GHz, is to be almost 85% harmonised

[138] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.24-25.
[139] Ibid., p.25.
[140] Ibid., p.29-31.
[141] non-functional requirement
[142] Scaled Agile, Inc. (2021): Nonfunctional Requirements.
[143] International Telecommunication Union

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worldwide.[144] Part of this conference was to formulate recommendations, including a recommendation on "Harmonization of frequency bands for evolving Intelligent Transport Systems applications under mobile-service allocations".[145]

The sale of frequency bands is ubiquitous today, as many frequencies available on the spectrum market in the EU have recently been auctioned off. There is a policy regarding the EU DSM [146], which divides the spectrum into four main parts: identification of needs, regulatory environment, harmonisation and policy priorities. The problem is that the spectrum market is administered locally in each country and thus the auctions do not necessarily run in harmony with each other. Among other things, this can lead to problems in cross-border radio situations.Furthermore, there are no regulations for so-called "re-farming", i.e. the resale or re-use of old frequencies, for example from the proprietary 3G frequency band. Another challenge is the harmonisation of the actual infrastructure, as this is not regulated throughout Europe. In France and Germany, for example, the main focus of expansion (coverage and performance) is on road density and not necessarily on population. This change in the architecture of the infrastructure is important for the development of automated transport, but has not yet been implemented everywhere in Europe.[147]

In addition to harmonising the frequency band, absolute compatibility of the individual components (hardware and software) of a system is also necessary. So-called **protocol interoperability** is necessary, so that each individual link in the end-to-end communication chain can clearly understand all other links and communicate with them. This includes, for example, the input/output of the individual communication components, as well as the formatting of the individual messages. Furthermore, the configurations, architecture and interfaces of the components must be compatible with each other. Especially for CCAM systems or V2X communication, interoperability is an essential component, which, however, is only partly covered by standardisations by either the telecommunication infrastructure or suppliers of the automotive industry (e.g. partly defined through 3GPP). The resulting gaps offer potential for errors if other vendors come up with the idea of applying their custom solutions.[148]

Finally, the lack of legislation in the area of **road traffic regulations** must also be pointed out. These are still not adapted to the use of automated vehicles. Standardised warning systems, which prompt the driver to take over the driving task (depending on the degree of autonomisation), as well as a Europe-wide (worldwide) standardisation for the homologation of automated vehicles do not yet exist or only exists in rudimentary form. It must be ensured that manufacturers have clear regulations, that are valid in all countries, otherwise situations may arise where vehicles are not allowed to drive into

[144] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.29.

[145] El-Sheikh (2019): FINAL ACTS of the World Radiocommunication Conference (WRC-19), p.560.

[146] Digital Single Market

[147] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.29.

[148] Ibid.

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Business enablers and non-functional aspects	
Challenge	**Possible solutions**
Spectrum harmonization	cross-border regulatory framework, standardization, security, MNO collaboration framework,
Regulation (network, data, road, traffic)	cross-border regulatory framework, standardization, regulation

Table 3.4: Challenges and possible solutions of using 5G in cross-border applications, category "Business enablers and non-functional aspects", original source from Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities

neighbouring countries because local laws and regulations would not allow this. There is also a need for more research into the impact of autonomous vehicles on road traffic in terms of their interaction with law enforcement agencies and their impact on public safety.[149]

Business related issues: The field of business models in the case of automated vehicles and their functions is still very new. Especially when looking across borders, new business opportunities often arise. Despite numerous EU-funded projects, there is currently no business solution that would be a clear favourite for new CCAM systems. In cross-border markets, there are a variety of technologies (telecommunications and computing) that are used and managed by different stakeholders. New business models are expected, so instead of the usual linear value chain, a multi-linear relationship model (MLR) is likely to be adopted, which basically uses multiple explanatory variables instead of one to predict an outcome.[150][151]

Depending on the use case, new operators will emerge, especially to manage network functionalities and provide a basis for adapting accounting and payment models. From a business perspective, it is important to cover its total expenses (totex), which consists of capital expenses (capex) and operational expenses (opex).[152] In the case of 5G deployment, the costs can be divided into three sub-areas as follows. The capex is represented by the costs for hardware and software in the individual vehicles, and the costs for the 5G network deployment. The third part, Operational Expediture, consists of the costs incurred by the operation of the system. In order to create a cost balance, there are various possibilities, for example to include part of the costs in the purchase price of the individual vehicles, or to introduce a subscription-based system. [153]

[149] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.30.
[150] Hayes (2021): Multiple Linear Regression (MLR).
[151] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.30.
[152] Wikipedia (2021): Investitionsausgaben — Wikipedia, Die freie Enzyklopädie.
[153] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.30-31.

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3.5.4.5 Protection and Management of Data

The challenges that arise with automated driving in connection with data security and data management are enormous. In this thesis, the entire chapter 4 is dedicated to the topic on a legal aspect, and in section 4.3.3, the data protection law is also discussed in more detail. In this subsection, the change of administrative domain in cross-border operation of automated vehicles, especially using services such as CCAM, is discussed in particular. The most important points, such as **data management** and **compliance with legal regulations in terms of security and privacy**, will be mentioned here.[154]

Compliance with legal regulations, security and privacy: The topic of privacy in this context is mainly about GDPR and how it should be handled in autonomous vehicles. Today, many privacy frameworks are hardly or not at all regulated. Although there are message formatting frameworks that are standardised and well-defined, such as DENM [155] or CAM [156], most manufacturers in the automotive sector often use their own systems or other proprietary systems that are hardly regulated or not regulated at all. Since a very large amount of data is processed in modern, automated vehicles, some of which is also GDPR-relevant, it is particularly important that the communication of the individual components such as sensors, ECUs, etc. also runs via GDPR-compliant message formats. This is particularly important for cross-border aspects, as it must be ensured that these regulations are fulfilled equally for all countries. Furthermore, the topic of cybersecurity is under discussion, which will be of great importance in the automotive sector in the future, as security in this context is closely related to the topic of safety. A lot of work is being put into the formulation of guidelines, laws for the protection of persons and components, which offers a lot of attack surface due to the surrounding infrastructure, the connected IT systems and the vehicles themselves. As early as July 2022, a new EU regulation formulated by the UN-ECE regarding automotive cybersecurity is due to come into force (EU Regulation 2019/2144). The cybersecurity topic is discussed in more detail in Chapter 3.7.5.[157]

Management of Data: The management of data becomes one of the main challenges in this area, especially in the case of cross-border operation of autonomous vehicles, as this often involves several different network domains, infrastructures, different vehicle manufacturers and their systems, as well as different government service providers. The interoperability between these individual entities is crucial for perfect interaction, which is necessary for the seamless functioning of integrated CCAM systems. Problems arise

[154] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.27.
[155] Decentralized Environmental Notification Message
[156] Cooperative Awareness Message)
[157] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.28.

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when cross-border operation leads to ambiguities in data law, data ownership or access, or liability issues in the event of a leak between two countries.[158]

The main problem, however, is the inconsistency of the data, as a trust problem arises due to different information statuses, for example in localisation or direction of travel etc. between two neighbouring countries or CCAM applications. Trustworthy and secure communication between the individual entities is fundamental for the successful introduction of automated vehicles and CCAM applications in cross-border traffic. This is not only true for border crossings within EU borders, but especially where EU and non-EU countries are adjacent. In order to ensure an authenticated exchange of information and messages, a trust domain agreed by all states would have to be created. One consideration here would be to use the blockchain (see Chapter 3.4.4) as a shared ledger, since in theory it is trusted by everyone and is forever accurate.[159] Particularly outside EU borders, this poses a great challenge, as the exchange of data would also include personal data that is subject to the GDPR law within the EU, which in turn would also have to be taken into account by other, non-EU states. In addition, the technical implementation of data transmission is also an issue that requires legal regulation. For example, there may be incompatibilities between EU and non-EU countries, as different technologies may be used for encryption, data anonymisation or privacy by design mechanisms.[160]

The processing of personal data is one of the most significant problems here, as the management of data in the sense of data ownership and processing is problematic with regard to the applicable laws, especially for people from other countries. This is exacerbated by the security concerns in cross-border CCAM operation regarding the handling of data leaks. Within the EU, trust and data protection management for Intelligent Transport System (ITS) communications is at least partially addressed in the guideline published by ETSI [161] (ETSI TS 102 941)[162], but even here not all aspects are taken into account, especially with regard to non-EU countries that are not subject to GDPR principles.[163]

3.5.5 Problem situation bad weather

Today, autonomous vehicles have already covered many thousands of kilometres and use a large number of sensors to perform the automated driving function. These sensors all have their advantages and disadvantages and are often merged into systems to be better suited for the individual tasks. The correct execution of this driving task is nowadays an

[158] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.27.

[159] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.28-30.

[160] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.27-28.

[161] European Telecommunications Standards Institute

[162] European Telecommunications Standards Institute (2019): Intelligent Transport Systems (ITS); Security; Trust and Privacy Management ETSI TS 102 941 V1.3.1.

[163] Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities, p.28.

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Protection and Management of Data	
Challenge	**Possible solutions**
Management of Data	Standardization, security, 5G-CCAM business models, cross-border message broker, MNO collaboration framework
Compliance (regulatory, security/privacy)	standardization, security, 5G-CCAM business models, cross-border regulatory framework

Table 3.5: Challenges and possible solutions of using 5G in cross-border applications, category "Protection and Management of Data", original source from Trichias et al. (2020): 5G Trials for Cooperative, Connected and Automated Mobility along European 5G Cross-Border Corridors - Challenges and Opportunities

increasingly manageable exercise under good traffic and weather conditions. One of the main problems to be overcome for a successful introduction of autonomous vehicles into road traffic is the correct functioning of these same functions in bad weather conditions. Through a variety of different tests, it has been shown that the individual sensors are subject to degraded performance just like the human driver. Sensors such as LIDAR or cameras may not work correctly in bad weather conditions such as snow or fog, feeding the vehicle with incorrect information. The processing of this incorrect information could, in the worst case, lead to unexpected deviations in driving, which could lead to accidents.[164]

Snow and ice on the road surface, in addition to the negative effects on visibility, also cause other problems with driving dynamics. The snow reduces the coefficient of friction on the road, and the problem here is that this is very difficult to detect in advance by a system. Traditionally, this is detected by the ESP system, by increased slip or the locking of the wheels, and the system intervenes accordingly. This poses a problem for autonomous driving systems, as they need such information in advance for the internal calculation (Plan-Sence-Act, see 3.7.1).[165]

The effects on the individual technical installations vary. Camera and radar systems are particularly negatively affected by external weather conditions. Apart from poor visibility, which can significantly reduce the visible distance (for radar up to 55% under heavy rainfall), there are also technical problems of icing and condensation of the lens.[166] LIDAR, on the other hand, offers better tolerance in bad weather because it is possible to filter out specific raindrops or snow using special filters. Fog correction is also possible, but there is no study yet on the accuracy that these techniques can guarantee in bad weather.[167] Various test methods are used to test the individual sensors, but all the methods currently used have their limitations. Virtual tests or so-called X-in-the-loop tests require accurate simulation data, whereas real-world test methods are strongly dependent

[164]Zang et al. (2019): IEEE Vehicular Technology Magazine, Nr. 2, Bd. 14,, p.2-3.
[165]Herrtwich (2016): Big Techday 9 - Fahren ohne Fahrer: Was funktioniert (und wie) und was eher nicht (und wieso)?, 43:00-44:15.
[166]Zang et al. (2019): IEEE Vehicular Technology Magazine, Nr. 2, Bd. 14,, p.8.
[167]Ibid., p.3-4.

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on when and where the tests are carried out and are often not well reproducible.[168]

Apart from problems on the side of technical instruments and control technology, a closer look at regulation on the basis of standards is also necessary here. If we look at the definition of the Operational Design Domain (ODD) from the SAE J3016 standard (see 2.2.1), the limits of the design domain are exceeded in the case of severe storms. Depending on the degree of autonomisation, a temporary suspension of the automated driving system may be the consequence. If it is not possible for the human driver to take over the driving task, an interruption of the dynamic driving task (DTT) would be possible in order to put the vehicle into a minimum risk condition, see 3.7.[169]

The safety of the intended functionality (SOTIF) described in ISO 21448 (see chapter 3.7.4) also applies in the situation of adverse weather. Compliance with ISO 21448 means that a system considers hazardous situations and adjusts decisions based on probability. In the case of an icy snow road, the system, which in many cases is supported by artificial intelligence, would have to react accordingly and handle the situation correctly. The goal is to correctly interpret such situations, take them into account and reduce the probability of a hazardous situation. The problem is, unfortunately, that the definition of the individual requirements is very vague and a correct execution/implementation of the issues defined in the standard is not clear due to the broad interpretation.[170]

3.6 Applications of new technology

This chapter focuses on the 4 main smart mobility applications that, based on expert knowledge, will have the greatest impact on changing the transport sector by 2030. Self-organised logistics (SoL), Mobility as a Service (MaaS), Connected Cooperative Automated transport (CCAM) and Cooperative Intelligent Transport Systems (C-ITS) are systems that consist of a combination of different technological concepts described in chapter 3.4.

3.6.1 Cooperative, connected and automated mobility, CCAM

One of the most important applications for automated transport is CCAM, or Connected Cooperative Automated transport. Here, the elements "connectivity" and "automation" are particularly important, as they set a trend in the context of the transport sector in the sense of (automated) mobility. CCAM applications are suitable for the road sector as well as for rail transport, for example, and are even being used today in some cases (e.g. driverless metro in Paris).[171]

[168] Hasirlioglu (2020): A Novel Method for Simulation-based Testing and Validation of Automotive Surround Sensors under Adverse Weather Conditions, p.1-3, 119.

[169] Mercedes-Benz Research & Development North America, Inc. and Robert Bosch LLC (2018): Reinventing Safety: A Joint Approach to Automated Driving Systems, p.16.

[170] Bellairs (2019): Why SOTIF (ISO/PAS 21448) Is Key For Safety in Autonomous Driving.

[171] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.39, 42.

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The development of applications and features that have contributed to CCAM development began early with the functions described in chapter 2.2.1, such as adaptive cruise control or lane departure warning. Modern CCAM applications are mainly used in more complex driving situations on motorways or in urban traffic and are designed for level 3 and level 4 functions according to SAE (see chapter 2.2.1.4 and 2.2.1.5) due to their capabilities.[172] [173]

The CCAM function chain is based on the classic **sense-plan-act paradigm** from robotics and automation literature, which will be discussed in more detail in Chapter 3.7. Basically, in the first step (Sense), the environment is perceived with the help of sensors (see 3.4.1.1) and with the help of AI (see 3.4.3) a so-called world model of the environment is created, including a classification of the objects. In the plan or think step, various predictions and expectation models are created based on the model with the help of algorithms and AI. These are subject to different boundaries and framework conditions with regard to the concept of the operational design domain (see 2.2.1). Once a solution has been selected, the chosen solution is ideally executed in the Act step. Before this, however, a check with double or triple security is carried out for important systems, and in case of doubt, an operator can still intervene here.[174][175]

CCAM applications therefore make use of a variety of technology concepts mentioned in chapter 3.4, such as different sensors, communication tools or artificial intelligence for the thinking process. CCAM opens up new possibilities for handling technology, including new control principles in traffic management, service applications (delivery, car sharing, etc.) or V2I communication in traffic management.[176]

A challenge here will certainly be the longer transition phase, in which all possible expansion stages of automation coexist. Particular attention must be paid to vulnerable road users such as pedestrians or cyclists, as they may not be able to distinguish between conventional vehicles and automated vehicles and their reactions. The reactions of road users to each other are also often unpredictable in this transition phase, as vehicles equipped with CCAM cannot trust other vehicles on the road to communicate with V2V technology.[177] Apart from these challenges, all the problems that the individual technological concepts are subject to can of course also be applied to the overall system. The introduction of 5G or a Europe-wide (or worldwide) introduction or synchronisation of guidelines will be decisive for an efficient introduction of CCAM applications. One of the key enablers for the introduction of CCAM will certainly be the use of C-V2X communication.[178] A more detailed discussion of the individual challenges and possible

[172] European Road Transport Research Advisory Council (2020): CCAM Strategic Research and Innovation Agenda, p.29, 33.
[173] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.40.
[174] Ibid.
[175] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.29.
[176] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.42.
[177] Ibid.
[178] Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.21.

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solutions, especially when it comes to cross-border operations, is covered in chapter 3.5.4.

3.6.2 Cooperative Intelligent Transport Systems, C-ITS

C-ITS applications use the short and long range communication technologies described in Chapter 3.4.2, and are also defined by the use of these technologies to exchange information and messages between vehicles or other transport users. Particular attention is paid to secure data transmission, which is realised with the help of a PKI [179]. With the help of certificates, which are managed by a trustworthy domain (blockchain for example, see 3.4.4), trust and revoke lists can be exchanged. Under certain circumstances, various smart sensors are also used in C-ITS applications, but the boundary between these and the CCAM applications already described becomes blurred if sensor data are involved. In the development of C-ITS, the Car2Car consortium presented a roadmap for the introduction of this application, which is defined in 3 ascending sub-phases (day 1 to 3). These days represent an increasing complexity of use cases. For example, according to this roadmap, the applications on day 1 would focus on cooperative awareness and decentralised notifications in addition to data generated and harmonised by Car2Car or C-Roards. Warning systems for Traffic Jam, Intersection Collision and Emergency Vehicle Warning would be appropriate and are already in use at many locations in Europe. Day 2 or phase 2 applications are still largely under development and should lead to improved cooperative awareness on the basis of sensor data. Use cases for this would be GLOSA (Green Light Optimised Speed Advisory), which uses traffic information to give the driver a speed recommendation in order to avoid a red light. In addition, systems are being introduced to protect vulnerable road users (Vulnerable Road User Protection, VRU), as well as a cooperative variant of Adaptive Cruise Control, "C-ACC". With Day 3, the applications are mainly focused on coordination data and intention. The aim is to negotiate a coordination of trajectory movement and manoeuvrability of vehicles among themselves in order to enable applications such as automated GLOSA, truck platooning and cooperative lane merging.[180]

As already mentioned, there is no exact definition boundary between C-ITS and CCAM when it comes to the use of smart sensors. Due to the use of sensor data, especially for some Day 2 and 3 applications, these applications are already moving towards a CCAM definition. Of course, there are many more possible applications, especially if you consider long-range communication. For example, manufacturers can remotely distribute software updates to the vehicle or monitor the health of the vehicle. In addition, functions for generating and distributing high-resolution map data, as well as teleoperated driving are also possible.[181]

[179] public key infrastructure
[180] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.36-38.
[181] Ibid., p.38.

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3.6.3 Mobility as a Service, MaaS

Mobility as a Service is a concept in which the focus is no longer on owning vehicles, but on getting around as a service. There are MaaS platforms that can be used to access a transport service, thus ensuring interoperability between individual entities. The definition of MaaS leaves some room for interpretation, but the key elements of the service are that the focus is on mobility rather than transport and that user needs are seen as the main focus. MaaS can therefore be seen as the integration of transport services, information and payment modalities into a single service that is available on demand.[182][183]

MaaS services are not only limited to road transport, other options such as bike, scooter, or train are also possible. Ownership varies depending on the sector and can therefore lie with the transport operator, the service provider or the user. Within the EU, there are different regulations that influence shared mobility, depending on the country; e-scooters are currently banned in the UK. Depending on the country, taxi licences may also be required for ride-hailing services. MaaS systems are differentiated according to their complexity in levels from 0 to 4, whereby level 0 - no integration, 1 - integration of information, 2 - integration of booking and payment and level 3 - integration of the service offer. At the highest level according to Sochor, et al., 2017, level 4, societal goals are also integrated.[184][185]

The challenges in the introduction of MaaS services are due to their multimodal nature. Standardisation of data and data handling are necessary. Due to the large amount of data, the processing of the data can be influenced by technologies such as AI or Big Data in order to meet the challenges such as the large amount of data, the high diversity of the data and possibly AI-supported prediction of user behaviour. Furthermore, the introduction of a suitable communication technology can also become an enabler of MaaS services. The factors for an introduction in the future are therefore similar to other application technologies, on the one hand in the supporting technology, i.e. how data is processed, accessed or which standards ensure the interoperability of the data. Apart from that, the regulation by the government and the willingness of people to adopt such a new technology is crucial.[186]

3.6.4 Self-organising Logistics, SoL

Self-organised logistics should also be mentioned here, as they are one of the 4 main smart mobility applications that will have an impact on transport.

[182] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.44.
[183] Alliance (2017): Bruss. MaaS Alliance AISBL, p.2.
[184] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.45.
[185] Sochor et al. (2017): A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals, p.8.
[186] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.45-46.

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SoLs are used when a central organisation, which cannot act very dynamically, is either time inefficient or when companies do not want to entrust all data to the central controlling body/control tower. Decentrally controlled and coordinated logistics chains mean that the individual parts of the logistics chain, i.e. individual vehicles, companies or loading units, can make decisions autonomously. These decisions are made using locally available data and integrated intelligence. For situations where a decision has to be made quickly and dynamically, such an approach is probably the better one, even if companies may currently have to accept a loss of quality due to limited data. In order to create situational awareness in autonomous vehicles, however, data processing must be realised in near real time.[187]

As with other applications, digitalisation and automation are the driving factors here; with the help of the technological concepts described in Chapter 3.4, a significant change can also take place in this area of application. In the future, the Sense - Plan - Act design paradigm described in Chapter 3.7 will also be used to a greater extent to assess the challenges. In the sense part, as the name suggests, real-time data is collected. Here, data transmission, for example with 5G technology, is particularly important, as is the storage and sharing of data (e.g. blockchain, 3.4.4). The collected data, which is relevant to the logistics process, is processed in the thinking or planning step with the help of special algorithms. Technologies such as artificial intelligence support this process, which can also support the human planner as self-learning algorithms in the acting step to make better decisions or, depending on the logistics chain, can also take over decisions for individual agents.[188]

3.7 Safety concepts

Depending on the level of autonomy, there are different concepts for safety. Conventional driving functions, which are called semi-automated up to a certain level (see chapter 2.2.1), require a different approach when it comes to complying with safety measures and regulations in road traffic. In contrast to future developments of so-called vehicle guidance systems, which manage without the intervention of a human supervisor, semi-automated systems always have a human in the vehicle who is ready to intervene and take appropriate measures in an emergency. Since at higher levels of automation (SAE level 4 or 5) it can be assumed that the system can and must function without such a supervisor, special safety functions are necessary to put a vehicle in a "safe state".[189]

When it comes to the safety of road vehicles, the ISO 26262 standard, which replaces IEC 61508 and provides a set of rules for safety-relevant electronic systems in motor vehicles, must be implemented by the automotive industry for reasons of product liability. This introduces a concept called safety mechanism, which has to ensure that solutions are implemented that avoid or mitigate the occurrence of errors or monitor the functional

[187] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.46.
[188] Ibid., p.47.
[189] Reschka (2016): Safety Concept for Autonomous Vehicles, p.473-474.

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process with regard to failures in order to avoid them. All this has the purpose of maintaining the functionality or the safe state.[190]

In particular, the definition of the "safe state" already mentioned is recorded here and will be briefly outlined below.

Definition of safe state according to ISO 26262: The ISO 26262 standard has some key terms and definitions that reflect the focus of the standard. First of all, it is important to understand that a safe state can sometimes have a different meaning depending on the domain. Basically, it describes that a malfunction detected by the system should lead to a change of state in which the system is put into a state in which there is no longer any danger from or to the system. This state is evaluated on the basis of the risk, and is considered "safe" if there is no longer any unreasonable risk. Risk is defined as a combination of the severity of the personal injury and the probability of an incident occurring. The risk is considered unreasonable if the current and future risk level is below a certain threshold, which in turn depends on the context in which the system has to function. It is now necessary to determine what level of risk is acceptable for a vehicle in road traffic in order to designate the respective state as a "safe state". The factors to be considered for automated vehicles are the applicable legal conditions, the objects around the vehicle (stationary or moving) and their intentions, the mission and the current capabilities of the autonomous vehicle. For a safe state, all these factors must always be weighed for the current situation, with the objective of keeping the probability of personal injury at an "acceptable" level of risk.[191][192] [193]

Minimal Risk Condition and Minimal Risk Maneuver: It should be noted that the term "minimal risk condition", often used in the context of safe states, does not refer to the level of risk in a state. The term MRC is defined in the British Standards Institution's Vocabulary for Connected and Automated Vehicles, based on the SAE J3016 standard, as follows[194]:

> "Stable, stopped condition to which a human driver or automated driving system brings a vehicle after performing the dynamic driving task fallback in order to reduce the risk of a crash when a given trip cannot be continued."[195]

An MRC does not necessarily describe the standstill of the vehicle, but can also be various intermediate preliminary stages; the "Safety first for Autonomous Driving (SaFAD)"

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[190] Mariani (2018): An overview of autonomous vehicles safety, p.2.

[191] Ibid.

[192] Kocsis et al. (2017): Safety concept for autonomous vehicles that operate in pedestrian areas, p.841-842.

[193] Reschka (2016): Safety Concept for Autonomous Vehicles, p.473-474.

[194] Ibid., p.474.

[195] The British Standards Institution (2020): BSI Connected and automated vehicles – Vocabulary BSI Flex 1890 v3.0:2020-10, p.6.

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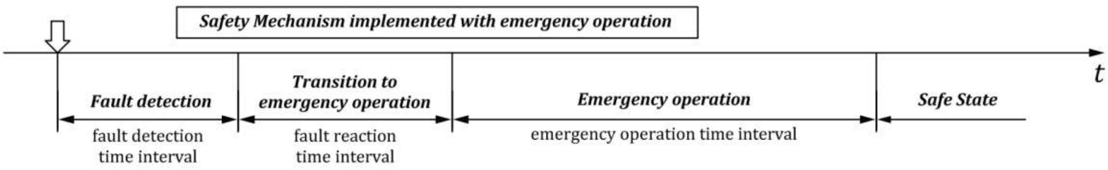

Figure 3.3: Safety Mechanism implemented with an emergency operation, from ISO (2018): Road vehicles - Functional safety ISO/FDIS 26262-1:2018

white paper also mentions degraded operation or takeover by the vehicle driver. The concept of MRC originates from principles of the ISO standard 26262, which is described there as a safe state and can be achieved with the help of a minimal risk manoeuvre (MRM). The MRM is described as an emergency operation and is defined as[196]:

> "tactical or operational manoeuvre triggered and executed by the automated driving system or the human driver to achieve the minimal risk condition."[197]

It is possible that due to the complexity of autonomous driving functions, several MRMs are necessary to bring the vehicle into an MRC.[198] Figure 3.3 shows the individual time intervals that lead to a safe state (or MRC).[199]

3.7.1 Sense-Plan-Act Design Paradigm:

In order to ensure the correct execution of automated functionalities, a control paradigm widely used in robotics is employed. The Sense - Plan - Act design paradigm (SPA) is used to execute systems and functions of the vehicle as well as active safety features during normal operation. In particular, to enable the introduction of SAE Level 4 and 5 driving functions, it is important that the vehicle is able to sense its environment in all situations, interpret it correctly and make decisions quickly accordingly. This basically describes the principles of the Sense-Plan-Act paradigm, which, however, are much more complex than one might think. The demands placed on such a system are much higher than those placed on a human driver. One of the reasons for this is that autonomous vehicles from level 4/5 onwards experience a shift in responsibility. Since with activated L4 or L5 driving systems the driver no longer has to be capable of taking over the driving task in dangerous situations, the responsibility also shifts to the vehicle manufacturers. This "responsibility" or "liability" shift represents a complex problem of autonomous driving and is dealt with separately in chapter 4.3.4.5.[200]

[196] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.34.
[197] The British Standards Institution (2020): BSI Connected and automated vehicles – Vocabulary BSI Flex 1890 v3.0:2020-10, p.6.
[198] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.34.
[199] ISO (2018): Road vehicles - Functional safety ISO/FDIS 26262-1:2018, p.9.
[200] Siemens (2020): Siemens Digital Industries Software, p.4.

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The following steps are carried out one after the other and, due to the use in iterations, after completion of the acting phase, the sensing phase is started again, followed by the planning phase, and so on.

Sense: In step 1, the sensing phase, all the sensors available on the vehicle are used to generate a 360° "world model" that is as accurate as possible. For this purpose, different combinations of sensors (lidar, radar, ultrasound, cameras, etc) are used, depending on their advantages and disadvantages, as described in chapter 3.4.1.1, in order to achieve the best possible result even in the most adverse weather conditions. For a better, more efficient classification of objects, Artificial Intelligence (see 3.4.3) is increasingly used. Above all, the introduction of 5G networks will play an important role in terms of V2V and V2I communication, since a networked handling of functionalities regarding the creation of the world model can bring many advantages in terms of speed and quality.[201] The SaFAD white paper also defines various capabilities that the respective step should have. So-called fail-safe capabilities, which should provide customer value, are for example:[202]

- Determining the position of the vehicle
- Identifying all surrounding static or dynamic objects and determining the distance to the vehicle
- Predicting the movement of objects in relation to the vehicle

Plan/Think: During the thinking and planning process, the data collected in the sensing phase is combined and analysed. This data is used to feed algorithms that generate prediction and anticipation models based on sensor data from the past. Depending on the ODD (see 2.2.1) and SAE level, different situations arise in which the driver cannot be expected to take over the driving task at all times. These calculations are critical and must comply with the highest safety and security standards. Once again, AI is being used to support the development of control models in order to perform driving functions such as steering, accelerator/brake within certain boundaries. Outside these limits, a predictable system is used to bring the vehicle into the desired situation.[203][204] The SaFAD white paper defined this step as the capability to create a roadmap that is both collision-free and lawful.[205] In order to create such a calculation in real time, built-in intelligence and machine learning are applied.[206]

Act: Finally, the last step is to execute what was chosen as the best decision in the Planning step. Depending on the SAE level, the driver can still intervene here.

[201] Siemens (2020): Siemens Digital Industries Software, p.5-6.
[202] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.29.
[203] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.41.
[204] Siemens (2020): Siemens Digital Industries Software, p.6-7.
[205] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.29.
[206] Siemens (2020): Siemens Digital Industries Software, p.6-7.

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In L4 or L5 applications, the decisions are made by the vehicle, which incorporates the technologies in 3 different key areas. Innovative control algorithms, electrical and electronics architecture (EE) and the ECU with embedded software are sub-areas that involve increasingly complex development complexity as the level of autonomy increases, rendering conventional manual decision-making processes useless. For more complex EE architectures, comprehensive model-based approaches must be used.[207] Another point that comes into play with fully autonomous levels of autonomy is redundancy, because if a human driver no longer has the possibility or the duty to monitor the process, it is necessary to introduce additional double or triple safety features (for example, double versions of mechanical systems, etc.). In the coming years, it will therefore become even more important to introduce fail-safe functionalities and self-monitoring systems that constantly monitor the system.[208] According to the SaFAD white paper, in addition to the fail-safe capabilities, which are responsible for the correct execution of the driving task and the interaction/communication with other road users in the Act phase, the SPA design paradigm also includes fail-degraded capabilities, which are constantly valid throughout all phases. These are composed of: [209]

- Determine if normal operation is possible, otherwise react accordingly (reduce system performance to perform degraded mode)
- Determining if the vehicle fails the degraded mode
- Ensuring that safe mode is initiated correctly
- Ensuring that the driver has the ability to control the vehicle

3.7.2 Functional Safety, ISO 26262

The standard ISO 26262 was published in its first version in April 2011 and came into force in November 2011. In December 2018, the standard was supplemented with additional content and has been in force since then as the "Second Edition" or ISO 26262:2018 in its current version. ISO 26262 is an adaptation of the IEC 61508 standard specified for the automotive sector and has been developed to standardise safety-relevant electrical/electronic systems in motor vehicles such as passenger cars, motorbikes and commercial motor vehicles. The main focus lies on hardware and software failures and providing an automotive safety lifecycle. This includes processes from development, production and management to operational use and servicing. This lifecycle is concluded with decommissioning. However, it is essential here that it does not just remain a correct function, but that it is also executed in the correct context. Therefore, functional safety aspects of the development process must also be included (requirement

[207] Siemens (2020): Siemens Digital Industries Software, p.8.
[208] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.41.
[209] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.29.

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specification, implementation and design, integration and verification, as well as validation and configuration).[210][211]

The risk assessment in the standard is performed using Automovive Safety Integrity Levels (ASIL), where specific risk classes are defined, ranging from A to D, D being the most stringent. The standard refers to hardware and software failures or problems when assessing risks, where hardware problems can be either systematic or random. The demands placed on autonomous vehicles and their functionalities correspond to ASIL category D, which means that 99% of the failures that would endanger the safety objective are either detected or the effects are handled in a safe manner. The goal is to have a system-wide failure rate lower than 10 FIT [212].[213][214]

safety mechanisms: With the introduction of the Second Edition, the focus was not only on fail-safe systems, but also on fault-tolerant systems. This means that a technical solution is implemented with so-called "safety mechanisms", which should ensure normal or degraded operation after the occurrence of an error.[215] Safety mechanisms are defined in ISO 26262:2018 under 3.142 as:

> "technical solution implemented by E/E functions or elements, or by other technologies, to detect and mitigate or tolerate faults or control or avoid failures in order to maintain intended functionality or achieve or maintain a safe state"[216]

3.7.2.1 Challenges

In the current version of ISO 26262 from 2018, many of the open questions of the first version from 2011 have been solved, which was mainly limited to the conventional safety equipment of the automotive industry and hardly addressed distributed systems and complex technologies such as those used in autonomous vehicles. The SaFAD white paper provides an expert-generated list of issues to be addressed. This includes first of all the treatment of the already mentioned open gaps in the two versions of ISO 26262 to devise solutions for availability requirements. Furthermore, the design of existing architecture must be adapted to the safety mechanism requirements (away from fail-safe, towards fail-operational or fail-degraded behaviour). Some of the missing architecture models in ISO 26262, which are contained in IEC 61508 for example (e.g. failure rate estimation), must be added. In order to meet all challenges with regard to achieving the specified ASIL, the individual architectural elements and functional elements must

[210] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.20.
[211] Mariani (2018): An overview of autonomous vehicles safety, p.1.
[212] Failures In Time - number of expected failures in 10^9 hours of operation
[213] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.20.
[214] Mariani (2018): An overview of autonomous vehicles safety, p.2.
[215] Ibid.
[216] ISO (2018): Road vehicles - Functional safety ISO/FDIS 26262-1:2018.

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also be well-defined, and a decomposition of the given architectural elements must be achieved. [217]

Currently, these issues are not addressed by ISO 21448 or ISO 26262. If the weaknesses of the individual technologies are taken into account and the challenges mentioned are met, the function can be defined as safe without manipulation. This means that hardware or software errors are detected/handled by the system. [218]

Furthermore, some experts criticise that ISO 26262 is not well designed for the use of artificial intelligence, which is increasingly used in autonomous vehicles.[219] Artificial intelligence is a complex topic and standards always need a lead time before they are adapted. Current literature says that AI is partly ready for a definition in standardisation, certain methods, procedures and definitions are ready, but fundamental areas still need scientific elaboration. In "Is Artificial Intelligence Ready for Standardization?" T.Zielke gives the necessary changes with the most important examples as follows[220]:

- in order to be able to explain AI-based decision-making processes comprehensibly, methods and tools are necessary.
- formal methods for verification of Deep Neural Networks (DNN) and assessment of the robustness of DNN.
- architectures and training methods for robust solutions (based on DNN).

3.7.3 Responsibility-Sensitive Safety Model (RSS)

The introduction of autonomous vehicles into road traffic is a long process. Co-existence with conventional vehicles moved by human drivers is therefore still the everyday street scene for a long time to come. With human drivers, the interpretation of responsibility in accidents is often a relatively imprecise one, often based on incomplete information. Human drivers make mistakes, sometimes these are difficult or impossible to understand if no witnesses were present. In order to be able to use a predictable and unambiguous model for autonomous vehicles, the Responsibility-Sensitive Safety Model (RSS) was conceived, because functional safety and reliability alone are not sufficient, but a combined "multi agent safety" is necessary.[221][222]

Human drivers follow a set of principles, partly learned and partly intuitive. However, these principles are subjectively interpreted and usually leave some room for interpretation. If an accident occurs with an autonomous vehicle, without clearly defined principles, a long

[217] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.21.
[218] Ibid.
[219] Hammerschmidt (2019): „ISO 26262 is not perfectly designed for Artificial Intelligence“.
[220] Zielke (2020): Is Artificial Intelligence Ready for Standardization?, p.270.
[221] Mariani (2018): An overview of autonomous vehicles safety, p.5-6.
[222] Shalev-Shwartz/Shammah/Shashua (2017): On a Formal Model of Safe and Scalable Self-driving Cars, p.6.

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clarification phase can arise, from which the recognition and acceptance of autonomous vehicles in road traffic would also suffer.[223][224]

If we had a precise and predictable model of the principles according to which an AV would act, we could save a lot of time in reconstructing the circumstances. Based on this assumption, the following principles were formulated by Shalev-Shwartz et al. for Mobileye, an Intel company, in 2017[225] :

1. Do not hit the road user in front
2. Do not cut-in recklessly
3. Right-of-way is given, not taken
4. Be careful in areas with poor visibility
5. If you can avoid an accident without causing another, you must do so

With RSS, safe decision-making is defined with the help of mathematical formulas. According to this, it is determined when and what constitutes a dangerous situation and how it arose, and finally how the vehicle has to react to it. Different road situations and driving situations/styles are evaluated and categorised. In contrast to human drivers, a pattern can be programmed that can anticipate dangerous situations depending on the quality of the programming.[226]

In principle, the RSS model can also be understood to formalise various "dilemma situations". If the autonomous vehicle is given precise instructions on how, for example, the safety distance, safe lane changing or priority rules are defined and how to behave in dangerous situations, the question of liability also arises here.[227] A human being would often act unpredictably, sometimes in the heat of the moment and with self-protection in mind. Chapter 4.3.4 discusses the topic of liability law in more detail.

3.7.4 Safety Of The Intended Functionality (SOTIF), ISO 21448

The "Safety Of The Intended Functionality" is described in the standard ISO/PAS 21448:2019. Initially, it was planned to use SOTIF as the 14th part of ISO 26262, but the subject area was so large that it became a separate standard. SOTIF was developed to describe safety in situations without a system failure. For the case of a system failure

[223] Mariani (2018): An overview of autonomous vehicles safety, p.5.
[224] Mobileye (2021): Responsibility-Sensitive Safety - A mathematical model for automated vehicle safety.
[225] Shalev-Shwartz/Shammah/Shashua (2017): On a Formal Model of Safe and Scalable Self-driving Cars, p.6.
[226] Mobileye (2021): Responsibility-Sensitive Safety - A mathematical model for automated vehicle safety.
[227] Mariani (2018): An overview of autonomous vehicles safety, p.6.

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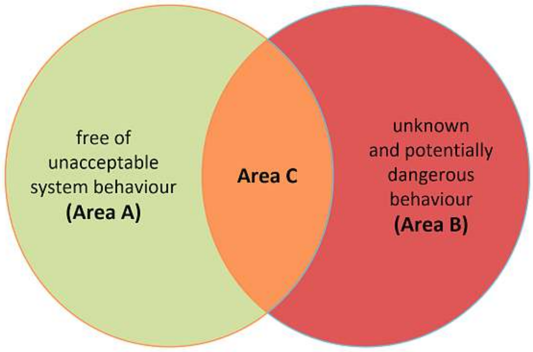

Figure 3.4: Venn-Diagram of possible system behaviour, original source from Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.17

there is already ISO 26262 (Functional Safety, see 3.7.2). This is particularly important for software development, the use of AI and machine learning.[228][229]

In order to be able to develop a "safe" function, an iterative development process of a function or the design process should be described, as well as a validation and verification of these processes.[230] Since a large amount of data is processed in autonomous vehicles by algorithms, artificial intelligence or machine learning, it is very important to create a secure basis for this. The verification of automated systems is very complicated, but it provides the necessary safety for AI supported systems to make correct decisions in scenarios where situational awareness is required.[231]

The standard basically describes three areas, which are well represented by a Venn diagram of two overlapping circles, see figure 3.4. It is assumed that there is an area with safe system behaviour (area A) and an unknown area with potential danger (area B). Area A is by definition "free of unacceptable system behaviour". Area C is formed by the intersection of the two areas A and B and describes known behaviour that could potentially be dangerous as well as unintended behaviour in specific situations.[232]

The general objective is to minimise Area B and C, i.e. to reduce the risk from known unintended behaviour and unknown potential behaviour to an acceptable level of residual risk.[233] This is achieved through verification (testing components/systems, simulating functions and identifying where improvements can be made) and validation (endurance tests, simulations, driving tests). Furthermore, various measures can already be applied during the design process, for example the presumed performance of a sensor.[234][235]

[228] Bellairs (2019): Why SOTIF (ISO/PAS 21448) Is Key For Safety in Autonomous Driving.
[229] Mariani (2018): An overview of autonomous vehicles safety, p.6.
[230] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.17.
[231] Bellairs (2019): Why SOTIF (ISO/PAS 21448) Is Key For Safety in Autonomous Driving.
[232] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.17.
[233] Ibid., p.19.
[234] Bellairs (2019): Why SOTIF (ISO/PAS 21448) Is Key For Safety in Autonomous Driving.
[235] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.19.

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Especially in bad weather, SOTIF plays an important role, because compliance with ISO 21448 means that these situations must also be taken into account. Chapter 3.5.5 deals with the situation of bad weather in more detail.

3.7.5 Cybersecurity

Cybersecurity works together with the already described dependability domains SOTIF and functional safety to ensure a dependable system.[236] Cybersecurity for cyber-physical vehicle systems is defined in SAE J3061, as amended on 14 January 2016. This standard provides a certain guideline for the life cycle of cyber-security relevant vehicles and defines basic principles of cyber-security, various methods and tools, as well as process models and foundations for the development of further standards.[237] Many methods are derived from the ISO 26262 standard, described in the functional safety chapter, see 3.7.2.

ISO/SAE 21434, which is currently still under development, is to become a new standard for cyber security. Publication was planned for the end of 2020, but the standard is currently still in the approval phase (FDIS). The aim of this standard is to define requirements for the entire vehicle life cycle and to recommend the introduction of a Threat Analysis and Risk Assessment (TARA). The detectability and prevention of cyber attacks should be made easier, especially for companies. The ISO/SAE 21434 standard specifies some processes, but leaves the execution of these and the technologies used open.[238]

Katrakazas et al. defines the term cyber-security in Katrakazas et al. (2020): Advances in Transport Policy and Planning as a set of technologies installed/used in autonomous vehicles that are "*used to protect the integrity of the network, software and data from attack, damage or unauthorised access*". The use of these technologies occurs during normal operation and is intended to identify, prevent or mitigate potential threats.[239] There is a direct connection between road safety and cybersecurity, as deliberately manipulated autonomous vehicles interfere with road traffic, which in the worst case can result in accidents.[240] Safety and security are often mistakenly confused or equated; this association is due to the overlapping properties that the topics are built upon. In contrast to safety, which focuses on a correctly functioning system, security, in this case cybersecurity, focuses on the ability to withstand an attack in the form of deliberate malicious actions against the system performed by humans. Due to its robustness against malicious actors, security relies on secure hashing algorithms and secrets to detect intended tampering. Furthermore, a security system must also be capable of dealing with the possibility that the data being processed has been tampered with by outside

[236] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.12.
[237] Vehicle Cybersecurity Systems Engineering Committee (2016): Cybersecurity Guidebook for Cyber-Physical Vehicle Systems.
[238] Doms et al. (2018): Highly Automated Driving - The new challenges for Functional Safety and Cyber Security, p.11-12.
[239] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.80.
[240] Ibid., p.73.

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parties. Verification of the data source and integrity is necessary to achieve an acceptable level of risk. It is difficult to meet the requirements of safety-related data, which are characterised by short processing deadlines, and the requirements of security, which tend to use cryptography, whose use is very resource-intensive. [241]

Due to the ever-increasing number of sensors, electrical components, control devices and communication equipment, the number of cyber-attacks on vehicles today is constantly growing and requires protective measures against such attacks. Modern networked, automated vehicles have a multitude of control units and modules, such as control units for engine, transmission, communication, infotainment, etc., which communicate with each other, with external servers (edge computing) or with other vehicles (V2V). As these modules often have access to essential functions and information of the vehicle, such as GPS data, engine control, chassis and body (locks or driving assistants), as well as online monitoring and diagnostics, there are potential incentives for malicious manipulations.[242][243] One of the main concerns is to limit the physical effect of breaches in security or software failures. In order to ensure cybersecurity in a uniform manner, a consolidated policy is necessary that maps the effects of cybersecurity attacks on road safety. There are still a number of problems to be solved, which are due to the different types and constant development of cyber-attacks on the one hand and the need for security systems to react in real time and process decisions in a time- and reaction-critical manner on the other. The heterogeneous characteristics of the electrical components and systems for communication in autonomous vehicles further complicate the development of a policy framework.[244]

It can therefore be concluded that a “safe state” can only be achieved if the principles of security are adhered to and the system works securely. Special security measures are introduced to protect the integrity of automated vehicles, their functions and components from unauthorized access or manipulation.[245] The threats to autonomous vehicles in terms of security can be multifaceted and can range from connectivity-related attacks such as Denial of Service (DoS) attacks to attacks involving autonomous elements. In ENISA [246] “Good practices for security of smart cars” report of 2019 and “Threat Landscape report” of 2017 defined some threats to the security and resiliency of automated vehicles.[247][248]

[241] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.21-22.
[242] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.80.
[243] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.22.
[244] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.74-75.
[245] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.22-23.
[246] European Union Agency for Network and Information Security
[247] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.81.
[248] ENISA (2019): GOOD PRACTICES FOR SECURITY OF SMART CARS, p.19-20.

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The threats are grouped according to the affected software modules and are described as follows.[249][250]

- **physical threats:** Describes threats such as injection of faults, "glitching" or unauthenticated access to hardware ports. Furthermore, this includes risks such as vandalism, theft or sabotage. Special attention is paid to the manipulation of ECUs or TCUs, which can be exploited to gain information by abusing the electro-magnetic emanations or power usage.[251]

- **outages and communication loss:** As already described in previous chapters (see chapter 3.5), it is of utmost importance for the correct functioning of automated vehicles and their functions that there is a stable network connection. Network outage, which can be the result of poor coverage or general network failures, is one of the most common threats to the safety of autonomous vehicles. Especially for applications that are latency-critical, network outages can lead to denial of service, for example, and make it difficult to distribute critical bug fixes. Since the introduction of 5G networks is not feasible from one day to the next, there will be more difficulties, especially in the transition phase. It is therefore advisable not to rely on a constant network connection quality when designing applications and systems, but to take into account a "degraded mode" in the event of a network failure.[252]

- **unintentional damages (software malfunctions and failures):** This includes errors that are caused by administrative errors in the backend, for example, or by the unintentional release of information such as diagnostic data. Furthermore, the use of data from unreliable information sources or the incorrect use of administrative interventions can also be critical for the consistency and correct functioning of the system. Basically, this includes all those unintentional changes, such as the unintentional modification of data in the system or code, which can lead to software bugs, which is one of the main reasons for potentially exploitable vulnerabilities in the system.[253]

- **nefarious activity/abuse:** One of the main issues when it comes to cybersecurity threats is malicious abuse of autonomous vehicles. This includes the manipulation of information, hardware and software, as well as denial of services, which can lead to a network outage. Exploitation of network connection losses could cause errors and feed the ECU with malicious payload. This can lead to unauthorised activity, identity theft or, in extreme cases, taking over the control of the vehicle. By modifying the vehicle's firmware, malicious control commands are conceivable,

[249] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.81-82.
[250] ENISA (2019): GOOD PRACTICES FOR SECURITY OF SMART CARS, p.19-20.
[251] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.81.
[252] Ibid.
[253] Ibid.

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for example to pursue criminal intentions. Changing the identity of vehicles can also be exploited to impersonate someone else in the backend or in V2V communication.[254][255]

- **hijacking/interception/hacking and phishing:** Systems with many functionalities and technical possibilities often offer incentives for malicious access. In autonomous vehicles, a large part of the applications is based on the principle of having a connection either to a data centre/server (edge computing) or to other vehicles (V2V communication). This communication often happens over unencrypted connections (4G, 5G or WIFI). This quickly opens up opportunities for criminals to perform session hijacking with so-called "man-in-the-middle" attacks. For example, the vehicle is made to believe that the attacker is a trustworthy backend system, which sometimes leads to the installation of manipulated rogue firmware on the vehicle. Pretending to be a specific vehicle in a V2V communication can also lead to payment information being obtained, for example, in order to cause financial damage to the affected party.[256]

- **loss of sensitive data/leakage:** When using autonomous vehicles, especially in applications with a higher degree of autonomy, a large amount of sensitive data is collected and transmitted. There is always a risk that this data, which consists of GPS position data, personal data such as IMSIs [257] or payment information and vehicle-related, personalised adaptations such as driving style and other characteristics, could fall into the wrong hands. These "leaks" could have several causes, for example through malicious interference such as theft, or accidents could also cause such malfunctions. Furthermore, it should be considered that when a vehicle is sold, data may also be unintentionally transferred to the next vehicle owner.[258]

The threats to cyber security are manifold and, in addition to the points just mentioned, also increasingly affect the hardware and the data generated from it as the level of autonomisation increases (from level 3 upwards, defined according to SAE J3016). These data, especially critical sensor data, position information, etc., are of great importance for the perception of the environment and the functional integrity of the individual automated driving functions.[259] If important data, be it local or remote data, is manipulated, in the worst case the actions generated in the "Sense - Plan - Act" paradigm (see chapter 3.7.1) are faulty and can lead to unpredictable consequences. Local data refers to data generated or sent in the vehicle, such as various bus systems, LIN [260] or in-vehicle protocols. Remote data refers to data generated during communication with backend systems, such as telemetry data, remote control services, V2X communication or GPS

[254] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.82.
[255] ENISA (2019): GOOD PRACTICES FOR SECURITY OF SMART CARS, p.19.
[256] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.82.
[257] International Mobile Subscriber Identity
[258] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.81-82.
[259] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.24.
[260] Local Interconnect Network

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navigation.[261] If malware were to be installed in the event of an attack, or critical data were to be manipulated, it could theoretically result in the vehicle occupant or driver no longer being able to enter the vehicle.[262]

3.7.5.1 Protection measures and approaches

In order to ensure cybersecurity and to counteract such attacks, it is necessary to take certain measures. In the following, the measures mentioned in the "Safety First for Automated Driving" (July 2019) white paper will be discussed, which was developed in cooperation with the largest and most important manufacturers and "big players" in the automotive and automation sector.[263] There are now two different approaches to combating attacks. Either one reacts posteriori to a threat occurrence, which means that action is taken during or after the occurrence of a threat in order to ward off the attack or limit its effects. Or a proactive approach is used, with measures taken during the design phase to minimise the likelihood of such an attack.[264]

In order to achieve the most comprehensive and complete coverage possible in terms of cybersecurity, cybersecurity standards and practices are based on a so-called "security-by-design" approach.[265][266] This means that potential hazards are already identified during the design phase, and their effects assessed. Only after all possible scenarios have been simulated a new module/application is rolled out. The question of liability is not addressed here, but software and hardware manufacturers must comply with all security standards and guidelines to which they are subject during the development and integration phase. This also includes the GDPR in the EU, which regulates IT security and privacy. In addition to the measures for protection against cyber attacks described later in the text, the basic principles and techniques of IT security must of course also be observed. These include strong authentication of user groups of automated vehicles and functions, strong encryption of communication, layering of messages and the use of gateways and proxies to control information access, the use of virtualisation and a separation of safety-critical and non-safety-critical functions (e.g. through edge-based server solutions).[267]

In order to anticipate cyber attacks, it may be possible to conduct continuous monitoring of data such as diagnostic data or other sensor data. Analysis of this data can indicate whether, for example, a fault will occur in the system or whether abnormal behaviour is taking place in the system. The conceivably large amount of data requires a highly developed analysis method, which can be helped by artificial intelligence (see chapter

[261] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.83.
[262] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.24.
[263] Ibid.
[264] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.85.
[265] Ibid.
[266] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.24.
[267] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.86.

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3.4.3) or machine learning, for example. A stable and fast network connection with low latency would be essential for this.[268]

To build security into the development process, the SaFAD white paper refers to the SDL process, which is described below.

SDL: The Trusted Computing Development Lifecycle, or Security Development Lifecycle, is a concept that uses a number of principles to make software development more secure and resistant to malicious attacks. The approach was first developed by Microsoft in 2004 and has since become the standard for many companies with various adaptations. The SDL process provides specific guidelines for each phase of software development and should be seen as a tool that is part of the development and maintenance process.[269]

Depending on the development process used, the phases described look different. The initial SDL from Microsoft describes the Requirement Phase, the Design Phase, Implementation, Review Phase, Release and Response.[270] According to the SaFAD white paper, three different categories can be roughly defined for the development of software relevant to autonomous vehicles, into which the practices can be divided. First, there are the preparatory measures or "preliminaries", which are intended to provide the basis for sound software development. This includes measures such as the creation of guidelines, procedures or policies. The second step comprises the development process itself. Various techniques are applied that are already established, such as code review, penetration tests, fuzzing, dynamic and static analysis of code. Furthermore, a modelling of the threats and a good definition of the security requirements are required. After the end of the development process and the release of the product, software or application, the product life cycle is not yet finished, so the third category deals with the maintenance of the software, how to react to incidents or the procedure for updates.[271]

SDL should help to provide a kind of security standard, which provides a cross-industry standardisation of security aspects in software developments and offers a comparability of "secure" products. Unfortunately, SDL is not yet fully utilised across the industry in many sectors. Especially with regard to automated vehicles and their driving functions, proactive addressing of security concerns during the development process is very important.[272][273]

Since time is a commodity that is usually very limited and you do not have an unlimited amount of resources in the form of time that you can spend on the various SDL practices, it is inevitable to make a trade-off in more complex processes. The SaFAD white paper describes this trade-off in three dimensions, which consist of the following.[274]

[268] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.86.
[269] Romeo (2021): Secure Development Lifecycle: The essential guide to safe software pipelines.
[270] Ibid.
[271] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.24.
[272] Romeo (2021): Secure Development Lifecycle: The essential guide to safe software pipelines.
[273] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.25.
[274] Ibid.

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1. system state (when mitigation is envisioned)
2. treatment strategy (how the risk is managed; avoiding, mitigating, accepting or transferring)
3. treatment manifestation (how a risk is addressed or how the chosen approach affects the risk)

The difficulty now is to decide where in this three-dimensional environment the best possible chosen point is for each situation.

Defense-in-depth: One approach, which is mainly known from the military sector, is defence-in-depth security. According to the NSA's definition, defence-in-depth is a strategy used to achieve information assurance in highly networked environments. The military definition differs from the use in the context of automotive cybersecurity, however. In the military environment, the strategy is built, among other things, on gaining time with the help of deliberately set up weaker perimeters for the attackers.[275] In the cybersecurity of autonomous vehicles, or in the context of information security, this is understood as the layered use of functions to achieve security goals. Defence-in-Depth has the task of minimising the probability that an attacker with malicious intent can successfully penetrate a system to cause damage. Low-level components and individual devices are already taken into account, right up to the actual autonomous vehicle and the infrastructure itself.[276]

The goals to be achieved in the security of an autonomous vehicle consist of Confidentiality, Integrity and Availability. This concept is also called the "**CIA Triad**" and should be the cornerstone of any security infrastructure. The goal of Confidentiality is to keep sensitive data confidential and to prevent unauthorised data access with the help of Encryption Services. Integrity, which is also often combined with authenticity, describes the consistency of systems, data or networks and has, among other things, the goal of proactively preventing or weakening access with targeted measures and, in certain cases, also providing a recovery of lost data. The third component, availability, is intended to ensure that authorised users always have access to the system, data or networks and, in the event of a conflict, to provide targeted measures to solve software or hardware problems.[277]

In order to meet these goals with regard to autonomous driving functions and systems, the goals of the CIA Triad must be adapted to embedded systems. The safety first for autonomous driving (SaFAD) white paper describes a layered structure for this, which can be roughly divided into the areas "Component Level", "Vehicle Level" and "Environmental Level", starting with the lowest entity, the individual components. At

[275] Small (2012): Defense in Depth: An Impractical Strategy for a Cyber World, p.6-9.
[276] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.26.
[277] Walkowski (2019): What Is the CIA Triad?.

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the component level, there are primitives such as hardware security modules or hardware with cryptographic functions to fulfil the CIA goals. When the individual components, such as microcontrollers, sensors, cameras or the like, are combined into devices, such as LIDAR or radar systems, the security primitives of the individual components can be used. In addition, there are the encryption/authentication of messages, the integrity and authenticity of firmware and software, security aspects of update functionalities, and functions to minimise denial-of-service attacks. The next layer would then be the merging of the devices into systems. Here again, new criteria/functions become relevant, such as resistance to DOS, secure group communication and attestation of the device status, as well as the use of redundant systems, "sensor fusion" and cross-referencing of different input data. Furthermore, a number of independent safety systems are used in the entire vehicle, so that the failure of a single system does not affect the function of the entire system in the best case. The next layer, which basically describes the infrastructure in which an automated vehicle moves, falls under Environmental Level. Data that is transmitted to and from the vehicle via this infrastructure can be easily authenticated and validated. Furthermore, the vehicle retains the decision authority. The visibility and access to the data for outsiders (e.g. personnel at infrastructural facilities) can be well limited and restricted specifically for each user, depending on access rights.[278]

With the help of the defence-in-depth strategy and the consideration of the stated goals of the CIA Triad, the probability that attackers are successful with targeted attacks can be minimised, and the reliability and trustworthiness can be increased. In the event of an attack, defence-in-depth minimises the negative effects.

3.7.5.2 Challenges and possible solutions

The fulfilment of cybersecurity goals will be one of the key enablers when it comes to the introduction of autonomous vehicles in road traffic. It can be assumed that the expansion of high-speed data transmission technologies, such as 5G networks, will be one of the basic prerequisites for the use of machine learning and other computation intensive technologies to efficiently protect autonomous vehicles against threats and to detect and combat them in near real time. However, the challenges that arise in the context of cyber security are manifold and require some changes, which will be addressed in the following.[279]

In the article "Cyber security and its impact on CAV safety", Katrakazas et al. shows that it is first important to ask how much time is needed to address a specific cyber attack before it becomes safety critical, and how the occupants of an autonomous vehicle can be protected from injury in the event of a specific cyber attack. For this, a categorisation of cyber-attacks and a quantification of the impact on safety must first be carried out. For example, micro simulations are suitable for this purpose, which provide a scalable model of the mapped cyber attacks.[280]

[278] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.26.
[279] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.86.
[280] Ibid., p.87.

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In principle, a revision and rethinking of the assessment of the dangers and risk potential of cyber attacks is necessary. A guideline regulating the degree of trust in communication between vehicles is necessary, especially when it comes to deciding whether it should be trusted more than, for example, the on-board sensors on the vehicle itself. Specific thresholds need to be defined for this, as well as a procedure for dealing with vehicles classified as dangerous. In order to be able to categorise and assess the hazards, it is important to rank the threats according to crash potential and injury level, on the basis of which a plan can be prepared as to which countermeasures can be taken. Further distinctions need to be made in the association between cyber security risks and traffic accident risks for different road types, traffic density or weather conditions.[281]

The SAE J3061 standard defines the guidelines for the life cycle of cyber-security relevant vehicles and specifies various methods, tools and processes.[282] However, since a distinction must be made between security leaks at the infrastructure level and on the vehicle side, the SAE J3061 standard must also be adapted accordingly. The distinction between system-level and local attacks is an important security aspect, as V2V communications often rely blindly on the secure connection between two vehicles. When designing cyber security in vehicles, the time a human/driver needs to regain control of an attacked vehicle should also be included in a regulation.[283] SAE J3061 is partly based on methods of ISO 26262, which defines functional safety in road vehicles. In this standard, changes are also necessary with regard to the Automovive Safety Integrity Levels (ASIL) calculation and to update these to take cyber threats into account.[284]

The topic of cyber security has long been a preoccupation of the industry, and there are a number of different governing bodies around the world that deal with cyber security. However, as cyber security threats are not local but global, it would be beneficial to create an international platform to cooperate against cyber threats. A common database would be desirable, which would represent a collected reference work of threats and possible solutions, as well as cooperative liability and security strategies.[285]

As already described several times, due to the large number of sensors and cameras, a large amount of data is available at any time, which could be helpful in the investigation of cyber attacks. However, problems arise here that could affect the privacy of the persons concerned, as well as ethnic problems.[286][287]

Katrakazas et al. specifically lists the following problems and points to possible problem-solving approaches.[288]

[281] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.88.
[282] Vehicle Cybersecurity Systems Engineering Committee (2016): Cybersecurity Guidebook for Cyber-Physical Vehicle Systems.
[283] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.88.
[284] Ibid., p.89.
[285] Ibid., p.88-89.
[286] Ibid., p.88.
[287] Amelung-Herzongerath/Troullinou/Thomopoulos (2015): Reversing the order: towards a philosophically informed debate on ICT for transport, p.11-13.
[288] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.87.

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- The breach of safety-relevant systems or problems with the protection of private data in V2X communication make encryption of communication, message layering or the use of proxies necessary. This also prevents incorrect information regarding speed and position data within platoons.[289]

- Unreliable communication could be counteracted by categorizing threats and their effects.[290][291]

- Through the continuous monitoring and analysis of diagnostic data, which are collected in autonomous vehicles, maliciously inserted information regarding the traffic flow can be prevented.[292][293]

- In vehicle control, cyber-security modules are often not taken into account. Compliance with security and privacy regulations on the hardware and software level is necessary.[294][295]

In conclusion, it can be argued that there is still a lot to be done in terms of the policy regulations. Research should be carried out to show the strong link between cyber attacks and the decline in the level of road safety. Closing the regulatory gap between the definitions of cyber-security and road safety requires stronger cooperation between policy makers. This is particularly important for the international use of autonomous vehicles.[296]

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[289] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.87.
[290] Ibid.
[291] Schoitsch et al. (2016): The Need for Safety and Cyber-Security Co-engineering and Standardization for Highly Automated Automotive Vehicles, p.1.
[292] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.87.
[293] Wang et al. (2018): Computer-Aided Civil and Infrastructure Engineering, Bd. 34,, p.4.
[294] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.87.
[295] Ferdowsi et al. (2019): IEEE Transactions on Communications, Bd. PP,, p.2-4.
[296] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.90.

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CHAPTER 4

Legal Aspects

The advance of technology is enabling a whole new approach to mobility. Autonomous driving is a topic that is subject to a strong trend of change today and will continue to be so in the future. The legal framework for autonomous transportation is, as is usually the case, only very slowly adjusted to the technical developments. The technological resources used in the deployment of automated vehicles vary depending on the level of autonomy. The levels of autonomy described in chapter 2.2.1 according to SAE J3016 specify what a vehicle must be able to do at the respective level and what is expected of the driver, but of course the legal framework conditions must also be adapted to the given circumstances. Partially automated vehicles and driving functions already exist today, but there is still a need for action, especially at higher levels of autonomy.[1]

In addition to the expansion of the infrastructure required for the realisation of automated vehicles, it is above all the task of the government to ensure a legal framework that is ideally valid throughout Europe and, in the best case, worldwide. McKinsey predicts that up to 15% of autonomous vehicles will be on the roads by 2030, even according to the most conservative estimates.[2]

When considering the legal situation in Europe, it is important to take into account the legal structure regarding the laws applicable to automated driving. The hierarchical structure of the legislation can be seen in figure 4.1. Starting with the international agreements and conventions, which are mainly defined by the Vienna Convention, the Geneva Convention and ECE regulations. One level below, regulations and directives within the EU are described, which concern those states that have not already ratified the conventions from the international legal level. At the national level, legislation and regulations concerning autonomous driving are defined and concern individual countries.

[1] Bundesministerium Verkehr, Innovation und Technologie (2018): Aktionspaket Automatisierte Mobilität 2019-2022, p.5-6.

[2] Siemens (2020): Siemens Digital Industries Software, p.3.

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Figure 4.1: The legal structure within the EU, concerning automated driving, from Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, own representation

Below the national level, the technical standards are defined. Most technical standards relevant for autonomous driving have already been discussed in Chapter 3.[3]

Automated driving functions of higher SAE levels still require in-depth testing, which is why the legal framework conditions for a necessary test operation also have a major impact on technical progress and the advancement of developments in terms of automated driving. In this chapter, the current legal situation in the described legal areas is presented and discussed, especially with regard to the development and test operation of autonomous vehicles, which is indispensable before a final introduction into road traffic.[4]

4.1 International agreements and conventions

Austrian traffic law is determined by international and European legal regulations. The international legal regulations are a supranational legal order consisting of rules and principles that apply to legal entities such as states and, in the context of autonomous driving, primarily concern interstate traffic. International laws are not directly applicable and only come into force through transposition into national law or through integration into EU law.

Over the course of time, beginning with the international conference in Paris in 1909, there

[3]Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.6.

[4]Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.50-51.

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have been numerous conferences and agreements that were intended to standardise and facilitate interstate border traffic. However, technical progress and new technologies also require the ongoing adaptation of these agreements. Above all, the Vienna Convention on Road Traffic of 1968 represents a legal framework that is still valid today and is one of the most important conventions alongside the UN/ECE regulations for harmonising vehicle regulations and the Convention on Road Signs and Signals and international regulations for freight transport. The International Convention on Road Traffic of 1949, which was adopted in Geneva, is also worth mentioning, but is not dealt with to this extent, as it has been mostly superseded by the Vienna Convention for Road Traffic of 1968.[5]

In the following, the most important agreements under international law for the context of autonomous driving will be described and examined.

4.1.1 Vienna Convention on Road Traffic of 1968

The Vienna Convention on Road Traffic of 1968 sets out various framework conditions for motor vehicles used for the carriage of passengers or goods, which represent minimum requirements or specifications with regard to the technical standards of these vehicles. The Convention, which in Austria came into force on 11 August 1982, standardises and norms the requirements for the registration of motor vehicles or motorcycles, specifies minimum requirements that holders of national driving licences must fulfil when driving motor vehicles, as well as international requirements with regard to traffic regulations and traffic signs.[6]

One of the definitions of the Vienna Convention on Road Traffic, which is important for the consideration of autonomous driving, is specified in Article 8. Art 8 para 1 stipulates that[7]

> *"Every vehicle and connected vehicles, when in motion, must have a driver."*(cited from original source:[8])

The definition of a "driver" is laid down in Art 1 lit v and is therefore

> *"any person who drives a motor vehicle or other vehicle (including bicycles)..."*(cited from original source:[9])

Furthermore, Art 8 para 3-4 defines the physical and mental fitness of the driver, as well as the required knowledge and ability of the driver of a motor vehicle. Of particular interest are Art 8 para 5, which specifies that

[5] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.51-53.
[6] Ibid., p.53.
[7] Ibid., p.54.
[8] o.A. (1968): Übereinkommen über den Straßenverkehr, Version of 16.06.2021.
[9] Ibid.

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> *"Every driver shall at all times be in control of his vehicle"*(cited from original source:[10])

as well as para 6, which describes that the driver of the vehicle shall avoid all other activities apart from driving the vehicle. Although the legal text does not explicitly refer to a human driver, it can be assumed from other implied human characteristics defined in other parts of the legal text (knowledge, abilities, physical and mental condition according to Art. 8 Para. 3 and 4) that a human driver is always referred to. [11]

For the definition of the term "driver", there are certain alternative approaches with regard to fully autonomous operation. For example, T.M. Gasser in "Grundlegende und spezielle Rechtsfragen für autonome Fahrzeuge" from 2015 raises the question of whether the "driver" would not become a passenger during the operation of a fully automated driving function, as he would no longer be assigned any tasks, depending on the degree of autonomisation.[12][13]

4.1.1.1 Amendments to the 1968 Convention on Road Traffic:

All these regulations have a strong impact on the introduction and use of autonomous driving systems and applications. For this reason, the Vienna Road Traffic Convention has been amended in 2016 to the effect that vehicles may also be allowed to drive automatically under certain circumstances. To this end, amendments were made to Article 8 and Article 39 by adding §5bis. This states that although a driver must be in the vehicle at all times, it can also be driven automatically [14] [15]

> *"when such systems can be overridden or switched off by the driver."*(cited from original source:[16])

More specifically, the amendment to the 1968 Convention on on Road Traffic now defines two cases. In the first case, driving systems that influence the driving behaviour of the vehicle are now compliant with Art 8 para 5 and Art 13 para 1, as long as their systems/components comply with the international ECE regulations.[17]

[10] o.A. (1968): Übereinkommen über den Straßenverkehr, Version of 16.06.2021.

[11] von Ungern-Sternberg (2018): Völker- und europarechtliche Implikationen autonomen Fahrens (2nd Edition), p.11-12.

[12] Gasser (2015): Grundlegende und spezielle Rechtsfragen für autonome Fahrzeuge, p.551.

[13] Komar (2017): Autonomes Fahren - Aktueller Stand und Untersuchung rechtlicher Aspekte, p.37.

[14] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.55.

[15] Krieger-Lamina (2016): Vernetzte Automobile. Datensammeln beim Fahren – von Assistenzsystemen zu autonomen Fahrzeugen. Endbericht, p.38.

[16] Economic Commission for Europe (2014): Report of the sixty-eighth session of the Working Party on Road Traffic Safety, p.9.

[17] Ibid.

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Furthermore, the already mentioned case is defined, in which systems may also be used, which are NOT compliant with international ECE regulations, as long as they can be overridden by the driver at any time.[18][19]

The inclusion of the ECE regulations in the legislative text of the Vienna Convention on Road Traffic due to the amendment in 2016 opens up a good opportunity for future technological development.

4.1.1.2 Development and test operation

If we now look at the legal provisions regarding the testing of new technologies and vehicles, the following statements can be made. In the case of tests that have the purpose of increasing the safety standard, there are exceptions in many articles, for example in Chapter IV, Art 60 lit c, which states that in the national area, for certain cases, the provisions can be deviated from, this is applicable

> *"for vehicles to carry out tests for the technical development and improvement of road safety."*(cited from original source:[20])

These exceptions refer, for example, to the provisions on technical requirements for motor vehicles (brakes, lighting and light equipment) defined in Annex 5. Other minimum requirements, such as compliance with traffic regulations (Art 2), the driver's duties and behaviour in traffic must be observed regardless of whether the vehicle is a test vehicle.[21]

4.1.1.3 Possible Amendments

The amendment of the Vienna Convention on Road Traffic in 2016, which concerns Art 8 para 5bis, has already made a big step towards enabling automated driving. However, certain changes are still necessary to enable automated driving, especially with a higher degree of automation. This concerns in particular the definition and interpretation of the term "driver" and the legal understanding of the scope of autonomous driving functions. Over time, proposed amendments have been presented by several Contracting Parties, such as Belgium and Sweden in March 2015[22] and France in March 2019[23]. In the following, these are briefly summarised and discussed in terms of their practicability.

[18] Böning/Canny (2021): Freiburger Informationspapiere zum Völkerrecht und Öffentlichen Recht, Bd. 1,, p.12.

[19] Economic Commission for Europe (2014): Report of the sixty-eighth session of the Working Party on Road Traffic Safety, p.9.

[20] o.A. (1968): Übereinkommen über den Straßenverkehr, Version of 16.06.2021.

[21] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.54-55.

[22] Economic Commission for Europe (2015b): Informal document No.2 - Autonomous Driving - Submitted by the Governments of Belgium and Sweden.

[23] Economic Commission for Europe (2019): ECE/TRANS/WP.1/2019/1 - Amendment proposal to Article 8 in the 1968 Convention on Road Traffic - Submitted by France.

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Requirement of a (human) driver: As explained several times throughout this chapter, the presence of a human driver is one of the key issues in the context of automated driving. Due to this necessity, which is a hurdle for autonomous driving, a proposed amendment in 2015 by Sweden and Belgium proposed to legally equate the human driver with the machine driver or system. This proposal may sound logical at first glance, but proves to be impractical for the following reasons. First of all, many standards within the Vienna Convention are based on the definition of "driver", all of which would be affected by the above amendment and would sometimes raise new legal issues.[24][25] For example, a partial legal entitlement of automated systems would not only mean that they would have to fulfil all the behavioural obligations of the Vienna Convention, but the equation of man and machine in this context would also raise some discrepancies, as Art. 41(1a) states that

> *"Every driver of a motor vehicle must be in possession of a driving licence"*(cited from original source:[26])

and according to Art. 41(1b)

> *"... the driver must have the required theoretical knowledge and practical skill..."*(cited from original source:[27])

Since these characteristics cannot be fulfilled by a machine, the implementation of this approach is not trivial and requires far-reaching changes that may go beyond its benefits.[28]

Decision-making by automated driving systems: A second proposed amendment, which was also presented by experts from Sweden and Belgium shortly after the first proposal just described, is that decision-making could also be done by automated driving systems. This would mean that autonomous systems would be recognised under Art. 8 of the Vienna Convention on Road Traffic. Paragraph 34 of the proposal presented in July 2015 raises the question of whether a "driver", as has been necessary up to now by definition, is still necessary or raises the question of a definition of the role of the driver.[29][30]

According to the proposal, a three-stage principle is suggested here for the definition of such systems, which reads as follows. Starting with paragraph 34 lit a, systems are defined to

[24] Fußbroich (2019): Die völkerrechtlichen Vorgaben für das automatisierte Fahren, p.13.
[25] von Ungern-Sternberg (2018): Völker- und europarechtliche Implikationen autonomen Fahrens (2nd Edition), p.11-13.
[26] o.A. (1968): Übereinkommen über den Straßenverkehr, Version of 16.06.2021.
[27] Ibid.
[28] Fußbroich (2019): Die völkerrechtlichen Vorgaben für das automatisierte Fahren, p.12-14.
[29] Ibid., p.14-15.
[30] Economic Commission for Europe (2015a): ECE/TRANS/WP.1/2015/8 - Autonomous Driving - Submitted by the Experts of Belgium and Sweden, p.7.

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> *"...take over some of the driving tasks..."*(cited from original source:[31])

Such systems are already covered in the current version of the Vienna Convention on Road Traffic and require an alert driver at all times who must be ready to take over the driving task.

The interesting part starts at paragraph 34 lit b, which refers to

> *"systems taking over all driving tasks on a certain road or trajectory..."*(cited from original source:[32])

The definition of these systems also requires a driver, but when the autonomous system is activated, the driver is no longer responsible for monitoring the driving environment. In the event of a system failure or error, the driver must still be prepared to take control of the vehicle or the driving task again.[33] This point b basically describes driving systems that would correspond to level 3 according to SAE J3016 2.2.1, since here the fallback performance of the dynamic driving task (DDT) still remains with the driver himself.[34]

The last of the three levels, which is described in paragraph 34 lit c, refers to

> *"Systems taking over all driving tasks from departure to arrival..."*(cited from original source:[35])

and by definition describes level 5 according to SAE J3016. A driver is no longer necessary and does not have to be able to drive the vehicle.[36]

In contrast to the last proposed amendment, which would foresee that a machine can also be equated with the definition of a "driver", the omission of the requirement for a driver, as mentioned in paragraph 34 lit c, does not lead to inconsistencies with the mentioned paragraphs, which impose human behavioural requirements on the machine. Unfortunately, the feasibility of implementation is also difficult here, since even with the amended legal text, compliance with the behavioural requirements is still necessary, even in the case of a "driverless" vehicle. Under normal circumstances, this is the responsibility of the driver, who is not present in such a scenario.[37]

[31] Economic Commission for Europe (2015a): ECE/TRANS/WP.1/2015/8 - Autonomous Driving - Submitted by the Experts of Belgium and Sweden, p.7.
[32] Ibid.
[33] Ibid.
[34] SAE international (2018): SAE International,(J3016), p.22.
[35] Economic Commission for Europe (2015a): ECE/TRANS/WP.1/2015/8 - Autonomous Driving - Submitted by the Experts of Belgium and Sweden, p.7.
[36] Ibid.
[37] Fußbroich (2019): Die völkerrechtlichen Vorgaben für das automatisierte Fahren, p.15.

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Amendment proposed by France 2019 Article 8, Paragraph 5: In March 2019, France presented a proposed amendment to Article 8, paragraph 5, which previously read as follows:

> *"Every driver (driver of animals) must be able to control his vehicle or guide his animals at all times."*(cited from original source:[38])

In the amendment proposal, paragraph 5 was extended by subparagraphs 5 (a), 5 (b) and 5 (c). Paragraph 5 (b) was supplemented by lit (i - ii). Of particular importance in this context is paragraph 5 (b), which states

> *"As an exception to the paragraph 1 above, some vehicles systems can take over all of the driving tasks of the driver."*(cited from original source:[39])

This would allow automated driving functions, and paragraph 5 (b) (ii) would also authorise higher levels of autonomy, as the driver would be relieved of his tasks when the driving system is activated. The fulfilment of the rules of conduct which are not fulfilled by the system is by definition the responsibility of the person who has activated the system, defined in paragraph 5 (b) (ii):

> *"...The provisions of the convention which apply to drivers, other than those linked to the driving tasks, apply to the person who has engaged the autonomous driving system. ..."*(cited from original source:[40])

It is not difficult to see that this proposed amendment does not provide a satisfying solution, as the rules of conduct would still have to be fulfilled by a passenger.[41]

4.1.1.4 Conclusion

The Vienna Convention on Road Traffic defines the minimum technical requirements for vehicles normally used in road traffic and the requirements for the driver. The need for a driver per se is seen by many experts as an obstacle to the introduction of fully autonomous (and highly autonomous) driving.[42] With the introduction of the amendment in 2016, Art 8 para 5bis created the possibility to hand over the driving task to an

[38]o.A. (1968): Übereinkommen über den Straßenverkehr, Version of 16.06.2021.

[39]Economic Commission for Europe (2019): ECE/TRANS/WP.1/2019/1 - Amendment proposal to Article 8 in the 1968 Convention on Road Traffic - Submitted by France, p.2.

[40]Ibid., p.3.

[41]Fußbroich (2019): Die völkerrechtlichen Vorgaben für das automatisierte Fahren, p.16.

[42]von Ungern-Sternberg (2018): Völker- und europarechtliche Implikationen autonomen Fahrens (2nd Edition), p.11.

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automated driving system (under certain circumstances).[43] The interpretation of the amendment of the Vienna Convention on Road Traffic in relation to fully autonomous driving is now somewhat problematic. On the one hand, it can be argued that systems that comply with the ECE regulations would also be able to take over longitudinal and lateral acceleration, on the premise that a driver is present. According to Antje von Ungern-Sternberg in "Völker- und europarechtliche Implikationen autonomen Fahrens" (Implications of autonomous driving under international and European law)[44], the omission of the obligation to monitor would make sense from this point of view, but it has not been clearly resolved in legal terms and the contracting parties have not taken a clear position in the course of the amendment procedure.[45]

This assumption would be contradicted by the fact that the remaining paragraphs repeatedly mention the driver's duties and rules of conduct. Since the driver is not explicitly exempted from these duties, it can be assumed that monitoring of the driving process is nevertheless necessary at all times and thus, from a legal point of view, driving systems up to SAE level 3 would be possible.[46]

These amendments brought the Vienna Convention on Road Traffic a little closer to the state of the art and enabled the use of various assistance systems.

If we now widen the focus and look at the remaining ratified countries, we can state the following. Depending on the state, Art. 13 and Art. 8 are interpreted differently, i.e. the interpretation varies between the driver must be in control of the vehicle at all times and the driver must be capable of being in control. Accordingly, the actions necessary to enable autonomous driving also differ. For countries that expect total control over the vehicle at all times, such as Germany, Austria, France or Italy, amendments are necessary. For the alternative interpretation, however, no significant changes are necessary.[47]

Looking at the proposed changes examined in 4.1.1.3, it becomes clear that although the proposals presented attempt to solve some problems, the introduction of these changes creates new problems. A meaningful amendment of the Vienna Convention on Road Traffic is a tough test for the experts and the question arises whether it is possible at all.

The Vienna Convention was drafted at a time when the autonomy or automation of individual transport was not yet conceivable; an adaptation of this (in the context of autonomous driving) outdated legal text may not be feasible and a complete amendment of road traffic law is the only solution to reconcile even stages of higher levels of automation without contradiction with road traffic and registration law.[48]

[43] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.60.

[44] von Ungern-Sternberg (2018): Völker- und europarechtliche Implikationen autonomen Fahrens (2nd Edition).

[45] Ibid., p.10.

[46] Ibid., p.10-11.

[47] Eugensson (2016): Overview of Regulations for Autonomous Vehicles, p.4-5.

[48] Fußbroich (2019): Die völkerrechtlichen Vorgaben für das automatisierte Fahren, p.16-17.

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4.1.2 UN/ECE regulations

The ECE Regulations, or "Agreement concerning the Adoption of Uniform Conditions of Approval and Reciprocal Recognition of Approval for Motor Vehicle Equipment and Parts, done at Geneva on 20 March 1958" as the original title of the agreement was, is one of the most important sets of regulations when it comes to the introduction of new vehicles or vehicle parts. The ECE regulations provide internationally recognised technical guidelines under which a technical component is recognised in all ratified countries.[49]

The introduction of this convention was intended to harmonise technical conditions in order to minimise obstacles in international trade. The original set of regulations was signed in Geneva in 1958 and has since been adapted several times to the technical conditions that have arisen over the course of time.[50] Austria signed the Convention as a contracting party in 1971, and in 1995 it was adapted as "Revision 2" and signed by the European Union in 1998. The current version "Revision 3" was adopted in 2017 and for the first time also deals with topics of automated driving and cyber security.[51][52]

Today, there are approximately 160 ECE regulations, all of which are based on the 1958 United Nations Economic Commission for Europe (UNECE) Vehicle Parts Agreement and define the technical specifications for vehicles, equipment and vehicle components as well as the mutual recognition of approvals between the contracting parties.[53][54]

As already mentioned in 4.1.1, the Vienna Convention on Road Traffic refers in specific articles to the ECE regulations, which gives the whole matter particular relevance. In the following, the regulations that are especially relevant for autonomous driving will be addressed.

4.1.2.1 Relevant regulations

The various regulations must be recognised by the contracting states or parties. Unless there are special circumstances that require a special regulation, these regulations are to be declared binding in Austria by ordinance according to § 26a para. 3 KFG.[55]

Among the 158 regulations, the following 3 stand out especially in the context of autonomous driving, as they specifically refer to the technical conditions that are considered in particular for autonomous driving functions.

[49] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.57.
[50] UN/ECE (2021): Text of the 1958 Agreement - Overview.
[51] UN/ECE (2017): Convention of 20 March 1958.
[52] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.57.
[53] Ibid.
[54] von Ungern-Sternberg (2018): Völker- und europarechtliche Implikationen autonomen Fahrens (2nd Edition), p.4.
[55] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.57.

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Automated vehicles, like conventional vehicles, must also comply with the applicable ECE regulations. There are no regulations specifically designed for automated vehicles, and so the general regulations must also be used for this purpose.[56]

Regulation 79 First and foremost, Regulation 79 is the most frequently mentioned regulation in today's literature. Regulation 79 refers to the steering equipment, has been revised several times over the years and is currently in revision 4, which contains a total of 3 amendments, the last of which was added in February 2021.

In the current version, automated driving systems are explicitly addressed and the term "Autonomous Steering System" is defined in 2.3.3 as:

> *"a system that incorporates a function within a complex electronic control system that causes the vehicle to follow a defined path or to alter its path in response to signals initiated and transmitted from off-board the vehicle. The driver will not necessarily be in primary control of the vehicle."*(cited from original source:[57])

However, according to 5.1.6, only steering systems are approvable insofar as the function does not lead to an impairment of the performance of the basic steering system. Furthermore, it must be possible for the driver to deliberately deactivate the function at any time.[58] These regulations are comparable to those mentioned in the Vienna Convention on Road Traffic.[59]

Until revision 2 of Regulation 79, 5.1.6.1 referred to the speed up to which an automatically commanded steering function may operate and states that such systems may only be used up to a speed of 10km/h (+20%) and that they shall be automatically deactivated.[60][61][62]

With Amendment 3 to Revision 2 in September 2017, this paragraph has been edited and expanded with a categorisation of the so-called ACSF (Automatically commanded steering function), which are now divided into categories of A, B1, B2, C, D and E. These categories now describe driving functions that reflect the range of functions of parking assistants or lane departure warning systems.[63]

Category A, for example, may only be used at low speeds (5.6.1.1.1 - only up to 10km/h +2km/h tolerance)[64], to perform a parking manoeuvre.

[56] Fußbroich (2019): Die völkerrechtlichen Vorgaben für das automatisierte Fahren, p.10.
[57] UN/ECE (2018b): UN Regulation No. 79 Revision 4, p.6.
[58] Ibid., p.13.
[59] Fußbroich (2019): Die völkerrechtlichen Vorgaben für das automatisierte Fahren, p.11.
[60] Böning/Canny (2021): Freiburger Informationspapiere zum Völkerrecht und Öffentlichen Recht, Bd. 1,, p.9.
[61] von Ungern-Sternberg (2018): Völker- und europarechtliche Implikationen autonomen Fahrens (2nd Edition), p.4.
[62] Watzenig (2018): Faktencheck Automatisiertes Fahren in Österreich, p.18.
[63] UN/ECE (2018b): UN Regulation No. 79 Revision 4, p.6.
[64] Ibid., p.19.

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A rough classification of ACSF can therefore be made into parking assistants (2.3.4.1.1 automatic steering functions at low speeds) and lane change assistants (2.3.4.1.2-6 corrective lateral movement).[65]

This type of classification will also be found in the "Automatisiertes-Fahren-Verordnung" in Chapter 4.3.2.[66]

Regulation 13H In addition to ECE Regulation 79, ECE Regulation 13H is another important regulation for automated driving. This regulation relates to the braking system fitted to the passenger vehicle. In its current version, the ECE Regulation 13H allows automated braking functions, especially emergency braking functions, to be used without restrictions.[67] So-called "Automatically commanded braking" (2.20) is thus defined as:

> *"a function within a complex electronic control system where actuation of the braking system(s) or brakes of certain axles is made for the purpose of generating vehicle retardation with or without a direct action of the driver, resulting from the automatic evaluation of on-board initiated information."*(cited from original source:[68])

Apart from their automated functions, all vehicles are subject to the conventional regulations concerning braking systems, and thus, according to 5.2.1, at least 3 independent braking systems must be installed. These are defined as "Service braking system" in paragraph 5.1.2.1, "Secondary braking system" in paragraph 5.1.2.2 and finally "Parking braking system" in paragraph 5.1.2.3.[69][70]

As 5.2.2 allows these systems to share components, dual-circuit braking systems are almost exclusively used in which the service and secondary braking systems share components. The conditions from 5.2.2.1 to 5.2.2.10 must be taken into account. These regulations also apply to automated braking systems that operate the brakes by use of electric motors. In this case, a redundant system must be used and, according to 5.2.2.8, two independent energy reserves must be available.[71][72]

Regulation 6 and 48 Regulation No. 6 (Direction indicators) and No. 48 (Installation of lighting and light-signalling devices) are also worth mentioning. These define guidelines for the use and installation of direction indicators, e.g. how to proceed when changing

[65] UN/ECE (2018b): UN Regulation No. 79 Revision 4, p.6.
[66] wko.at (2019): Rahmenbedingungen für automatisiertes Fahren.
[67] Fußbroich (2019): Die völkerrechtlichen Vorgaben für das automatisierte Fahren, p.11.
[68] UN/ECE (2018a): UN Regulation No. 13-H Revision 4, p.7.
[69] Ibid., p.10-11.
[70] Lutz/Tang/Lienkamp (2012): Analyse der rechtlichen Situation von teleoperierten und autonomen Fahrzeugen, p.3-4.
[71] UN/ECE (2018a): UN Regulation No. 13-H Revision 4, p.12.
[72] Komar (2017): Autonomes Fahren - Aktueller Stand und Untersuchung rechtlicher Aspekte, p.43-44.

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lanes. Of course, these regulations also apply to vehicles equipped with automated driving functions. As the operation of the direction indicators is neither regulated in Regulation No. 6 nor in Regulation No. 48, the activation and deactivation during an overtaking manoeuvre with an automated driving function, for example, cannot be defined exactly.[73][74]

In the context of autonomous driving, a closer look at the definition of "Direction indicator" in paragraph 1.1, which is defined as

> *"a device mounted on a motor vehicle or trailer which, when operated by the driver, signals the latter's intention to change the direction in which the vehicle is proceeding..."*(cited from original source:[75])

Since the currently applicable version of Regulation No. 6, revision 7, explicitly assumes a "driver" who operates the lever, it is not entirely clear whether the regulation is satisfied here in the case of automatic operation. According to expert opinions, for example Lennart S. Lutz in Automated Vehicles in the EU: Proposals to Amend the Type Approval Framework and Regulation of Driver Conduct, it does not prevent the driver from operating the lever manually, even if a system can do this automatically. The legal requirement is therefore met.[76]

4.1.2.2 Development and test operation

To address the legal situation for the development of vehicles, it should be noted that there is an exemption for specific vehicles in this particular situation. This means that this special case is handled by the UNECE working group in a special way and that vehicles which do not comply with the regulations applicable in Austria, i.e. some of whose components do not contain an ECE test mark, are nevertheless suitable or approved for test operation.[77]

4.1.2.3 Possible Amendments

Each of the ACSF categories in ECE Regulation 79 has different specific requirements and regulatory limits depending on the type. In the most advanced category E, it is

[73] Lutz (2016): Automated Vehicles in the EU: Proposals to Amend the Type Approval Framework and Regulation of Driver Conduct, p.2.

[74] Cacilo et al. (2015): Hochautomatisiertes Fahren auf Autobahnen - Industriepolitische Schlussfolgerungen, p.116.

[75] UN/ECE (2020): UN Regulation No. 6 Revision 7, p.4.

[76] Lutz (2016): Automated Vehicles in the EU: Proposals to Amend the Type Approval Framework and Regulation of Driver Conduct, p.2.

[77] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.58.

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already possible to perform the driver-initiated function, for example changing lanes, autonomously for a certain time without being influenced by the driver.[78]

One possible change that is already under discussion is the adjustment of the maximum operating speed to 130km/h, which would allow the use of the automated steering functions in everyday situations. For SAE level 3 automated driving functions, the driver would have to be prepared to intervene if the system is outside the control limits or if there is a defect. A warning time of four seconds is recommended by experts in several places in the literature.[79][80][81]

Further recommendations, especially when it comes to a possible approval of level 4 functions, is a detailed definition of the necessary sensors and their areas of application and control limits. This is necessary, for example, in order to prescribe which distance must be able to be detected by a sensor. In addition, various tests regarding extreme situations will be necessary before approval in order to ensure a certain degree of reliability. For good traceability after an accident, experts suggest a mandatory data storage system, which could provide valuable data in such a case. [82]

4.1.2.4 Conclusion

Every vehicle that is to be registered either in the EU or in a country that has ratified the ECE regulations must comply in all respects with the applicable ECE regulations. This of course also applies to automated vehicles and their driving functions. It is therefore of great importance that all technical components and equipment on the vehicle are compliant with the regulations. Due to their position in the legal structure within the EU, the UN/ECE regulations are one of the most important legal frameworks when it comes to the introduction of automated vehicles. The most important regulations just considered can be summarised as follows.

The ECE regulations considered were number 6 (Direction indicators), 13H (Braking of passenger cars), 48 (Installation of lighting and light-signalling devices) and 79 (Steering equipment). On the basis of the examination of the individual regulatory texts, it became apparent that although regulations 6 and 48 describe a "driver" in paragraph 1.1, according to experts, the absence of this driver is not in contradiction with the legal text.[83] In ECE Regulation 13H, which refers to the vehicle's braking system, emergency braking functions are explicitly defined as "automatically commanded braking" in paragraph 2.20.[84] The regulation in 5.2.1, which prescribes 3 independent braking

[78] Lutz (2016): Automated Vehicles in the EU: Proposals to Amend the Type Approval Framework and Regulation of Driver Conduct, p.2-3.

[79] Dittmers (2019): Autonomous Driving - Overview of the Current Legal Framework, p.8.

[80] von Ungern-Sternberg (2018): Völker- und europarechtliche Implikationen autonomen Fahrens (2nd Edition), p.6.

[81] Lutz (2016): Automated Vehicles in the EU: Proposals to Amend the Type Approval Framework and Regulation of Driver Conduct, p.3.

[82] Ibid.

[83] Ibid., p.2.

[84] Fußbroich (2019): Die völkerrechtlichen Vorgaben für das automatisierte Fahren, p.11.

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systems, is also not in conflict with automated driving functions, in which automated braking or emergency braking functions in particular can be carried out by redundant electric motors.[85][86]

UN/ECE Regulation 79, which defines the steering of the vehicle, is often cited in the literature as one of the key issues when it comes to the introduction of autonomous driving.[87] As mentioned above, the regulation has been adapted through several revisions and in the current version explicitly defines "autonomous steering systems" in paragraph 2.3.3. Here, the steering systems are divided into two classes, parking assistants (2.3.4.1.1) on the one hand and lane change assistants (2.3.4.1.2-6) on the other.[88] According to the regulation, it is permissible if steering systems, which fall into one of the categories, can be interrupted at any time by the driver's intervention, as long as they exist alongside the main steering system. However, the primary responsibility remains with the driver of the vehicle at all times.[89][90] Furthermore, ACSFs may be used at speeds not exceeding 10km/h (+20%).[91][92] Since the driver must be ready to take over the driving task again at any time, according to the current law only a level of automation of SAE Level 3 can be realised here (see 2.2.1).[93][94]

Due to these restrictions, ECE Regulation No. 79 is seen as a primary obstacle to the introduction and type approval of automated vehicles and needs to be revised to allow for higher degrees of autonomy.[95][96][97]

4.2 Regulations and directives within the EU

If the legal structure within the EU is taken to a level further down in the hierarchy, we come to European Union law and its regulations and directives within the European Union. Transport policy in particular was an important issue when the founding treaties came into force and is still essential today, especially for achieving the goals of the domestic market.

[85] UN/ECE (2018a): UN Regulation No. 13-H Revision 4, p.12.
[86] Lutz/Tang/Lienkamp (2012): Analyse der rechtlichen Situation von teleoperierten und autonomen Fahrzeugen, p.3-4.
[87] Lutz (2016): Automated Vehicles in the EU: Proposals to Amend the Type Approval Framework and Regulation of Driver Conduct, p.2.
[88] UN/ECE (2018b): UN Regulation No. 79 Revision 4, p.6.
[89] Dittmers (2019): Autonomous Driving - Overview of the Current Legal Framework, p.7-8.
[90] Lutz (2016): Automated Vehicles in the EU: Proposals to Amend the Type Approval Framework and Regulation of Driver Conduct, p.2.
[91] von Ungern-Sternberg (2018): Völker- und europarechtliche Implikationen autonomen Fahrens (2nd Edition), p.4.
[92] Watzenig (2018): Faktencheck Automatisiertes Fahren in Österreich, p.18.
[93] Dittmers (2019): Autonomous Driving - Overview of the Current Legal Framework, p.7-8.
[94] Fußbroich (2019): Die völkerrechtlichen Vorgaben für das automatisierte Fahren, p.11.
[95] Böning/Canny (2021): Freiburger Informationspapiere zum Völkerrecht und Öffentlichen Recht, Bd. 1,, p.8.
[96] Lutz (2016): Automated Vehicles in the EU: Proposals to Amend the Type Approval Framework and Regulation of Driver Conduct, p.2.
[97] Dittmers (2019): Autonomous Driving - Overview of the Current Legal Framework, p.8.

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The promotion of fundamental rights such as the free movement of persons, the freedom to provide services and the free movement of goods are complemented in the transport sector by road safety, environmental protection and sustainability. The regulations and directives in force at the EU level must be implemented by the member states in national law and no longer enable the member states to issue their own regulations on the issues covered by the EU regulations. The purpose of this is to achieve EU-wide harmonisation of transport policy, which in the context of the domestic market is not only an enabling instrument, but itself an important element of that market and promotes the general objective of reducing road accident fatalities. [98]

Although there are of course a large number of regulations and legal acts that have an impact on transport policy and the transport sector, it is not possible within the scope of this thesis to discuss all points of contact.[99] Instead, the goal is to provide a good overview of the current situation and the main problem areas.

In the following section, the most important regulations and directives for the context of automated driving are examined and discussed. The relevant topics are determined by technical regulations for vehicles, such as Regulation VO (EU) 2018/858, as well as the General Safety Regulation VO (EU) 2019/2144, and data protection-relevant topics, which are dealt with in the GDPR(General Data Protection Regulation) as well as guidelines of the EDPB (European Data Protection Board)[100][101].

4.2.1 Regulation on the approval of motor vehicles, VO (EU) 2018/858

EU Regulation 2018/858 as amended on 30 May 2018 deals with the approval of motor vehicles and their components (systems, parts or technical units). The date of effect was 1 September 2020, thus amending Regulation (EC) 715/2007 and (EC) 595/2009, and repealing Directive 2007/46/EC. This creates an EU-wide harmonised approval procedure that defines the technical requirements for vehicles of different types (cars, trucks or buses), systems or components.[102]

A regular new registration or type approval of a vehicle therefore requires that the requirements specified in Regulation (EU) 2018/858, as well as specified ECE regulations or individual legal acts, are met. The connection to the ECE regulations described in Chapter 4.1.2 can be seen in Annex II and is defined in Article 5. [103][104]

[98] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.62-63.

[99] Ibid., p.63.

[100] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.4-10.

[101] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.62-63.

[102] Ibid., p.64.

[103] Ibid.

[104] European Parliament, Council of the European Union (2018b): Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018, p.15.

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4.2.1.1 Development and test operation

When it comes to the creation of testing grounds, the situation becomes particularly interesting, because Article 39 of Regulation (EU) 2018/858 explicitly provides an exemption for new concepts and techniques in the context of type approval. This exception makes it possible for states to approve vehicles for test purposes, even if they do not comply with the legal acts listed in Annex II. However, this requires permission from the Commission, which can also impose restrictions on validity. According to Article 2 para. 4 of Regulation (EU) 2018/858, individual approvals are not mandatory for prototypes that have a specific purpose, for example, the performance of a specified test. Test operation in road traffic is possible under the responsibility of the manufacturer.[105]

However, Article 45 of Regulation (EU) 2018/858 defines the regulations for national individual vehicle approvals, which allow the member states to make exceptions to technical requirements if alternative requirements are specified.[106]

4.2.1.2 Conclusion

To summarise, it can be stated that Regulation (EU) 2018/858 defines the technical framework for the approval of vehicles of different types and refers to other EU-Regulations and ECE/UN regulations.[107] In order to drive technical progress, it is possible to approve vehicles intended for test purposes and using technologies that do not comply with the directive, either by type approval with the permission of the Commission, or by individual approval with the provision of alternative technical requirements.[108]

4.2.2 General Safety Regulation (EU) 2019/2144

Regulation (EU) 2019/2144, in addition to the already mentioned Regulation (EU) 2018/858, is particularly important for automated vehicles. According to its official title, Regulation (EU) 2019/2144 provides for:

> *"Type-approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, with regard to their general safety and the protection of the occupants and vulnerable road users."*(cited from original source:[109])

[105] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.65-66.

[106] European Parliament, Council of the European Union (2018b): Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018, p.41.

[107] Ibid., p.87-97.

[108] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.81-82.

[109] European Parliament, Council of the European Union (2019b): Regulation (EU) 2019/2144 of the European Parliament and of the Council of 27 November 2019.

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The "General Safety" Regulation was drafted on the 27th of November 2019 and, in its current version, amends Regulation (EU) 2018/858 in various aspects and repeals 19 regulations, such as Regulation (EU) 661/2009 or Regulation (EU) 78/2009.[110] Above all, it aims to promote general safety by increasing the safety requirements for vehicles within the EU in order to take special account of vulnerable road users such as cyclists or pedestrians. The power to adopt delegated acts of Regulation (EU) 2019/2144, or General Safety Regulation, has been in force since 5 January 2020, according to Article 12(2). A comprehensive entry into force and commencement date is specified in Article 19 as the 6th of July 2022.[111][112]

The regulation provides for a number of safety-related innovations to be introduced over time. The introduction of these is specified in a fixed timetable and is planned up to the year 2029.[113] The most important elements for automated driving are discussed below.

First of all, it can be stated that this regulation is formulated in a significantly more modern way than previous legal texts, some of which have been revised frequently (see Vienna Convention on Road Traffic of 1968). In the definition of terms, Article 3(21) clearly defines Automated Vehicles as

> *"a motor vehicle designed and constructed to travel autonomously for specified periods of time without continuous supervision by a driver, but where driver intervention is still expected or required"*(cited from original source:[114])

as well as fully automated driving or vehicles, which are thus defined under Article 3(22) as

> *"a motor vehicle designed and constructed to travel autonomously without supervision by a driver."*(cited from original source:[115])

In addition to conventional requirements that affect the registration of all vehicles, there are special requirements for automated vehicles, among others. The aforementioned phased introduction of innovations provides in Article 7(2) for a sophisticated emergency braking assistance system that, in the first phase, is able to detect obstacles and moving vehicles in front of the car (Art. 7(2)(a)) and only in the second phase a system that can also detect moving obstacles such as pedestrians and cyclists (Art. 7(2)(b)).[116][117]

[110] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.6.
[111] Ibid., p.5-6.
[112] European Parliament, Council of the European Union (2019a): Regulation (EU) 2019/2144 Document Summary.
[113] bmvi.de (2021): New vehicle safety systems.
[114] European Parliament, Council of the European Union (2019b): Regulation (EU) 2019/2144 of the European Parliament and of the Council of 27 November 2019.
[115] Ibid.
[116] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.9.
[117] European Parliament, Council of the European Union (2019b): Regulation (EU) 2019/2144 of the European Parliament and of the Council of 27 November 2019.

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Under Article 11, the special requirements are defined in more detail and include, in addition to the conventional requirements for vehicles, the following technical specifications listed from a to f:[118]

a) systems to replace the driver's control of the vehicle, including signalling, steering, accelerating and braking;

b) systems to provide the vehicle with real-time information on the state of the vehicle and the surrounding area;

c) driver availability monitoring systems;

d) event data recorders for automated vehicles;

e) harmonised format for the exchange of data for instance for multi-brand vehicle platooning;

f) systems to provide safety information to other road users.

original source from VO (EU) 2019/2144, Article 11.

These complement the mandatory advanced vehicle systems listed in Article 6(1), which consist of (a) intelligent speed assistance, (b) alcohol interlock installation facilitation, (c) driver drowsiness and attention warning, (d) advanced driver distraction warning, (e) emergency stop signal, (f) reversing detection and (g) event data recorder.[119]

Of particular interest here is the event-related data recorder, which is described in more detail in Article 6(4). Here, for example, data generated before, during or after an accident in an automated vehicle must be recorded in order to serve road safety when analysing this data.[120] Article 6(4)(a) describes the data to be collected as

> *"...vehicle's speed, braking, position and tilt of the vehicle on the road, the state and rate of activation of all its safety systems, 112-based eCall in-vehicle system, brake activation and relevant input parameters of the on-board active safety and accident avoidance systems..."*(cited from original source:[121])

The data collected in this way is of course subject to strict data protection guidelines and must be anonymised in accordance with Article 6(4)(c), as well as making it impossible

[118] European Parliament, Council of the European Union (2019b): Regulation (EU) 2019/2144 of the European Parliament and of the Council of 27 November 2019.
[119] Ibid.
[120] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.8.
[121] European Parliament, Council of the European Union (2019b): Regulation (EU) 2019/2144 of the European Parliament and of the Council of 27 November 2019.

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to identify vehicles and vehicle owners in accordance with Article 6(4)(d).[122][123] The introduction of such data recorders is supposed to take place in the 2nd phase of implementation, i.e. by the 6th of July 2022 at the latest.[124][125][126]

4.2.2.1 Development and test operation

In Part 2 of a draft of the European Commission regarding the implementation of the Regulation (EU) 2019/2144, the conditions and regulations relating to tests are defined. According to Paragraph 1, tests

> *"...shall confirm the functionality of the system and the safety concept of the manufacturer as described in part I of this Annex as well as the minimum performance requirements described in Annex II."*(cited from original source:[127])

The general conditions for testing on a test site are described relatively extensively, various scenarios are defined in paragraph 8. However, an explicit requirement for limited testing under real conditions is still missing. This fact is also criticized in an article by Digitaleurope which refers to a draft of the European Commission. Tests under real conditions are important in order to verify parameters such as emissions or the correct functioning of various systems in real operation within their intended ODDs.[128][129]

4.2.2.2 Conclusion and remarks

In summary, the introduction of Regulation (EU) 2019/2144 will have a positive impact on the realisation of automated driving. With the general goal of increasing road safety, the General Safety Regulation defines the framework conditions for this in order to minimise road accidents, but also to create legal certainty. The focus here is definitely on safety, but the creation of a domestic market is also an objective that is being pursued in the EU strategy for the mobility of the future.[130]

[122] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.8.

[123] European Parliament, Council of the European Union (2019b): Regulation (EU) 2019/2144 of the European Parliament and of the Council of 27 November 2019.

[124] European Parliament, Council of the European Union (2021): Application dates of the safety measures under the General Vehicle Safety Regulation (EU) 2019/2144 (VRU-Proxi-17-17).

[125] German Road Safety Council (2020): Statement by the German Road Safety Council DVR on EDR and DSSAD, p.6.

[126] bmvi.de (2021): New vehicle safety systems.

[127] European Commission (2021a): Draft of ANNEXES to the COMMISSION IMPLEMENTING REGULATION (EU) 2019/2144.

[128] DIGITALEUROPE (2021): DIGITALEUROPE's comments on the draft Implementing Act on ADS, p.3.

[129] European Commission (2021a): Draft of ANNEXES to the COMMISSION IMPLEMENTING REGULATION (EU) 2019/2144, p.10.

[130] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.4-5.

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Regulation VO (EU) 2019/2144 contributes to achieving the goal of the future version "Vision Zero", which aims to reduce the number of accidental deaths within the EU to close to zero by 2050.[131] As the transposition of the Directive is not due until the 6th of July 2022, it is not yet possible to form an exact conclusion on the quality of the transpositions of the individual member states. However, on the basis of drafts on the implementation of the regulation published by the European Commission, conclusions can be drawn about how individual countries are proceeding with the transposition into national law. The implementation of the regulation, which must be enforced in the individual member states, is being closely monitored by experts. A team from "Digitaleurope", which represents the digital technology industry in Europe, made the following comments on a draft of the European Commission regarding the implementation of the regulation.[132][133]

First of all, various deficiencies are identified with regard to some definitions. According to Digitaleurope, basic definitions of key concepts such as DDT, ADS, supervision, intervention and monitoring of the DDT or the concept of risks and mitigation are missing. Reference is made to the definition by SAE described in Chapter 2.2.1, which is intended to provide an up-to-date definition that provides a more detailed link between the standards and the regulations.[134]

In the further course of the analysis by Digitaleurope, comments are made on the topic of human supervision and vehicle behaviour, as well as fail safe strategy and HMI requirements.[135] These are based on a draft, which is subject to revision up to the date of mandatory implementation.

Human supervision: It is suggested that remote supervision by a human is only necessary in situations where the automated vehicle is driving without a driver.[136]

Expected vehicle behaviour: In Annex II, point 4, the draft defines the "Expected vehicle traffic behaviour in emergency conditions", which specifies a fixed TTC (Time-to-Collision)0. This is defined as

> *"Time-to-collision at the moment of the cut-in of the vehicle or cyclist by more than 30 cm in the lane of the vehicle equipped with an ADS"* (cited from original source:[137])

[131] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.5.
[132] European Commission (2021b): Draft of COMMISSION IMPLEMENTING REGULATION (EU) 2019/2144, laying down rules for the application of Regulation (EU) 2019/2144 of the European Parliament and of the Council as regards uniform procedures and technical specifications for the type-approval of motor vehicles with regard to their automated driving system (ADS).
[133] DIGITALEUROPE (2021): DIGITALEUROPE's comments on the draft Implementing Act on ADS.
[134] Ibid., p.1.
[135] Ibid., p.1-2.
[136] Ibid., p.2.
[137] European Commission (2021a): Draft of ANNEXES to the COMMISSION IMPLEMENTING REGULATION (EU) 2019/2144.

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and is calculated with the following formula.

$$TTC \geq \frac{v_{rel}}{2a} + \frac{1}{2}\tau + \tau_{reaction}$$

The individual variables are represented by "v_{rel}" (relative speed in $\frac{m}{s}$), "a" (deceleration in $\frac{m}{s^2}$), "τ" (time until deceleration occurs in s) and "$\tau_{reaction}$" (reaction time in s).

Digitaleurope is expressing criticism here, as a fixed TTC would be excessive in some scenarios and insufficient in others. A dynamic TTC that includes the dynamic variables of speed, reaction time and performance (braking) of the vehicles would be appropriate at this point.[138]

Fail safe strategy: Annex II, point 5 deals with the Fail Safe Strategy. In the draft version, a subsection defines that the ADS must have certain capabilities to recognise the limits of the system (ODD boundaries) and therefore:

> *"...shall perform a minimum risk manoeuvre in case of the ODD boundaries are reached..."*(cited from original source:[139])

This would imply that regardless of the risk potential, an MRM [140] is always performed. Digitaleurope raises concerns on this point and offers the following suggestions for improvement in the interest of the customer experience.

It is recommended to divide the exits of ODD [141] into three different groups. For planned ODD exits, it is suggested that the system should be requested to take over the driving task, and only after this request has not been met, the vehicle should be brought to a safe stop. Unplanned ODD exits are further divided into critical and non-critical events. In the case of non-critical exits of the ODD, such as temporary losses of perception parameters, it is suggested that the system suppresses the takeover request for a short time and only issues it when a return to the ODD is not possible. Unscheduled and critical exits from the ODD should continue to be subject to an MRM immediately as planned (after an appropriate time for the driver to take over). Critical incidents include, for example, sensor failure.[142]

[138] DIGITALEUROPE (2021): DIGITALEUROPE's comments on the draft Implementing Act on ADS, p.1-2.
[139] European Commission (2021a): Draft of ANNEXES to the COMMISSION IMPLEMENTING REGULATION (EU) 2019/2144.
[140] Minimal Risk Maneuver
[141] Operational Design Domain
[142] DIGITALEUROPE (2021): DIGITALEUROPE's comments on the draft Implementing Act on ADS, p.2.

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HMI requirements: The explanations in Annex II, point 6, which define the requirements for HMI [143], are still relatively moderate in the draft under discussion. In this regard, Digitaleurope offers a supplement on the topic of emergency button, as the draft only includes the requirement for the presence of this kind of button.[144] Measures are recommended to prevent accidental activation of the emergency button as well as the ability that the emergency button brings the vehicle to a standstill immediately and without further action by the vehicle occupants.[145]

4.2.3 General Data Protection Regulation (EU) 2016/679

An automated vehicle or automated driving function collects, processes and stores a large amount of data during operation, which is essential for the correct functioning of these systems. Since a large amount of data is potentially highly personal and requires protection, the General Data Protection Regulation (EU) 2016/679, which entered into force on 25th of May 2018, focuses on the protection of individuals with regard to the processing of personal data and the free movement of data.[146]

In Article 5, the GDPR defines various principles under which the non-automated, partially automated and fully automated processing of personal data is to be carried out. The principles basically aim at a **responsible handling of data**, which requires **integrity and confidentiality**, as well as **processing in good faith**. **Transparency and accountability**, as well as **accuracy and purpose limitation** are also important. Furthermore, care is taken to enforce **data minimisation and storage limitation**.[147]

It should be noted that autonomous or automated driving is not specifically addressed by the GDPR; the aim is to standardise regulations regarding the protection of personal data in the European Union, especially with a focus on public authorities and private corporations. Nevertheless, the regulations of the GDPR also extend to the focus of this thesis, automated driving.[148]

The data generated by automated driving can often be used to identify a specific driving profile, a vehicle or even a driver, and therefore this data must be protected. According to Article 14 the individuals affected must be able to obtain information about their data, as well as to demand that the data be corrected or deleted. The responsibility for the data lies with the person or company that determines how and what data is stored

[143] Human Machine Interface

[144] European Commission (2021a): Draft of ANNEXES to the COMMISSION IMPLEMENTING REGULATION (EU) 2019/2144, p.10.

[145] DIGITALEUROPE (2021): DIGITALEUROPE's comments on the draft Implementing Act on ADS, p.2.

[146] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.77.

[147] Ibid., p.78.

[148] Dittmers (2019): Autonomous Driving - Overview of the Current Legal Framework, p.11.

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or processed. In the context of automated driving, this role is usually assigned to the vehicle manufacturer.[149][150][151]

In order to preserve the anonymity of the individuals concerned, the operator is obliged under Article 25 para. 1 to introduce appropriate measures which are intended to protect the data on the one hand and to make the data anonymous on the other. The so-called data protection by design and by default is intended to ensure that data protection is taken into account even during the development and programming of the applications.[152]

Just as important as para. 1 is Article 25 para. 2, which states that

> *"the controller shall implement appropriate technical and organisational measures for ensuring that, by default, only personal data which are necessary for each specific purpose of the processing are processed..."*(cited from original source:[153])

This means that, taking into account the aforementioned principle of data minimisation and storage limitation, only as much data as is strictly necessary may be collected and processed.[154][155]

Article 40 defines the rules of conduct, which according to Dittmers in "Autonomous Driving - Overview of the Current Legal Framework" are also an important aspect of automated driving. It is important to acknowledge that this paragraph offers the possibility of implementing a certain degree of self-regulation with the help of industry-specific best practice guides in order to close any possible gaps in the regulations.[156]

4.2.3.1 Development and test operation

With regard to the authorisation for test operations and research purposes, it can be noted that the GDPR leaves certain leeway in the regulation of data processing and that the national legislature can take into account "*safeguards and derogations relating to processing for archiving purposes in the public interest, scientific or historical research purposes or statistical purposes*" for legitimate purposes under Article 89(2) of the

[149] Dittmers (2019): Autonomous Driving - Overview of the Current Legal Framework, p.11.

[150] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.78.

[151] Kunnert (2017): „Autonomes Fahren“ aus datenschutzrechtlicher Sicht, in Eisenberger/Lachmayer/Eisenberger (Hrsg), Autonomes Fahren und Recht (2017), 169, p.187-188.

[152] Böning/Canny (2021): Freiburger Informationspapiere zum Völkerrecht und Öffentlichen Recht, Bd. 1,, p.21.

[153] European Parliament, Council of the European Union (2018a): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016.

[154] Böning/Canny (2021): Freiburger Informationspapiere zum Völkerrecht und Öffentlichen Recht, Bd. 1,, p.21.

[155] Dittmers (2019): Autonomous Driving - Overview of the Current Legal Framework, p.11-12.

[156] Ibid., p.12.

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GDPR.[157] Furthermore, Article 5 (1) (b) and (e) already refers to Article 89 and at the same time defines the exception for the collection of personal data for:

> *"...specified, explicit and legitimate purposes..."*(cited from original source:[158])

The processing of this data is furthermore only:

> *"... for archiving purposes in the public interest, scientific or historical research purposes or statistical purposes..."*(cited from original source:[159])

Article 9 defines the processing of personal data of special categories. Article 9(1) prohibits the processing of highly personal data, such as political orientation, religious beliefs or other biometric and genetic data that could uniquely identify a natural person. Paragraph 2 provides a number of exceptions under which these data may be processed and Article 9(2)(j) provides an exception for scientific purposes, such as testing or research.[160][161]

As already mentioned, the data subjects must be informed about their data according to Article 14, and here too there are various exceptions in favour of science. For example, Article 14 para. 5 lit b allows an exception if

> *"the provision of such information proves impossible or would involve a disproportionate effort..."*(cited from original source:[162])

In this case, however, the controller has the obligation to take appropriate measures to protect the data subjects' rights.[163][164]

4.2.3.2 Possible Risks

The risks to data protection in the context of automated, connected driving are many and complex and in some cases difficult to assess. In Kunnert's "Autonomes Fahren aus datenschutzrechtlicher Sicht" (Autonomous Driving from a Data Protection Perspective),

[157] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.78.

[158] European Parliament, Council of the European Union (2018a): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016.

[159] Ibid.

[160] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.78.

[161] European Parliament, Council of the European Union (2018a): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016, p.38.

[162] Ibid.

[163] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.78.

[164] European Parliament, Council of the European Union (2018a): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016, p.41-42.

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various risks regarding privacy are addressed, which mainly stem from the use of localisation data, data from various sensors for the operation of the vehicle and its systems or the driver himself, accident data storage or data from V2V or V2I communication.[165]

Localisation Data: Especially the storage and processing of localisation data are mentioned again and again in connection with data protection and play a central role when it comes to pointing out risks in connection with connected vehicles. Due to the large amount of data, it would be easy to create user profiles of a driver, which would sometimes allow conclusions to be drawn about his or her place of residence, identity and other private matters. This data is highly sensitive and requires special protection, as it is naturally of interest to various bodies, be it insurance companies, for direct advertising purposes, the police and law enforcement agencies, or sometimes even malicious intent. These risks are dealt with in Chapter 4.2.4.1 by the EDPB, which also makes various recommendations.[166][167]

Sensor Data: Further risks would exist not only for the vehicle occupants, but also for persons in the immediate vicinity of the vehicle, for example as a result of camera-based recording of the environment. Especially if these data were stored in the vehicle or cloud-based. In this case, the legitimate interest of authorities or insurance companies in the context of preserving evidence conflicts with the interest of other road users in protecting their privacy. In combination with location data and time of day, one could speak of sensitive data in the same way as in the aforementioned situation with user profiles. The problem is possibly even more serious than one might assume, insofar as one can assume that many passers-by are not even aware of a recording and the lack of transparency in this context can have a negative impact on the exercise of fundamental rights.[168]

Driver Monitoring: Depending on the level of autonomy (see SAE J3016, Chapter 2.2.1), readiness for "fallback performance" from the driver is either assumed or not. In lower levels of autonomy, the driver is still expected to take over the driving task again after a certain reaction period, if the circumstances so require. When it comes to monitoring the driver's ability to take over, the risk of monitoring comes into play. According to Kunnert, a distinction is made here as to whether only short-term storage takes place, which would be less questionable in terms of data protection law, or long-term storage, for example to enable pattern recognition. In this case, further use of this data,

[165]Kunnert (2017): „Autonomes Fahren“ aus datenschutzrechtlicher Sicht, in Eisenberger/Lachmayer/Eisenberger (Hrsg), Autonomes Fahren und Recht (2017), 169, p.190-196.

[166]European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.15-16.

[167]Kunnert (2017): „Autonomes Fahren“ aus datenschutzrechtlicher Sicht, in Eisenberger/Lachmayer/Eisenberger (Hrsg), Autonomes Fahren und Recht (2017), 169, p.190-192.

[168]Ibid., p.192-193.

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for example to clarify the causes of accidents, fitness for driving, etc., would lead to greater encroachment on the fundamental data protection rights of the respective driver/user.[169]

Accident Data Logger: The purpose of an accident data logger is to record predefined data that can be used to clarify the cause of an accident. According to Kunnert, when considering the data protection aspects, different scenarios and risk potentials arise depending on the interpretation of the parameters. Depending on the extent and type of data stored on driving dynamics, occupants, the environment or diagnostics, and for how long the data is stored, as well as the type of storage, whether in the vehicle or in an external cloud storage, the risk potential must be considered and evaluated in a differentiated manner. The EDPB also deals with this question in the next chapter 4.2.4.1, especially when it comes to the storage of "offence-related data".[170][171]

Communication; V2V, V2I: Finally, we will look at the data used in fully automated driving, which is obtained during communication between vehicles, infrastructure and backend (V2V, V2I, V2B). As this data is used to execute control commands at higher levels of autonomy, it is of increased security relevance, as this would provide an opportunity for malicious manipulation. Kunnert is particularly concerned with the security concept of "public key infrastructure" (PKI), which currently harbours high risks due to fixed long-term certificates (LTC), unique identification of vehicles (vehicle ID) and undefined number and change intervals of temporary certificates (TC). The envisaged online exchange of keys, which TC was requested with which LTC, also in combination with an envisaged pseudonymisation, calls into question the usefulness for identifying monitoring. In the following chapter, the EDPB also deals with the risks that are raised by possible applications that process data in order to enable remote control or remote diagnosis.[172]

4.2.3.3 Conclusion and Recommendations

Since large amounts of data are generated and processed during the operation of automated and networked vehicles, great consideration must be given to data protection. If the aforementioned principles defined by the GDPR are observed during development and operation, there is no major problem with the introduction of such systems.[173][174] The

[169] Kunnert (2017): „Autonomes Fahren“ aus datenschutzrechtlicher Sicht, in Eisenberger/Lachmayer/Eisenberger (Hrsg), Autonomes Fahren und Recht (2017), 169, p.193-194.

[170] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.17.

[171] Kunnert (2017): „Autonomes Fahren“ aus datenschutzrechtlicher Sicht, in Eisenberger/Lachmayer/Eisenberger (Hrsg), Autonomes Fahren und Recht (2017), 169, p.194-195.

[172] Ibid., p.195-196.

[173] Böning/Canny (2021): Freiburger Informationspapiere zum Völkerrecht und Öffentlichen Recht, Bd. 1,, p.21.

[174] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.77.

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GDPR is not an obstacle when it comes to the development and test operation of automated vehicles, or the processing of personal data during their operation. Under certain conditions, there are exemptions for specific scientific test cases.[175]

Nevertheless, it is important to find solutions to certain obstacles in order to minimize the mentioned risks as much as possible. Possible solutions according to Kunnert are as follows:

- Default setting when recording location data is not set to "Record" (exception: Accident Data Logger)
- Make licence plates and faces of foreign road users unrecognisable already during recording with video-based environmental sensor technology or do not record/hide them at all.
- Monitoring of the driver and his/her condition only without storage and with minimal/necessary data
- Accident data loggers should only record a necessary minimum of data, as well as overwrite themselves after a short time (ring memory). Digital signing as well as limited access on a technical level (certified experts).
- Storage in the accident data memory only when the ADS is active and no storage outside the vehicle.
- In order not to question the authenticity and authenticity of traffic messages, no connection of LTC and specific identifiers (vehicle ID, number plate, etc.) may be established.
- TCs in V2V and V2I communication must be changed frequently in a definable way and the assignment to vehicles determined by means of LTC must be kept short.
- Introduction of blocking lists and prohibition of other storage of TCs.
- Definition of usage rules: Disclosure of data only in anonymised form, prohibition of storage in vehicles, fastest possible deletion of data, limited duration of use of LTCs, etc.
- Consent as opt-in rather than opt-out; GDPR Article 4(11) requires active confirmation of will.
- Direct V2V communication, e.g. via WLAN, is preferable to communication via a traffic centre.

original source from Kunnert (2017): „Autonomes Fahren“ aus datenschutzrechtlicher Sicht, in Eisenberger/Lachmayer/Eisenberger (Hrsg), Autonomes Fahren und Recht (2017), 169, p.200-204, own representation.

[175] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.78.

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4.2.4 Guidlines of the European Data Protection Board (EDPB)

The European Data Protection Board (EDPB) has the mandate to identify and issue guidelines and recommendations in relation to the application of the GDPR. On the 28th of January 2020, guidelines were first published that focus on the processing of personal data in the context of connected cars and mobility-related applications. On the 9th of March 2021, these were revised after public consultation. In the development of the guidelines, this independent body also refers to the Directive on Privacy and Electronic Communications (ePrivacy Directive) in addition to the GDPR.[176]

In paragraph 11 EDPB, particular attention is paid to Article 5(3) of the ePrivacy Directive, as unlike Article 6 or Article 9 of the ePrivacy Directive, it does not only address providers of public communications networks or electronic communications services, but specifically

> *"... does not only apply to electronic communication services but also to every entity that places on or reads information from a terminal equipment without regard to the nature of the data being stored or accessed"*(cited from original source:[177])

In para 12 and following, the guideline refers to the definition of "**terminal equipment**" noted in Directive 2008/63/CE, which according to Article 1 (a) 2008/63/CE refers to

> *"equipment directly or indirectly connected to the interface of a public telecommunications network to send, process or receive information..."*(cited from original source:[178])

The type of transmission technology is not decisive here. Subsequently, para 13 defines that a networked vehicle conforms to this definition of terminal equipment and therefore Article 5 (3) of the ePrivacy Directive can and must be applied.[179][180]

The first section of the guidelines also contains various definitions and comments, such as the non-professional use of connected vehicles and the processing of personal data in this context. It deals with data collected and processed in the vehicle and exchanged between entities such as the vehicle and other means of communication such as a smartphone. In paragraphs 3 and 29 it is stated that the data dealt with are personal data. Paragraph 29 of the EDPB reads:

[176] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.10.
[177] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021.
[178] Ibid.
[179] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.10.
[180] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.7.

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> *"Much of the data that is generated by a connected vehicle relate to a natural person that is identified or identifiable and thus constitute personal data..."*(cited from original source:[181])

It should be mentioned that the EDPB also lists risks with regard to connected vehicles, which are defined in paragraph 46 to 60. The risks regarding data protection and privacy of data include "Security of personal data", "Further processing of personal data", "Excessive data collection", "Lack of control and information asymmetry" and "Quality of the user's consent" and described briefly in the following section.[182][183]

4.2.4.1 Possible Risks

The risks identified in the EDPB guidelines provide important guidance on the potential barriers to the development of automated driving. In the following, the points already mentioned are highlighted and discussed.

Security of personal data: The Article 29 Working Party has already criticised the dangers with regard to data security and control in Internet of Things systems, but these dangers are even more serious in connected vehicles. Due to technical progress and the multitude of functions and applications offered in a connected vehicle, many interfaces and services such as Wi-Fi, USB and RFID are used, which opens up a much larger attack surface and the potential vulnerability is even higher. Especially in view of the fact that vehicles usually involve people such as passengers or pedestrians, this makes the situation of a security breach particularly precarious. Paragraph 60 also points out the dangers of storing data, some of which is stored in the vehicle itself or externally in the case of cloud computing applications. Unauthorised access to the data would represent a high security risk and a violation of data protection. Unauthorised access could occur especially during maintenance work, which may require access to system levels of the vehicle.[184]

Further processing of personal data: The collection and processing of data always requires the consent of the data subject; in para 53 of the EDPB Guidelines, reference is made to Article 5 para 3 of the ePrivacy Regulation. If collected data is now to be processed further, further consent must be obtained in accordance with Article 6 of the GDPR. Alternatively, the data controller could also be processed under Article 23 para. 1 of the GDPR if it can demonstrate that the processing of these data protects the objectives defined in lit a to lit j. According to the objectives of the ePrivacy Regulation,

[181] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021.

[182] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.11.

[183] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.13-15.

[184] Ibid., p.13, 15.

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it is necessary to inform data subjects of any further processing of data relating to them and to give them the opportunity to opt out. The EDPB now points out that according to Article 6 para. 4 of the GDPR, it would be possible to carry out further processing on the basis of a compatibility test, but this would undermine the principles of the consent requirements.[185][186]

This aspect becomes particularly interesting when one looks at the examples given by the EDPB. In addition to the transfer of telemetry data, for example to car insurance companies, which can use this data to create driver profiles in order to personalise insurance policies, the focus is also on further processing by law enforcement. The processing of personal data relating to criminal convictions and offences is defined in Article 10 of the GDPR and would include, for example, the processing of speed and location data for the purpose of prosecuting speeding offences. If specific conditions are met, manufacturers could provide law enforcement with these specific data, but the mere purpose of collecting data only for fulfilling requests made by law enforcement does not meet the requirement of "*specified, explicit and legitimate purposes*" under Article 5 para 1 lit b GDPR.[187][188]

To the extent that law enforcement authorities are recognised as third parties under Article 4(10) of the GDPR and are authorised by law, the law enforcement would be

> *"...a natural or legal person, public authority, agency or body other than the data subject, controller, processor and persons who, under the direct authority of the controller or processor, are authorised to process personal data"*(cited from original source:[189])

Provided that all legal conditions in force in the Member State were fulfilled, manufacturers would be entitled to hand over the necessary data. However, the EDPB underlines that the initial consent to process data would never allow further processing afterwards and that data subjects must be informed in any case.[190]

Excessive data collection: One of the principles of the GDPR is data minimisation, which means collecting only as much data as necessary. The problem of excessive data

[185] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.14.

[186] European Parliament, Council of the European Union (2018a): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016, p.37.

[187] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.14.

[188] European Parliament, Council of the European Union (2018a): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016, p.35.

[189] Ibid.

[190] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.14.

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collection arises due to the ever-increasing number of sensors and functions within a connected, automated vehicle. Furthermore, especially with algorithms such as machine learning, a very large data pool is necessary in order to process such an algorithm efficiently.[191]

Lack of control and information asymmetry: In the course of a vehicle's life, it is sometimes used by many different people, and the same is true for connected vehicles. According to the EDPB, it becomes problematic when it comes to data protection consent. Information about the collection or use of personal data may only be disclosed to the vehicle owner, while a second owner or other person who uses the vehicle only temporarily, such as a leaser or rental car, may not have the opportunity to exercise their data protection and privacy rights in a timely manner. Many functions in a connected vehicle are activated by default or are activated automatically depending on the situation. This makes it very difficult for the driver, who may not be the owner or the one who has agreed to the data protection regulations, to keep control over his or her data.[192]

Quality of the user's consent: The quality of users' consent is an important issue, which also addresses the aforementioned lack of control over their consent. It is assumed that, taking into account the guidelines of the EDPB, data subjects freely give specific and informed consent and that they provide an unambiguous indication of the data subject's wishes. The problem that second owners or occasional drivers of the connected vehicle do not have the possibility to refuse consent should be taken into account. Operators must also be careful in the modalities from whom they obtain consent, be it the owners or the drivers of the vehicles, and must also obtain separate consent in such cases. This of course also applies to cases where already stored information is retrieved from the vehicle or new information is stored and in certain cases also concerns Article 5 para. 3 of the ePrivacy Directive. According to the EDPB Guidelines, these consents must be treated in accordance with the provisions of the GDPR.[193]

According to the GDPR, valid consent must be informed, which means that the data subject must be aware that data is being processed in the vehicle. Often this is not the case, which would mean that the consent of the individual does not provide a stable legal basis on which data processing can be carried out. This problem results in a "low-quality" consent. Finally, it should be noted that under Article 6 of the GDPR, the lawfulness of processing also implies a responsibility of the controller towards persons who are not required to give consent under the ePrivacy Directive.[194]

[191]European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.15.

[192]Ibid., p.13.

[193]Ibid.

[194]Ibid., p.14.

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4.2.4.2 Conclusion and Recommendations

In addition to the risks mentioned, the EDPB guidelines also contain recommendations on certain topics. These recommendations are primarily aimed at the vehicle manufacturers and suppliers of technical systems that act as data controllers or processors.[195]

Categorisation of Data: Special attention is paid to the categorisation of data, which means that personal data should be categorised according to their sensitivity and considered separately. For example, a distinction should be made here as to whether the data only contain technical details, such as vehicle-specific information like speed, distance travelled or data on the condition of the engine or tyres, or whether they require special attention. The EDPB has filtered out three different categories of data that warrant special attention. These are location data, biometric data or offence-related data.[196][197]

The EDPB emphasises that **location data** in particular can tell a lot about the person concerned and must therefore be treated with special care. Therefore, principles are defined regarding location data. On the one hand, it must be obvious to the person at all times that the collection of data is activated, it must be possible to deactivate the collection of location data, as well as to define a limited storage period. Furthermore, there must be precise information about the purpose for which the data is collected. The activation of the data collection should not happen automatically with the start of the vehicle, but only if absolutely necessary, and the access frequency must be adequately configured depending on the type of application.[198]

Biometric data is covered by Article 9 of the GDPR ("*Processing of special categories of personal data*"). This defines exceptions under which these particularly sensitive data may be used or processed. For example, authentication of the owner, for the provision of personal profiles or to gain access to the vehicle. The EDPB uses the following guidelines for the sensitive data that are conceivable here. First, biometric data should be stored in the vehicle in an encrypted way and the processing of this data should be done in real time without ever being stored. To ensure robust authentication, the biometric sensors used should be resistant to attacks and the number of authentication attempts should be limited.[199]

The third category mentioned by the EDPB includes **data that discloses criminal offences or other infractions**. This type of data is dealt with in Article 10 of the

[195] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.15.

[196] Ibid.

[197] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.11.

[198] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.15-16.

[199] Ibid., p.16-17.

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GDPR. The EDPB recommends using local processing of the data, as, with some exceptions, external processing of the data is prohibited. Particular care should be taken in the protection against illegitimate manipulation of data. According to Article 10 of the GDPR, this type of data can only be processed under the control of official authorities for the purpose of criminal investigation and prosecution.[200][201]

Data protection by design, Data protection by default: The next big point are the measures to enable data protection. Here, reference is made to Article 25 of the GDPR, which underlines these very principles. Minimising the collection of personal data, ensuring that data subjects are well informed and have easy access to their data, as well as providing settings that preserve privacy, should be ensured at the design stage and by default. In this context, three measures are recommended, which are detailed in the guidelines.[202][203][204]

Local processing of personal data is recommended where possible, which in the opinion of the Article 29 Working Party is preferable to cloud computing in most respects. This includes ensuring that local data is not lost through the sale of components or unauthorised access, but "by-design" gives the owner of the data some guarantee of full control over his data. Local processing of data has the advantage that the categories of sensitive data already mentioned can also be processed, and the risk in terms of cybersecurity is lower. Alternatively, the so-called "hybrid processing" is mentioned, which can be used in cases where local processing of data cannot be applied. For example, data on driving behaviour is processed by telematics service providers on behalf of insurance companies or in the vehicle itself. Thus, the insurance companies would not have access to the raw data, but only to the output. This would be in line with the principle of data minimisation.[205][206]

Although local data processing is always preferable, there may be situations in which processing of data outside the vehicle is unavoidable. In such cases, **anonymisation and pseudonymisation of the data** is of utmost importance. The methods recommended by the Article 29 Working Party in "Opinion 05/2014 on Anonymisation Techniques" can

[200] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.17.

[201] European Parliament, Council of the European Union (2018a): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016, p.39.

[202] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.18.

[203] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.11.

[204] European Parliament, Council of the European Union (2018a): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016, p.48.

[205] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.18-20.

[206] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.11.

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be used to anonymise the data. An anonymised dataset is anonymous when it is no longer possible to identify the anonymised individuals. The EDPB notes that anonymous data are not covered by the principle of data protection and that European data protection legislation does not apply. Unlike anonymised data, pseudonymised data are reversible and, unlike anonymised data, are covered by the GDPR. Pseudonymisation can be used in cases where it is not necessary for the process that the data subjects are identifiable. If pseudonymisation is reinforced by security safeguards, it can reduce the risk of misuse and thus increase the protection of personal data.[207][208]

Finally, the EDPB recommends carrying out a **data protection impact assessment** in this context and introducing this as a best practice already in the design process. This is particularly necessary for sensitive data and external processing, as there is a high risk for individuals. The data protection impact assessment, which is defined in the GDPR under Articles 35 and 36, identifies and mitigates risks and helps to save the rights of individuals.[209][210][211]

Informations: An important part of the EDPB's recommendations concern being informed. It emphasises that data subjects must always be informed about the identity of the data controller, their rights under the GDPR, the recipients of their data, as well as the purpose and duration of the processing and storage. The following list of information must be provided by a data controller, be it a vehicle manufacturer or another service provider, to the data subjects concerned in an easily readable, clear form. Most of the requirements are already reflected in the legal text of the GDPR under Article 13.[212]

- Information about the data protection officer provided
- Information about the recipients and further processing of the data
- Information about the period of data retention and how this period is determined as well as the purpose of the processing of data (incl legal basis for processing)

[207] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.20.
[208] Kunnert (2017): „Autonomes Fahren“ aus datenschutzrechtlicher Sicht, in Eisenberger/Lachmayer/Eisenberger (Hrsg), Autonomes Fahren und Recht (2017), 169, p.191.
[209] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.21.
[210] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.11.
[211] European Parliament, Council of the European Union (2018a): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016, p.53-55.
[212] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.21.

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- Information about the right to request rectification or erasure or restriction of processing by the data controller, the right to withdraw consent at any time and the right to lodge a complaint with a supervisory authority
- Information in case of transfer of data from the controller to a third country or international organisation
- Information on whether the provision of personal data is a legal or contractual obligation (including the consequences of not providing it)
- Information about who has what obligations in the case of joint data controllership
- Information on the existence of automated decision making and profiling

original source from European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.21-22, own representation.

Article 14 of the GDPR deals with those information obligations where data has not been obtained directly from the data subject concerned but has been collected, for example, by the vehicle manufacturer from dealers. The information obligation here applies as described above and must additionally inform the data subject in accordance with Article 14 para. 2 lit a to g, for example, of the category of personal data collected, the source of the data, as well as whether the data have been obtained from publicly accessible sources. The EDPB's recommendations comply with Article 14 para. 3 regarding the period after which the data controller must notify the data subjects. Especially when data subjects cross borders to other countries and sometimes new data controllers come into play, the requirements of the GDPR must be taken into account and new information regarding the new controller and its required information must be provided. For better comprehensibility, the EDPB calls for a standardised icon in the Guidelines, which will appear in the event of changes relating to Article 13 or 14 GDPR.[213][214]

Rights of the data subjects: The rights of a person laid down in the GDPR with regard to the control of his data, i.e. access, rectification, deletion and restriction of processing, must be ensured and made possible by the provision of suitable tools by the vehicle manufacturer. This should give the vehicle owner the possibility to easily transfer his data in case of a sale of the vehicle and an automatic deletion of the unnecessary data in such a case should take place. A kind of profile management system should be introduced to enable the driver to set his privacy settings centrally and easily, as well as to set said changes regarding the consent.[215]

[213] Ibid., p.22-23.
[214] European Parliament, Council of the European Union (2018a): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016, p.41-42.
[215] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.23.

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Security measures: To ensure the security of personal data, the EDPB recommends implementing a number of mechanisms and policies. On the one hand, strong emphasis should be placed on **encryption** to prevent unauthorised access to the data. The encrypted communication should be based on state-of-the-art algorithms and include a key-management system that is unique for each vehicle. Of course, a regular renewal of the keys as well as an adequate protection of the encryption keys is crucial. Access should only be possible through reliable authentication of the user with the help of certificates or passwords.[216]

Furthermore, vehicle manufacturers should already take into account during development that the data and information are partitioned according to their category. In this way, data that relies on telecommunication capacities should be separated from more important vehicle functionalities (vehicle's vital functions). Especially for these sensitive data and functions, special secure communication channels should be used and the manufacturer must be able to quickly provide these technologies with security patches. In the event of an attack, a log should be recording the history of the last 6 months and an alarm should indicate an attack. It must be possible to introduce a downgraded mode in the event of an attack.[217]

Transfer of personal data: There are cases where data must be transferred either to third parties or to data controllers outside the EU. If a data controller transfers the data to a commercial partner, this must be done in accordance with Article 6 of the GDPR, which describes the lawfulness of processing. If a data subject has not opted out of such a transfer, the commercial partner receiving the data assumes responsibility for compliance with all the Directives of the GDPR. If personal data is transferred to a data processor, it must be ensured that the data processor is bound by a contract pursuant to Article 28 GDPR not to use the data for its own purposes. When personal data is transferred to other EU countries, special safeguards must be implemented to ensure that it remains protected as far as possible. It is necessary for the data controller to ensure that the transfer of this data only takes place in compliance with the conditions in Chapter 5 "*Transfers of personal data to third countries or international organisations*" of the GDPR.[218][219]

4.3 Legislation and regulation in Austria

The legal framework relevant at national level in the context of automated driving is discussed in this chapter. In addition to simple legislative framework, EU directives that

[216] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.24.

[217] Ibid.

[218] Ibid., p.24-25.

[219] European Parliament, Council of the European Union (2018a): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016, p.49-50.

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have been transposed into national law are also relevant at national level.

In Austria, the topic of automated driving is receiving intensive attention. In 2016, the Federal Ministry of Transport, Innovation and Technology (BMVIT) presented an action plan focused on the connected vehicle and sets targets for the planned period between 2016 and 2018. In 2019, a new action package called "Automated Mobility" was presented, which provides current targets until 2022 and contains a review of measures, milestones and activities that have already been implemented. This chapter addresses laws specifically adapted to automated driving, such as the Automated Driving Regulation (AutomatFahrVO), but also relevant aspects of the Motor Vehicle Act (KFG). Furthermore, the legal situation regarding liability law will be examined and the possibilities for test operations will be discussed.[220][221]

Since there is always some room for legislative improvement at the national level, this aspect is particularly interesting in terms of the progress for autonomous driving, since in contrast to the EU level, changes can still be made more easily here.[222]

4.3.1 Motor Vehicle Act ("Kraftfahrgesetz", KFG)

The legal situation regarding automated driving in Austria is relatively simple and not well developed. In Austria, legislation explicitly dealing with autonomous driving was only published in 2016, and this within a very minimalist framework. The 33rd KFG amendment is certainly at the centre of these innovations.[223]

The legal situation regarding autonomous driving in Austria is characterised by historical legislation. On the one hand, the Vienna Convention on Road Traffic of 1968 is worth mentioning, which is an international treaty that standardises traffic regulations and was described closer in chapter 4.1.1.

Above all, the Motor Vehicle Act or "Kraftfahrgesetz" (KFG) of 1967 is authoritative in Austria with regard to the handling of motor vehicles of any kind. With the 33rd amendment of the KFG, which was implemented in July 2016, the operation of automated driving functions in vehicles became possible for the first time, which should enable testing of autonomous driving systems in order to strengthen the domestic industry and increase the attractiveness of Austria as a test location.[224][225]

[220] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.7.

[221] Bundesministerium Verkehr, Innovation und Technologie (2018): Aktionspaket Automatisierte Mobilität 2019-2022, p.10-11.

[222] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.5.

[223] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.147.

[224] Bundesministerium für Verkehr, Innovation und Technologie (2016): 33. KFG-Novelle.

[225] Krieger-Lamina (2016): Vernetzte Automobile. Datensammeln beim Fahren – von Assistenzsystemen zu autonomen Fahrzeugen. Endbericht, p.38-39.

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These amendments, which are very important for the introduction of automated or networked vehicles, refer to §102 KFG, which has been amended in paragraph 3a and 3b.[226]

According to §102 para. 3a, the following now applies under certain circumstances:

> *"If provided for by regulation, the driver may assign certain driving tasks to assistance systems or automated or networked driving systems present in the vehicle, ..."* (translated, cited from original source:[227])

This applies on the condition that these systems are approved or meet the specified requirements for test purposes.

§102 para. 3b states that the driver is released from the duties described, but with the proviso that:

> *"...the driver remains responsible at all times to resume his driving duties."* (translated, cited from original source:[228])

However, an ordinance of the Federal Minister for Climate Protection, Environment, Energy, Mobility, Innovation and Technology must determine under which circumstances this may be possible. Section 102 (3b) 1-5 defines that it must be specified (1) in which traffic situations, (2) on which types of roads, (3) up to which speed ranges, (4) with which vehicles and (5) with which assistance systems or automated or connected driving systems a transfer of driving tasks can be carried out. The execution and parametrisation of these criteria is not discussed in detail, only that it must be verified by sufficient virtual and real tests.[229][230]

In order to comply with the principle of legality, further obligations for the driver would have to be specified in more detail in the StVO for reasons of competence in order to also refer to the enforcement competence of the federal states. Such a provision is still missing in the StVO [231].[232]

This 33. novella to the KFG created the breeding ground for further developments and formed the basis for the "AutomatFahrV" regulation described in Chapter 4.3.2.

[226] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.7.
[227] Bundesministerium für Verkehr, Innovation und Technologie (2016): 33. KFG-Novelle.
[228] Ibid.
[229] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.25-26.
[230] Bundesministerium für Verkehr, Innovation und Technologie (2016): 33. KFG-Novelle.
[231] Straßenverkehrsordnung
[232] Dür (2018): Autonomes Fahren – Ein Rechtsvergleich mit DE und den USA.

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4.3.1.1 Test operation

In addition to §102 para 3a KFG, which allows drivers to transfer certain driving tasks to automated driving systems, §34 para 1 KFG and §34 para 6 KFG are also important, especially for test operations and trials of new technologies. As already described, in order for §102 para 3a KFG to be applicable, an ordinance must be issued specifically for this purpose, which prescribes requirements for these special test purposes, or the systems to be tested are specially approved.

For the approval of special test vehicles or prototypes, there are special exemption conditions in §34 para 1 KFG, under which a vehicle or system can be approved for the purpose of testing at the request of the producer. However, this "exceptional approval" may only be granted if

> *"...there are no objections to it from the point of view of traffic and operational safety."* (translated, cited from original source:[233])

Also useful for the purpose of testing is §34 para 6 KFG, which states that the Federal Minister for Climate Protection, Environment, Energy, Mobility, Innovation and Technology may deviate from the applicable provisions on the design and equipment of vehicles if, as in the case of §34 para 1 KFG, this does not give rise to concerns regarding traffic and operational safety.[234]

These paragraphs allow the use of driving assistance systems or vehicles on public roads for test purposes that would normally not be subject to approval. The AutomatFahrV (Automatic Driving Ordinance) resulting from this legal basis and described in Chapter 4.3.2 allows the following use cases, provided the general conditions are met.[235][236]

a) use of motorway pilots with automatic lane change

b) testing of automated/autonomous minibuses up to a speed of 20km/h

c) teleoperated or self-driving army vehicles

4.3.1.2 Legal challenges

Even if at first glance it would seem that the approval of an automated vehicle for road traffic would be simple, there are still a number of obstacles that need to be clarified. On the one hand, a step-by-step approval process is required, because automated vehicles take over the tasks of a driver in many respects, who is obliged to guarantee compliance

[233] Bundesministerium für Verkehr, Innovation und Technologie (2021): Gesamte Rechtsvorschrift für Kraftfahrgesetz 1967, Fassung vom 09.09.2021.

[234] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.25.

[235] Ibid.

[236] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.150.

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with the rules defined in the StVO [237]. In the case of automated driving, this obligation must be assumed by the vehicle. The technical approval of the vehicle as defined in the KFG is therefore still necessary, but not sufficient on its own. Similar to a driver's licence test or approval of a pharmaceutical product, automated vehicles must also be subjected to extensive examinations, analyses and tests before they can participate in road traffic.[238]

In order to promote these measures, test drives are an important intermediate step towards approval. As already mentioned, §102 (3b) requires both virtual and real tests, which must be subjected to sufficient analysis after completion.[239][240]

According to Lachmayer in "Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten" (Traffic Law: Legal Deficits of the Regulations on Test Drives), more detailed explanations are needed in the context of test drives as to how the tested driving situations are to be categorised and when test drives are to be interrupted or cancelled. Furthermore, there is a lack of a system of standards that can be used during tests and afterwards in road traffic to ensure the safety of road users and to guarantee the objectives of traffic law.[241]

Furthermore, missing legal foundations are explained, which are primarily related to the Automated Driving Regulation (AutomatFahrV), which is based on the 33rd amendment of the KFG. In this context, specific reference is made to the Implementation Ordinance, which has the purpose of concretising framework conditions at the legal level, but cannot be used to standardise further content in addition to the law. According to Lachmayer, this is exactly the case here, as no adequately defined legal basis has been created at the legislative level. The legal challenges with regard to the AutomatFahrV will be dealt with in more detail in chapter 4.3.2. In this chapter, the problems that already arise in the KFG will be highlighted.[242]

As already mentioned in chapter 4.3.1, according to §102 para. 3b KFG, it should be determined under which traffic situations, types of roads, speed ranges, which vehicles or assistance systems, etc. are to be used. test drives may be carried out, or under which these may be approved. This already shows a problem due to unspecified requirements, which are supplemented in §§ 7 ff AutomatFahrV by application cases, but are not specified in more detail. They are even extended with requirements for which there is no legal basis (for example, in §7 AutomatFahrV for the application case "autonomous minibus" no specifications are made with regard to the type of road, but "at least 1000

[237] Straßenverkehrsordnung
[238] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.149.
[239] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.25-26.
[240] Bundesministerium für Verkehr, Innovation und Technologie (2016): 33. KFG-Novelle.
[241] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.149-150.
[242] Ibid., p.160.

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test kilometres" are added as a condition).[243][244]

There are further discrepancies between §102 para. 3a and b KFG and the application cases described in the AutomatFahrV regarding new driver obligations. For example, the KFG never mentions emergency systems or special actuation obligations, but in § 7 para 6, § 8 para 7 or § 9 para 7 AutomatFahrV special driver obligations are referred to, which oblige the driver that " if a critical situation arises, the driver must immediately actuate the emergency system". Further regulatory deficits are dealt with in chapter 4.3.2.1.[245]

Also worth mentioning are obstacles to the approval of automated driving systems, to which driving tasks can be transferred according to §102 para. 3a KFG. This is not only possible for test purposes, but also when these systems are specifically approved. Under the circumstances already mentioned, which the BMVIT has to determine (traffic situation, type of road, speed range, types of vehicle, types of assistance system), the exception from the driver duties for the transfer of driving tasks according to § 102 para 3b KFG is permissible "in all cases according to § 102 para 3a". From this formulation it can be concluded that the transfer of driving tasks according to § 102 para 3b KFG must be specified in detail in an ordinance, also for cases in which driving systems according to § 102 para 3a Z 1 KFG have been approved. The problematic phrasing is again found in the AutomatFahrV, which defines under §1 para 1 line 1 that

> *"...these systems are approved, in series production and can be assigned to the applications of section 3"* (translated, cited from original source:[246])

Here, the term "approval" is repeated and in addition production "in series" is demanded. A more detailed specification of what an approval should look like is missing. Also, § 1 Abs 1 Z 2 AutomatFahrV does not require an "approval" for test purposes, which is defined in § 102 Abs 3b KFG and thus does not comply with the requirements of § 102 Abs 3a KFG. In this context, Lachmayer in "Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten" concludes that corresponding concretisations of the framework conditions regarding the exemption from driver obligations and for the transfer of driving tasks to approved systems are also necessary for approved driving systems.[247][248][249]

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[243] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.160.

[244] AutomatFahrV (2016): Verordnung des Bundesministers für Verkehr, Innovation und Technologie über Rahmenbedingungen für automatisiertes Fahren (Automatisiertes Fahren Verordnung – AutomatFahrV), Fassung vom 12.09.2021, p.3.

[245] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.160.

[246] AutomatFahrV (2016): Verordnung des Bundesministers für Verkehr, Innovation und Technologie über Rahmenbedingungen für automatisiertes Fahren (Automatisiertes Fahren Verordnung – AutomatFahrV), Fassung vom 12.09.2021.

[247] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.6.

[248] Lachmayer (2017b): Zeitschrift für Verkehrsrecht, Nr. a, Bd. 12,, p.516.

[249] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.162-163.

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In addition to the aforementioned obstacles regarding the concretisation of framework conditions, there are special obstacles for test operations that are worth mentioning. Especially when it comes to the notification procedure for the exemption from the driver's obligations according to §102 KFG, it becomes clear that an authorisation procedure is necessary, for which the legal basis would have to be defined in more detail. Furthermore, the problem consists of the problems mentioned above in terms of the principle of legality, which is not satisfied by the mere repetition of the legal text (relating to the term "approval" of a system). In addition, problems arise from the driver's obligations referred to in §102 para. 3a KFG and their reference to the legal control of driving behaviour in road traffic. The wording of the legal text on the takeover of driving tasks by automated and autonomous systems includes the performance of driving tasks and the regulation of these exceptions to the driver's obligations would already have to be dealt with in the StVO for reasons of competence.[250]

4.3.1.3 Conclusion and Recommendations

At the national level, the Federal Ministry of Transport, Innovation and Technology has been working on the realisation of a future with automated vehicles and systems in Austria since the end of 2015. For this purpose, the aforementioned "Action Plan for Automated Driving" was drafted in June 2016 and the 33rd amendment to the Motor Vehicle Act (KFG) was passed in July 2016. Especially the amended §102 KFG, which was adapted to the conditions of automated driving in paragraphs 3a and 3b, is very important for the further development of connected vehicles. These new legal foundations made it possible to carry out test drives on public roads for the first time, but these sparsely worded legal texts were not sufficient to serve as a suitable legal foundation for test drives of automated vehicles.[251][252][253]

In combination with the AutomatFahrV, which is based on it, there are also obstacles that arise, as described in 4.3.1.2, due to a lack of concretisation of the required framework conditions or partly contradictory formulations of the legal texts.[254][255]

In "Traffic Law: Legal Deficits of the Regulations on Test Drives", Lachmayer also specifically points out that there can be obstacles both in the authorisation procedure for test drives and for those affected in cases of damage in the context of test drives due to constitutional and simple legislative problems. The form of action due to blanket exemptions at the regulation level and notification obligations of the vehicle operators make it difficult to obtain effective legal protection. For the sake of legal certainty, whether

[250] Lachmayer (2017b): Zeitschrift für Verkehrsrecht, Nr. a, Bd. 12,, p.516.
[251] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.7.
[252] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.147.
[253] Bundesministerium für Verkehr, Innovation und Technologie (2016): 33. KFG-Novelle.
[254] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.162-163.
[255] Lachmayer (2017b): Zeitschrift für Verkehrsrecht, Nr. a, Bd. 12,, p.517.

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for affected road users or applicants for test drives, the creation of a legal framework that provides clear foundations in conformity with fundamental rights is necessary.[256]

A constitutional solution to the aforementioned competence-related problems regarding driver obligations would be to make an **exception in the StVO**. An "extension" of the term "driver" in the StVO to non-human road users would be conceivable in favour of test drives. §45 of the StVO is most likely to be considered for this purpose, in order to grant exemptions for test drives in the existing legal situation. However, it should be mentioned here that according to §45 para. 2c StVO, a mechanism exists that requires an additional authorisation at the federal state level. Alternatively, instead of an authorisation procedure by means of a notification, an ordinance as in the context of the KFG would also be conceivable.[257][258]

Authorisation procedures would have to be introduced both in the StVO and in the KFG, either as a notice variant or a certificate variant. An administrative procedure within the meaning of the General Administrative Procedure Act (AVG) would have to be carried out and an assessment would have to be made on the basis of special standards, traffic safety within the framework of the StVO and operational safety within the framework of the KFG, by means of expert committees or authorised specialists.[259]

As a possible solution for a **lack of legal determination**, Lachmayer suggests in "Traffic Law: Legal Deficits of the Regulations on Test Drives", in addition to a possible integration of missing legal requirements (regarding data processing, requirements for test drivers or the design of authorisation procedures) into existing laws, a possible enactment of an independent law (for example AutomatFahrG), which would summarise regulations for test drives of automated vehicles.[260]

4.3.2 AutomatFahrV

In 2016, the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT) drew up an action plan, which outlined goals and measures for the realisation of an automated future for the period 2016-2018. Among other things, this also included the outlining of framework conditions for carrying out test drives on public roads. On this basis, the Automated Driving Ordinance or "Automatisiertes Fahren Verordnung" (AutomatFahrV) was adopted. In 2018, another action plan called the "Automated Mobility Action Package" was drawn up, which was intended to continue where the first

[256] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.166-167.
[257] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.93-94.
[258] Lachmayer (2017b): Zeitschrift für Verkehrsrecht, Nr. a, Bd. 12,, p.516-517.
[259] Ibid., p.517.
[260] Ibid., p.517-518.

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action plan left off and describes the period between 2019-2022.[261][262]

The AutomatFahrV, or "Automatic Driving Ordinance" was issued by the BMVIT on the basis of §102 para. 3a and 3b KFG, as well as §34 para. 6 KFG. This ordinance provides the legal framework for testing automated vehicles outside of private test sites and thus facilitates the implementation of the measures of the first action plan of the Federal Ministry for Transport, Innovation and Technology (BMVIT) published in June 2016.[263][264]

The introduction of the Automated Driving Ordinance made it possible to test or use automated systems in Austria in the first place, as this ordinance exempts drivers from specific driving duties in individual cases by means of a special permit issued by the BMVIT. In concrete terms, §102 of the Austrian Motor Vehicle Act (KFG) previously stipulated that a driver must always hold the steering wheel with one hand while driving and must take the driving position in the intended manner.[265]

As already noted in chapter 4.3.1.1, section 2 of the AutomatFahrV defines the use cases for test purposes.

The three use cases described in the AutomatFahrV are defined as follows. §7 AutomatFahrV describes the use of "**autonomous minibuses**", which according to §7 para 1 are

> *"...a vehicle of categories M1, M2 and M3 equipped with a system capable of performing all driving tasks at a speed of up to 20 km/h."* (translated, cited from original source:[266])

§8 AutomatFahrV describes the "**motorway pilot with automatic lane change**", which according to §8 para 1 is

> *"...a system capable of taking over the longitudinal and lateral guidance of the vehicle on motorways and highways."* (translated, cited from original source:[267])

[261] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.7.

[262] Bundesministerium Verkehr, Innovation und Technologie (2018): Aktionspaket Automatisierte Mobilität 2019-2022, p.10-11.

[263] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.25-26.

[264] AustriaTech (2017): Automatisiertes Fahren in Österreich - Monitoringbericht 2017, p.10.

[265] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.7.

[266] AutomatFahrV (2016): Verordnung des Bundesministers für Verkehr, Innovation und Technologie über Rahmenbedingungen für automatisiertes Fahren (Automatisiertes Fahren Verordnung – AutomatFahrV), Fassung vom 12.09.2021.

[267] Ibid.

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For the purpose of completeness, the "**self-driving army vehicle**" defined in §9 AutomatFahrV should also be mentioned here, which according to the definition is

> *"...a vehicle of the classes N1, N2, N3, T1, T2, T3, T4 and T5, which is equipped with a system that is capable of taking over all driving tasks by itself or by teleoperation."* (translated, cited from original source:[268])

With the 1st amendment to the AutomatFahrV[269] in November 2018, automatized assistants should be allowed to operate outside of test drives under certain conditions. With this novella, "**highway pilots with automatic lane-keeping**" (§11 AutomatFahrV), as well as "**parking assistants**" (§10 AutomatFahrV), which can park the vehicle without occupants, should be possible. [270]

Since the introduction of the AutomatFahrV, certain driving tasks can be transferred from the driver of the vehicle to existing assistance systems in accordance with §102 para. 3a KFG if a licence is available. In this context, §1 para 1 AutomatFahrV defines that

> *"...these systems are approved, in series production and can be assigned to the applications of section 3"* (translated, cited from original source:[271])

This would mean, that the UN/ECE regulations are complied with. In the case of "Application cases for approved systems in series production", the approved cases in §10 Para. 1 and §11 Para. 1 refer to compliance "in the sense of ECE Regulation No. 79".[272][273]

In addition to systems that have already been approved, the Ordinance specifies special requirements for test purposes under §1 Para 1 Z 2 AutomatFahrV. Under §3 AutomatFahrV it is defined that

[268] AutomatFahrV (2016): Verordnung des Bundesministers für Verkehr, Innovation und Technologie über Rahmenbedingungen für automatisiertes Fahren (Automatisiertes Fahren Verordnung – AutomatFahrV), Fassung vom 12.09.2021.

[269] Bundesministerium für Verkehr, Innovation und Technologie (2019a): 1. Novelle zur AutomatFahrV.

[270] Bundesministerium für Verkehr, Innovation und Technologie (2019b): 1. Novelle zur AutomatFahrV, Vereinfachte wirkungsorientierte Folgenabschätzung.

[271] AutomatFahrV (2016): Verordnung des Bundesministers für Verkehr, Innovation und Technologie über Rahmenbedingungen für automatisiertes Fahren (Automatisiertes Fahren Verordnung – AutomatFahrV), Fassung vom 12.09.2021.

[272] Bundesministerium für Verkehr, Innovation und Technologie (2019a): 1. Novelle zur AutomatFahrV, p.2.

[273] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.7.

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> *"...vehicles equipped with such systems may only be used if the driver occupies the seat provided for him/her in the intended manner"* (translated, cited from original source:[274])

Furthermore, according to §5 Abs 1 AutomatFahrV, vehicles that are approved according to §1 Abs 1 Z2 AutomatFahrV must

> *"... be equipped with an accident data recorder, which must also be used during the test drive"* (translated, cited from original source:[275])

In addition, liability insurance is required in accordance with §1 para 3 Z1 AutomatFahrV and the group of persons who can submit a test application is differentiated depending on the application, for example, self-propelled army vehicles can only be tested by the Federal Ministry of Defence and Sport in accordance with §9 AutomatFahrV.[276][277]

The use and activation of the system is differentiated on the basis of the various approved systems. According to § 10 para 6 und 7 AutomatFahrV, the parking aid may be used on all types of roads up to a speed of 10km/h, the freeway assistant defined in § 10 AutomatFahrV may, as the name suggests, only be used on freeways or expressways according to § 11 para 2 und 6. An exception here is the construction site area.[278]

According to § 3 para 2 AutomatFahrV,

> *"The driver may assign certain driving tasks to these systems, but always remains responsible for resuming his driving tasks."* (translated, cited from original source:[279])

The driver's responsibility at all times is to use the "emergency system" described in § 10 para 5 and § 11 para 5 AutomatFahrV in critical situations, which is intended to initiate immediate deactivation of the systems and allow the driver to override them.[280]

[274] AutomatFahrV (2016): Verordnung des Bundesministers für Verkehr, Innovation und Technologie über Rahmenbedingungen für automatisiertes Fahren (Automatisiertes Fahren Verordnung – AutomatFahrV), Fassung vom 12.09.2021.
[275] Ibid.
[276] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.7.
[277] AutomatFahrV (2016): Verordnung des Bundesministers für Verkehr, Innovation und Technologie über Rahmenbedingungen für automatisiertes Fahren (Automatisiertes Fahren Verordnung – AutomatFahrV), Fassung vom 12.09.2021, p.2-3.
[278] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.3-4.
[279] AutomatFahrV (2016): Verordnung des Bundesministers für Verkehr, Innovation und Technologie über Rahmenbedingungen für automatisiertes Fahren (Automatisiertes Fahren Verordnung – AutomatFahrV), Fassung vom 12.09.2021.
[280] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.4.

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4.3.2.1 Legal challenges and test operation

First of all, it should be noted that when describing the legal challenges of the AutomatFahrV, a connection to the KFG described in Chapter 4.3.1.2, especially §102 KFG, must of course always be recognized. This is due to the fact that the AutomatFahrV builds on and is based on many basic legal components of the KFG. Several legal challenges have already been described and can be found in 4.3.1.2.

In theory, the AutomatFahrV is intended to specify the requirements for testing automated vehicles on public roads. Here, particular attention is paid to the factors of which traffic situation, speed range or which systems can be used. A test of driverless vehicles is not possible, since a driver must be in the vehicle at all times in order to be able to manually take control of the vehicle in an emergency.[281] This would correspond to a level 3 classification according to SAE J3016 2.2.1, since the fallback performance must be executed by the human driver.

As already described in 4.3.1.2, many of the legal challenges in connection with the AutomatFahrV arise from contradictory or ambiguous definitions of legal provisions. In "Traffic Law: Legal Deficits of the Regulations on Test Drives", Lachmayer describes the problem that the implementation of test drives cannot be based on a notification alone. § 1 Abs 1 AutomatFahrV as well as § 102 Abs 3b KFG provide that test drives, in which the driving task can be handed over to the respective systems in the application cases defined in §7 AutomatFahrV, can be carried out without further approval by the BMVIT, as long as the conditions of the regulation are met. In § 1 para. 3 AutomatFahrV, a reporting obligation is defined by the necessary transmission of data, which is then confirmed by a certificate, for example in the form of a public document, according to § 1 para. 4 AutomatFahrV.[282]

Lachmayer points out that a number of obligations are imposed on the applicant, for example an information obligation according to §1 para. 7 AutomatFahrV, which obliges the applicant to "inform the road operator responsible for the high-ranking road network prior to the test drives and to include them in the planning. Also in §1 Abs 5 AutomatFahrV in connection with the requested period for the test drive of an applicant is mentioned. Lachmayer concludes that due to the wording of the paragraphs in §1 AutomatFahrV a mere notification is not sufficient to perform test drives, rather an application to the BMVIT should be evaluated with appropriate evidence. It is important to emphasize here that there is no automatic issuance of a certificate and the application can also be rejected by the BMVIT.[283][284]

The problem that follows from this conclusion requires a consideration of the constitutional concept of a governmental notice. A notice is defined in constitutional law as a legal norm

[281] AustriaTech (2017): Automatisiertes Fahren in Österreich - Monitoringbericht 2017, p.10.

[282] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.156-157.

[283] Bundesministerium für Verkehr, Innovation und Technologie (2019a): 1. Novelle zur AutomatFahrV, p.2.

[284] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.157.

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with an invidivual, sovereign, normative administrative act, which follows a procedure such as a permit in an external relationship between the authority and the person subject to the norm. Lachmayer suggests that, although the ordinance does not speak of an approval by notice, this certificate is to be interpreted as a notice in a constitutional manner. Accordingly, the procedure is to be interpreted as a notification procedure/approval process.[285][286]

The classification as a notification procedure/approval process has constitutional implications for the applicants and also requires the integration into the existing constitutionally specified forms of action of the administration. If this is not possible, the regulation would be unconstitutional as it stands.[287]

Another problem that arises from the classification as a "reporting obligation" is that the fulfilment of the requirements is fulfilled purely formally, a verification would not take place. The requirements defined in § 1 AutomatFahrV from the government side lack a legal basis and the application cases mentioned in section 2 (§§ 7ff AutomatFahrV) are, according to Lachmayer, to be regarded as insufficient with regard to their concretisation.[288]

With regard to the test application, further obstacles arise, as it influences the requirements of the regulation, according to § 1 para 3 AutomatFahrV, by requesting additional information. According to the information provided, this information is not required by the regulations, but may be relevant for an accelerated issuance of the notice. If a differentiation in terms of processing time takes place here, it requires a factual justification on the one hand and a legal basis on the other, which does not exist. The situation is similar with the so-called "Code of Practice", which is described in Chapter 4.3.2.3. This code is basically a supplementary guideline and compliance with these guidelines is, in theory, not legally mandatory. According to Lachmayer, however, the Code of Practice has legal relevance through its inclusion in the application form, and may pose a problem with regard to the principle of legality.[289]

The insufficient concretisation in many respects has already been discussed in Chapter 4.3.1.2. The missing content in the regulation range from the lack of concretisation of the framework conditions for testing the use cases defined in §§ 7 ff AutomatFahrV to necessary information obligations towards the population. As already mentioned, the concrete framework conditions for speed ranges, automated driving systems or the specification of the concrete test route are missing.[290]

[285] RechtEasy.at (2021): Bescheid.

[286] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.157, 159.

[287] Ibid., p.158.

[288] Ibid.

[289] Ibid., p.159.

[290] Ibid., p.161.

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For example, the

> *"sum of the total number of real, virtual and experimental test kilometres driven with the system to be tested"* (translated, cited from original source:[291])

mentioned in § 1 para 3 lit g AutomatFahrV raises a certain problem of determination. Such a regulation could have been made at the level of the law, but would have to be specified at the level of the ordinance. However, this is not the case, and so it is uncertain how many kilometres should have been driven to justify an authorisation.[292]

4.3.2.2 Code of Practice

The so-called "Code of Practice" was drafted by the BMVIT in addition to the Automated Driving Ordinance as a guideline for testing automated vehicles. This is one level below the ordinance and is classified as "soft law". Compliance with the requirements defined in the Code of Practice is voluntary on the part of the applicants and is not legally binding. The purpose of the Code of Practice is to promote responsible testing and, in addition to various definitions, also includes guidelines on safety requirements to be observed and behavioural instructions before and during test drives.[293][294]

The requirements for test drivers, as well as their training and requirements for driver's licences are also part of the Code of Practice, as are guidelines for the duration of tests and the behaviour of test drivers. Minimum technical requirements for the vehicle and the handling of data in terms of privacy and cyber security are defined. It also defines which types of data must be recorded and how they are to be recorded.[295]

As already mentioned, the Code of Practice is NOT legally binding, but in "Traffic Law: Legal Deficits of the Regulations on Test Drives" Lachmayer expresses his concerns about the legal relevance of its inclusion in the application form for testing automated vehicles on public roads.[296]

4.3.2.3 Conclusion

The AutomatFahrV was established by the BMVIT on the basis of the 33rd amendment to the KFG, in particular § 102 para 3a and 3b KFG and § 34 para 6 KFG. With the

[291] AutomatFahrV (2016): Verordnung des Bundesministers für Verkehr, Innovation und Technologie über Rahmenbedingungen für automatisiertes Fahren (Automatisiertes Fahren Verordnung – AutomatFahrV), Fassung vom 12.09.2021.

[292] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.161.

[293] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.8.

[294] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.166.

[295] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.8.

[296] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.159, 166.

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help of this ordinance, it was possible for the first time to test automated vehicles and systems outside of test sites for the use cases defined in §§ 7 ff AutomatFahrV, as well as § 10 and § 11 AutomatFahrV. Due to the fact that the driver must be able to activate the "emergency system" at any time, a Level 3 autonomisation level is possible according to SAE J3016.[297][298]

The AutomatFahrV is considered to be a key instrument for promoting automated driving in Austria, but according to Lachmayer, it is a difficult task to develop, as the legal basis was already insufficient at the beginning of the enactment. The conceptual problems of the KFG described in Chapter 4.3.1.2 were carried over into the AutomatFahrV and resulted in an insufficient specification of requirements. This is not surprising, since due to the tiered structure of the legal system, the missing legal basis cannot be corrected by an ordinance.[299]

Due to the fact that a simple declaration is not sufficient for the approval of the execution of test drives, Lachmayer concludes in "Traffic Law: Legal Deficits of the Regulations on Test Drives" that an application must be submitted to the BMVIT, which will be evaluated. Accordingly, this is not an authorisation as a "blanket exception" or the issuing of a certificate, but rather the issuance of a notification, which requires a notification procedure/approval process. In addition to the problems of determination, this leads to further constitutional problems that need to be solved.[300]

As a result to the problems described in 4.3.2.1, Lachmayer concludes that the AutomatFahrV in its current version must be considered unconstitutional and unlawful and does not provide a constitutional basis for the operation and testing of automated vehicles on public roads. Accordingly, numerous further legal regulations are still required, not only to enable testing on public roads, but also to form a legal basis for the civil, regular use of autonomous vehicles.[301]

4.3.3 Data Protection

At the national level, data protection in Austria has so far been regulated by the "Datenschutzgesetz 2000". On 25 May 2018, the "Datenschutzgesetz 2000" was replaced by the EU General Data Protection Regulation (GDPR), which has already been described in detail in Chapter 4.2.3, and which is extended in Austria by the Datenschutzgesetz (DSG). In contrast to the old DSG2000, the GDPR is directly applicable.[302][303]

Due to the almost identical legal provisions with regard to the focus of autonomous driving at national level, reference can be made here to Chapter 4.2.3 in the majority of

[297] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.25-26.
[298] AustriaTech (2017): Automatisiertes Fahren in Österreich - Monitoringbericht 2017, p.10.
[299] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.165.
[300] Ibid.
[301] Ibid., p.165-166.
[302] dsb.gv.at (2021): Datenschutzrecht in Österreich.
[303] onlinesicherheit.gv.at (2019): Datenschutz-Grundverordnung und Datenschutzgesetz.

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cases, as well as to the guidelines of the European Data Protection Board described in Chapter 4.2.4.

With regard to the legal situation, specifically at national level, due to national laws such as the AutomatFahrV, situations arise which require consideration according to their relevance for data protection. In §5 AutomatFahrV, for example, there are special legal provisions for the use of accident data recorders. The recording of personal data requires consideration of how it is protected in accordance with the General Data Protection Regulation. According to § 5 para 1 AutomatFahrV, it is necessary for test drives of vehicles that correspond to the use cases defined in section 2 for test purposes, that

> *"each vehicle shall be equipped with an accident data memory, which shall also be used during the test drive."* (translated, cited from original source:[304])

According to Lachmayer in "Traffic Law: Legal Deficits of the Regulations on Test Drives", there is no legal basis for the legal provisions defined in §§ 5 ff AutomatFahrV that justifies an obligation to use an accident data memory. This also applies to § 6 AutomatFahrV, which deals with the use of test data and also the case of captured video recordings. [305]

4.3.4 Liability Law - National legal foundations

Liability law has interesting civil law viewpoints regarding the operation of automated vehicles. In particular, the question of who is liable for damages if an accident occurs with automated vehicles is a question that is often discussed in the media.[306]

If new liability constellations arise due to the use of new technology, there would be a need for change if these could not be solved with existing legal regulations. The aim is always to ensure that the injured party is compensated for the damage suffered, especially if another party is obliged to compensate the damage. The current legal basis for liability legislation and compensation regulations can be found in different laws depending on the application, depending on whether regulations provide for **fault liability**, **intervention liability** or **strict liability**.[307]

Simple legal bases for general damage compensation regulations can be found in §§ 1293ff ABGB ("Allgemeines bürgerliches Gesetzbuch" - General Civil Code). In the context of automated vehicles and new technologies, strict liability regulations are becoming increasingly relevant, i.e. where liability is considered independent of fault. For this purpose, the EKHG ("Eisenbahn- und Kraftfahrzeughaftpflichtgesetz" - Railway and

[304] AutomatFahrV (2016): Verordnung des Bundesministers für Verkehr, Innovation und Technologie über Rahmenbedingungen für automatisiertes Fahren (Automatisiertes Fahren Verordnung – AutomatFahrV), Fassung vom 12.09.2021.

[305] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.164.

[306] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.162.

[307] Ibid., p.163.

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Motor Vehicle Liability Act) is used in the course of strict liability for damage claims in connection with the operation of (among others also automated) vehicles. In the event that damage occurs due to defects in products, the PHG ("Produkthaftungsgesetz" - Product Liability Act) is used. In combination with the Motor Vehicle Liability Insurance Act, which is laid down in the KFG, the ABGB, EKHG and PHG are intended to close all legal gaps regarding compensation for damage suffered due to the use or testing of automated vehicles or new technologies and, in combination, to create a solid basis for liability rules.[308][309]

In the following, the aforementioned legal foundations of liability law in the context of automated driving are explained and it is examined whether there is a need for action under the current legal framework, as described in Chapter 4.3.1 and 4.3.2.

4.3.4.1 ABGB - General Civil Code

The General Civil Code or ABGB has been in force since 1812 and is thus the oldest valid code in the German legal system. The ABGB regulates legal relationships between private individuals, such as personal law, family law, inheritance law, property law, ownership law, contract law and the compensation law. The compensation law regulates, among other things, the conditions under which a person is entitled to compensation for damages.[310]

In the context of automated driving, §§ 1293ff ABGB should be considered here, as already mentioned. Here, the thirtieth main section defines what "damage" is, which means:

> *"... any harm that has been caused to someone's property, rights or person. ..."* (translated, cited from original source:[311])

In §1295 para. 1 ABGB it is defined that everyone is entitled to

> *"claim compensation from the damaging party for the damage which the latter has inflicted on him through fault..."* (translated, cited from original source:[312])

The **liability for fault** standardised in §§1293ff ABGB serves as the first connecting point, also for new technologies such as automated vehicles and their systems. The

[308] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.163-166.

[309] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.9.

[310] oesterreich.gv.at (2021): ABGB - Begriffslexikon.

[311] ABGB (2021): Gesamte Rechtsvorschrift für Allgemeines bürgerliches Gesetzbuch, Fassung vom 02.10.2021.

[312] Ibid.

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person causing the damage is at fault, this can be the driver of the vehicle, but also the current user. The driver is therefore the first point of contact in the event of an accident and must assume responsibility for the damage if he or she has acted "in breach of duty of care".[313][314]

It should be noted at this point that, depending on the degree of autonomisation or the technology/systems used, the duty of care by people in road traffic varies, as tasks in road traffic can be performed by automated systems. This means that a liability shift can occur here, whereby the manufacturers of the vehicle or the programmers of the software would have to take on fault-based liability in the event of damage. If the problems causing the damage do not lie with the manufacturer, but with a supplier, it would be even more difficult to enforce the claims, as the manufacturer would then try to assign the liability to the supplier. This problem is discussed in more detail in Chapter 4.3.4.5. [315][316]

As a result, the fact that the driver is the first point of contact in the event of an accident will not change much in the case of Level 3 and Level 4 vehicles that can be approved in the future. What will change is the standard of care in road traffic, which will vary depending on the degree of autonomisation.[317]

4.3.4.2 EKHG - Railway and Motor Vehicle Liability Act

In addition to fault liability, which is standardised by the ABGB (Austrian Civil Code), there is also the **strict liability** of the owner of a motor vehicle in Austria, which is specified by the EKHG ("Eisenbahn- und Kraftfahrzeughaftpflichtgesetz" - Railway and Motor Vehicle Liability Act) and constitutes liability without fault.[318][319]

Owner liability: The owner of a vehicle is liable according to §5 para. 1 EKHG for

> *"...the compensation of the damages specified in § 1, the operating company is liable in the case of the railway, and the keeper is liable in the case of the*

[313] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.164.
[314] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.9.
[315] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.164.
[316] Hey (2019): Die außervertragliche Haftung des Herstellers autonomer Fahrzeuge bei Unfällen im Straßenverkehr, p.243-245.
[317] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.9.
[318] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.164.
[319] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.9.

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> *motor vehicle"* (translated, cited from original source:[320])

It is irrelevant whether the owner was in the vehicle at the time of the accident, nor what degree of autonomy the vehicle has. Besides, in the case of short-term use of vehicles (e.g. car-sharing), the owner's liability is not transferred to the user.[321] Liability is excluded according to §9 para. 1 EKHG if

> *"...the accident was caused by an unavoidable event which was neither due to a defect in the condition nor to a failure of the equipment of the railway or the motor vehicle"* (translated, cited from original source:[322])

If, therefore, the "defect is in the condition", the cause of the damage is due to the defectiveness of the automated vehicle or system, the manufacturer is liable for the damage caused. This legal framework is applicable and valid for currently licensed vehicles as well as for testing vehicles and new technologies.[323][324][325]

Driver liability: Since the driver is not necessarily the owner of the particular vehicle he is driving, the driver or "user" is defined in §6 para. 3 EKGH as a person who assumes the use of the vehicle with the intention of controlling it. The driver of the respective vehicle is only liable if he breaches the duty of care. This exception to liability is defined in §6 para. 2 EKGH, according to which

> *"...a duty of compensation of such a user to be derived from general civil law is excluded if he proves that the damage was not caused by his fault."* (translated, cited from original source:[326])

In view of the currently approvable levels of automation, an intervention by the vehicle driver can be expected at any time up to level 3 according to SAE J3016 (see chapter 2.2.1). Accordingly, the driver is not released from his duty of care and is liable under current law if he violates it.[327]

[320] EKGH (2021): Gesamte Rechtsvorschrift für Eisenbahn- und Kraftfahrzeughaftpflichtgesetz, Fassung vom 02.10.2021.
[321] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.165.
[322] EKGH (2021): Gesamte Rechtsvorschrift für Eisenbahn- und Kraftfahrzeughaftpflichtgesetz, Fassung vom 02.10.2021.
[323] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.164-165.
[324] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.9-10.
[325] Templ (2016): Manz, Bd. ZVR 2016/7,, p.12.
[326] EKGH (2021): Gesamte Rechtsvorschrift für Eisenbahn- und Kraftfahrzeughaftpflichtgesetz, Fassung vom 02.10.2021.
[327] Cacilo et al. (2015): Hochautomatisiertes Fahren auf Autobahnen - Industriepolitische Schlussfolgerungen, p.140-141.

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4.3.4.3 PHG - Product Liability

The Product Liability Act defines the strict liability provisions for the use of new technologies, including automated vehicles and their systems.[328]

The Product Liability Act was transposed into national law in 1985 on the basis of EC Directive 85/374/EEC and defines the term "product", which according to §4 PHG is

> *"any movable tangible thing, even if it is part of another movable thing or has been connected to an immovable thing, including energy"* (translated, cited from original source:[329])

The interpretation of this definition in the case of software is not clear. In the case that the software is delivered on a physical data carrier, fewer (to no) problems arise here than in the case of digital transmission methods. Nevertheless, according to Lachmayer in "Extra Law - Mobility" a qualification of software as a product in the sense of the PHG can be assumed.[330]

Furthermore, the Product Liability Act defines the cases of liability according to §1 PHG, for example §1 para. 1 PHG, which states that

> *"If, due to the flaw of a product, a human being is killed, injured in the body or damaged in the health, or if a physical thing different from the product is damaged, the person is liable for the compensation of the damage"* (translated, cited from original source:[331])

This can affect the entrepreneur who manufactured the product and placed it on the market (according to §1 para. 1 no. 1 PHG) and the importer who imported the product for distribution in the European Economic Area (according to §1 para. 1 no. 2 PHG).[332]

The "flaw" referred to in §1 PHG is defined in more detail in §5 PHG and is to be divided into three categories according to §5 para. 1 nos. 1-3. A distinction is made between flaws in the presentation of the product (**instruction flaw**, §5 par. 1 no. 1 PHG), flaws in the use of the product which can be expected (**production flaw/fabrication defect**, §5 par. 1 no. 2 PHG) and flaws in view of the time at which the product was put into circulation (**design flaw**, §5 par. 1 no. 3 PHG). Here, the manufacturing

[328] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.164.

[329] PHG (1988): Bundesgesetz vom 21. Jänner 1988 über die Haftung für ein fehlerhaftes Produkt (Produkthaftungsgesetz), Fassung vom 08.10.2021.

[330] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.164.

[331] PHG (1988): Bundesgesetz vom 21. Jänner 1988 über die Haftung für ein fehlerhaftes Produkt (Produkthaftungsgesetz), Fassung vom 08.10.2021.

[332] Templ (2016): Manz, Bd. ZVR 2016/7,, p.12-13.

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flaw differs from the design flaw, as the manufacturing flaw represents an outlier in the manufacturing process.[333]

4.3.4.4 KFG - Liability Insurance

In addition to the relevant regulations in the ABGB, EKHG and PHG already described, the KFG regulates the conclusion of liability insurance. Every vehicle on the road that is used in public traffic must be covered by compulsory liability insurance by its owner. This liability insurance plays a central role in the transport sector and therefore vehicles may only be used in road traffic if, according to §36 lit. d,

> *"... the prescribed motor vehicle liability insurance (§ 59) or liability (§ 62) exists"* (translated, cited from original source:[334])

In the context of automated driving, it is possible that, for example, by prescribing increased liability insurance, claims for damages in the event of an accident are secured.[335]

4.3.4.5 Liability shift in fully autonomous driving

In the future, the driver will be responsible in much less cases. As a result, the vehicle owner would be accused, but because the accident, due to technical complexity, almost always is due to a technical defect, here again the manufacturer would be held liable. Liability could even be shifted from the owner to the manufacturer. The manufacturer is subject to strict standards in terms of producer and product liability. For the consideration of an accident with autonomous vehicles, however, with the current legal situation, a gap arises, the manufacturer would not be responsible for unpredictable autonomous decisions of the vehicle. Part of the responsibility may be transferred to the supplier, but there are still difficulties with burden of proof.[336]

At autonomous trips, the driver usually has no longer to stand up for situational injustice. Reasons why the owner is generally liable for the danger emanating from the vehicle, no longer apply exclusively to the owner, but more and more to the manufacturer.[337]

These specific questions and problems arise at levels of autonomisation above the currently legally feasible level of Level 3 or 4. A 2018 report by the Federal Ministry of Transport, Innovation and Technology indicates that with the currently applicable liability regime described in subchapter 4.3.4.1- 4.3.4.4, no unsolvable new liability problems would arise

[333] Cacilo et al. (2015): Hochautomatisiertes Fahren auf Autobahnen - Industriepolitische Schlussfolgerungen, p.141.
[334] Bundesministerium für Verkehr, Innovation und Technologie (2016): 33. KFG-Novelle.
[335] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.163-164.
[336] Hey (2019): Die außervertragliche Haftung des Herstellers autonomer Fahrzeuge bei Unfällen im Straßenverkehr, p.243-245.
[337] Ibid.

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in the event of accidents involving Level 3 or 4 vehicles. Here, a shift in liability would occur with an increasing degree of automation and thus liability would lie less on the basis of a breach of the driver's duty of care and much more on the basis of an abstract strict liability of the owner or a manufacturer's liability or product liability.[338]

4.3.4.6 Conclusion

Liability law at national level in Austria in the context of automated driving is mainly shaped by the ABGB, EKHG, PHG and, with reference to liability insurance, also by the KFG. In questions of liability in connection with vehicles on public roads, a distinction is made between fault liability, intervention liability and strict liability.[339][340]

Liability for fault is standardised in the ABGB under §§1293ff and serves as the first starting point for liability issues in the context of new technologies and automated vehicles. It is defined that the person who causes the damage is also responsible for the damage caused. The first contact person is the driver if he or she has violated the duty of care. However, depending on the degree of autonomy, the duty of care does not necessarily lie with the driver; liability can also pass to the manufacturer or supplier. The so-called "liability shift" is legally solvable with today's levels of autonomy (level 3-4), but poses a problem with higher levels of autonomy, especially in terms of provability.[341][342][343]

The EKHG defines the strict liability of the owner, which under §5 para 1 EKHG defines that the owner is liable for the compensation of the damage. It is not relevant whether the owner was present in the vehicle or not, but there are various circumstances under which liability is transferred to the user (e.g. in the case of car-sharing or cases described in §9 para. 1 EKHG). However, since under the current law a maximum of level 3 vehicles or systems can be approved, liability under §6 para. 2 EKGH remains with the driver, as he is not released from his duty of care at any time.[344][345][346][347]

[338] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.10.

[339] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.163-166.

[340] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.9.

[341] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.164.

[342] Hey (2019): Die außervertragliche Haftung des Herstellers autonomer Fahrzeuge bei Unfällen im Straßenverkehr, p.243-245.

[343] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.9.

[344] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.164-165.

[345] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.9-10.

[346] Templ (2016): Manz, Bd. ZVR 2016/7,, p.12.

[347] Cacilo et al. (2015): Hochautomatisiertes Fahren auf Autobahnen - Industriepolitische Schlussfolgerungen, p.140-141.

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If the software in an automated vehicle is seen as a "product" in the sense of the PHG, faults can be differentiated into instruction flaws, fabrication flaws or design flaws according to §5 para. 1 nos. 1-3.[348] The PHG defines the strict liability provisions for the technologies that are also used in automated vehicles. According to §1 para. 1 PHG, the "person" must pay for the damage if a defective product kills or injures a person or damages another physical object.[349]

As an instrument to improve the provability of damage events and to avoid possible liability shifts, it is conceivable that "black boxes" or tachographs will be used in the future to record the course of the accident.[350]

In summary, it can now be stated that with the technical systems and vehicles that can be approved today, the existing liability rules of the ABGB, EKHG and PHG do not present any gaps in liability law and compensation for damages incurred. The testing of new technologies also does not pose any problems under the current legal framework and there is therefore no need to standardise special exemption conditions for testing purposes. The new scenarios that arise in liability law can often be countered with the obligation to contract increased liability insurance.[351] In the future, an increasing degree of automation may lead to a shift in liability away from negligence on the part of the driver and towards abstract strict liability on the part of the owner or manufacturer and product liability.[352]

[348]Cacilo et al. (2015): Hochautomatisiertes Fahren auf Autobahnen - Industriepolitische Schlussfolgerungen, p.141.
[349]Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.164.
[350]Krieger-Lamina (2016): Vernetzte Automobile. Datensammeln beim Fahren – von Assistenzsystemen zu autonomen Fahrzeugen. Endbericht, p.39.
[351]Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.165-166.
[352]Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.10.

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CHAPTER 5

Conclusion

The topic of automated driving is very extensive and will continue to be a highly debated topic in the future. Since the legal framework is usually adapted very slowly to new technical conditions, there may still be many obstacles in the transition period towards fully autonomous vehicles. The large number of research projects and scientific papers worldwide shows that this topic is not without reason seen as one of the "megatopics" of the automotive industry and that work is being done at full speed to realise autonomous driving.[1]

Even in the earliest years of automotive history, the dream of "autonomous" or automated driving was a goal that was pursued in a large number of studies, prototypes and test drives. In addition to increased comfort and the "family togetherness" mentioned in McCall's magazine published in 1954, the focus there was mainly on increased safety through automated driving systems.[2][3] This driving factor is still an essential component that drives research in the field today. Today, automated driving engages a variety of different industries and is not without reason considered one of the 4 megatopics of the automotive industry. Autonomous driving sometimes has many positive effects and impacts, for example a reduction in the number of accidents. Depending on the system and the environment, very high improvements are possible here; according to statistics of the European Parliament, 95%-98% of traffic accidents are attributable to human error. Worth mentioning here is a reduction of up to 38% through the introduction of automatic emergency braking systems.[4] A better utilisation of time and thus higher productivity, as well as financial advantages, can be realised. The use of automated vehicles also offers

[1] Scheffels/Gelowicz (2018): Autonomes Fahren: Definition, Level & Grundlagen.
[2] Kröger (2015): Das automatisierte Fahren im gesellschaftsgeschichtlichen und kulturwissenschaftlichen Kontext, p.45, 53.
[3] Wünsche (2013): Geschichte des Automatischen Fahrens.
[4] Brenner/Herrmann (2018): Digital Marketplaces Unleashed, p.431.

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better parking management in urban areas, as well as better mobility for elderly people or people with disabilities.[5][6][7]

5.1 Technology and Safety

The definition and technical issues surrounding automated driving are regulated in a large number of standards. One of the most important standards is SAE J3016, which contains important definitions and divides automated driving into 6 essential levels of autonomy which are described in chapter 2.2.1. The chapter 3, "Technology and Safety", contains a description of the most important aspects of automated driving. In this chapter, the safety approach and the 12 guiding principles under which the operation of level 3/4 vehicles must take place according to the white paper "Safety First for Automated Driving, SaFAD" published in July 2019 are discussed first.[8]

The communication of the automated driving system and the transport infrastructure is one of the key issues when it comes to the realisation of automated driving. Their interaction with the environment is realised by a combination of a physical component and underlying computer-aided information processing, therefore these systems are also called cyber physical systems.[9]

5.1.1 Technological concepts

Based on the technical progress achieved and expected in recent years, as well as the versatility of the possible applications of the individual technologies, EU officials, stakeholders and selected literature came to the conclusion that the technologies shown in Fig 3.1 are to be attributed certain key functions in the development of automated driving.[10]

Based on the key technologies, the most important technological concepts were presented and explored in chapter 3.4. The use of sensor-based technologies would require a perfect infrastructure, which can sometimes become a serious obstacle, as well as the processing and storage of data protection relevant data.[11][12] The advantage of being able to use the existing infrastructure is opposed to the rarely perfect environment in reality. Vehicle cooperation and communication is divided into low-distance and high distance communication, which have different technical requirements. The communication

[5] Losch (2021): Selbstfahrende Autos: Senioren als lukrative Zielgruppe.

[6] Tschiesner (2019): How cities can benefit from automated driving.

[7] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.73.

[8] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.10.

[9] Linnhoff-Popien/Schneider/Zaddach (2017): Digital Marketplaces Unleashed, p.432.

[10] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.22.

[11] Ibid., p.25.

[12] Frisoni et al. (2016): European Parliament, Directorate-General for internal policies, policy department B: Structural and Cohesion Policies, Transport and Tourism, p.77.

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technologies ITS-G5 and C-V2X are fundamentally different and are not compatible, but much more precarious is the fact that both operate in the same 5.9GHz frequency band and even interfere. It is currently not clear which technology will prevail. Especially in cross-border use, there are obstacles caused by poor coverage and insufficient infrastructure.[13][14]

The challenges in the use of artificial intelligence, which are described in chapter 3.4.3, often result in difficulties in international use, mainly due to the use of different data-sharing ecosystems. Furthermore, the handling of personal data and cyber security will be one of the main challenges. AI must be explainable and controllable, i.e. it must be comprehensible and understandable for humans why the system proposes the decision and must also give humans the possibility to intervene.[15]

The Blockchain (Chapter 3.4.4) is of particular interest for cross-border use, but its use in the field of automated vehicles is still very new, which is why current solutions are hardly or not at all standardised, which can lead to incompatibilities. The main issues in the use of a blockchain as a shared ledger are data regulation and data sovereignty. Control over data and sharing has not yet been fully clarified due to the state of development, and many companies do not yet want to relinquish control due to a lack of trust. Data regulation also comes into consideration in cross-border operations, where it must be clarified how and where data access can or must be granted.[16]

5.1.2 Technological challenges and impact of 5G network

The 5G network is one of the key factors for the introduction of automated driving (chapter 3.5). A number of projects have been funded by the European Commission to investigate the impact and challenges of 5G network.[17][18] Valuable knowledge has been generated that gives a very good overview of the options and challenges in the context of automated driving. The use cases Cooperative Manouvre, Cooperative Perception, Cooperative Safety, Autonomous Navigation and Remote Driving were defined. 5G network was described as an enabler for V2X communication due to very low end-to-end latency, very high reliability and the possibility to handle a very high density of connected vehicles as well as high positioning accuracy.[19]

For the use of 5G network in the sense of cross-border use, five key performance indicators (KPIs) were defined, which consist of high data throughput, low latency, reliability and availability, seamless connectivity and real-time communication. The studies on this topic revealed a large number of challenges, which above all, identified network coverage, MNO collaboration and data plane routing, continuity of service, business enablers and

[13] Luber/Donner (2020): Was ist 802.11p (pWLAN / ITS-G5)?.
[14] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.27-28.
[15] Ibid., p.35.
[16] Ibid., p.30.
[17] European Commission (2020): Europe boosts investment with 70 million Euro in 5G with strong focus on connected transport by launching 11 new projects.
[18] Schroten et al. (2020): The impact of emerging technologies on the transport system, p.28.
[19] Fernandez et al. (2019): 5GCAR Scenarios, Use Cases, Requirements and KPIs, p.9,57.

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non-functional aspects as well as protection and management of data and, if feasible, also defined possible solutions.[20] [21]

In addition to cross-border use, the use in bad weather conditions also brings various problems with it (Chapter 3.5.5). The investigation of different sensors has shown that individual sensors are subject to degraded performance just like the human driver. For example, LIDAR does not function properly in bad weather such as snow, fog or heavy rain and feeds the vehicle with incorrect data. In addition to poor visibility, poor road conditions such as snow or icy roads are also a factor that can cause problems for the internal calculation of driving systems.[22] Besides the technical problems, a closer look at regulation on the basis of standards is also necessary. The definition of the Operational Design Domain (ODD) from the SAE J3016 in chapter 2.2.1 describes the limits of the design domain. These would be exceeded in cases of heavy storms. Depending on the degree of automation, a temporary suspension of the automated driving system is necessary and required. If it is not possible for the human driver to take over the driving task, an interruption of the dynamic driving task (DTT) should be executed in order to put the vehicle into a minimum risk condition.[23]

Furthermore, a system is only compliant with ISO 21448 (SOTIF) if a system considers hazardous situations and adjusts decisions based on probability. However, more specific definitions are still missing here, a correct execution/implementation of the issues defined in the standard is not clear due to the broad interpretation.[24]

The described technologies and concepts lead to different applications of the new technologies (chapter 3.6). Also for the four main smart mobility applications, CCAM, C-ITS, MaaS and SoL, there are different challenges and solutions, which could be identified with the help of the above mentioned EC funded projects.

5.1.3 Safety concepts

Chapter 3.7 describes the safety concepts, which are primarily defined by standards such as ISO 26262. The "Functional Safety" standard of 2018 closes many open questions of the 2011 version, but also leaves questions unanswered. Missing automotive architecture models, such as those described in ICE 61508, must be supplemented, such as failure rate estimation. The design of the existing architecture must be adapted to the safety mechanisms, away from fail-safe to fail-operational or fail-degraded behaviour. In order to meet all challenges with regard to achieving the specified ASIL, the individual architectural elements and functional elements must also be well-defined, and a decomposition of the

[20] Kaloxylos/Gavras/De Peppe (2020): Empowering Vertical Industries through 5G Networks - Current Status and Future Trends, p.21.

[21] Fernandez et al. (2019): 5GCAR Scenarios, Use Cases, Requirements and KPIs, p.9,57.

[22] Zang et al. (2019): IEEE Vehicular Technology Magazine, Nr. 2, Bd. 14,, p.3-8.

[23] Mercedes-Benz Research & Development North America, Inc. and Robert Bosch LLC (2018): Reinventing Safety: A Joint Approach to Automated Driving Systems, p.16.

[24] Bellairs (2019): Why SOTIF (ISO/PAS 21448) Is Key For Safety in Autonomous Driving.

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given architectural elements must be achieved.[25] Furthermore, some experts criticise that ISO 26262 is not well designed for the use of artificial intelligence, which is increasingly used in autonomous vehicles.[26] Artificial intelligence is a complex topic and standards always need a lead time before they are adapted. Therefore, special methods and tools are needed to explain AI-based decision making. Architectures and training methods for robust solutions based on DNN, as well as formal methods for the verification of DNN are necessary.[27]

In addition to ISO 26262 (chapter 3.7.2), RSS (chapter 3.7.3) and subsequently ISO 21448 (SOTIF) (chapter 3.7.4) are defined. RSS defines safe decision-making with the help of mathematical formulas. According to this, it is determined when and what a dangerous situation is, how it occurred and how the vehicle must finally react to it.[28]

The "Safety Of The Intended Functionality" is described in the standard ISO/PAS 21448:2019. SOTIF was developed to describe safety in situations without a system failure. For the case of a system failure there is already ISO 26262. The standard basically describes three areas, which are well represented by a Venn diagram of two overlapping circles, the general objective is to reduce the risk from known unintended behaviour and unknown potential behaviour to an acceptable level of residual risk. This is achieved through verification and validation. Especially in bad weather, SOTIF plays an important role, because compliance with ISO 21448 means that these situations must also be taken into account.[29][30]

The cyber-security of automated vehicles is discussed in chapter 3.7.5 and is defined for cyber-physical vehicle systems in SAE J3061. Here, the term "cyber-security" is defined by Katrakazas et al. in "Advances in Transport Policy and Planning (2020)" as a set of technologies installed/used in autonomous vehicles that serve "to protect the integrity of the network, software and data from attack, damage or unauthorised access". As there is a direct link between road safety and cybersecurity, cybersecurity is an important factor for a successful introduction of automated vehicles. Due to the ever-increasing number of sensors, electrical components, control units and communication devices, the number of cyber attacks on vehicles today is constantly increasing and requires protective measures against such attacks. Many systems that are critical for the vehicle's infrastructure communicate with each other or with external servers (edge computing). Even during communication with other vehicles (V2V), possible malicious manipulations are to be expected. It can be concluded that a "safe state" can only be achieved if the principles of security are adhered to and the system operates safely. Special security measures are introduced to protect the integrity of automated vehicles, their functions and components

[25] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.21.
[26] Hammerschmidt (2019): „ISO 26262 is not perfectly designed for Artificial Intelligence".
[27] Zielke (2020): Is Artificial Intelligence Ready for Standardization?, p.270.
[28] Mobileye (2021): Responsibility-Sensitive Safety - A mathematical model for automated vehicle safety.
[29] Bellairs (2019): Why SOTIF (ISO/PAS 21448) Is Key For Safety in Autonomous Driving.
[30] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.17-19.

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from unauthorized access or manipulation.[31][32]

The 2019 ENISA report "Good practices for security of smart cars" and the 2017 "Threat Landscape report" define some threats to the security and resilience of automated vehicles, consisting of physical threats, failures and communication losses, unintended damage (software malfunctions and failures), nefarious activities, hijacking/interception/hacking and phishing and loss of sensitive data. To counteract the threats, active intervention can be carried out during development by means of SDL (Security Development Lifecycle) and the "defence-in-depth" approach, which originates from the military sector and is interpreted in the context of autonomous driving as the multi-layered use of functions to achieve security goals.[33][34]

Meeting cybersecurity goals will be one of the most important prerequisites for the introduction of autonomous vehicles on the road. It is expected that the expansion of high-speed data transmission technologies, such as 5G networks, will be one of the basic prerequisites for the use of machine learning and other computationally intensive technologies to efficiently protect autonomous vehicles from threats and to detect and combat them in near real time. However, the challenges related to cyber security are multifaceted and require some amendments.[35]

In order to be able to assess the impact of a cyber attack, it is necessary to make a scalable model of the cyber attacks mapped, for example by means of microsimulations, and to consider how much time is needed to address a particular cyber attack before it becomes security-critical. A policy governing the level of trust in inter-vehicle communication is necessary, especially when deciding whether it should be trusted more than, for example, the on-board sensors in the vehicle itself. Certain thresholds need to be set for this, as well as a procedure for dealing with vehicles classified as dangerous. The SAE J3061 standard needs to be adapted to distinguish between system-level and local attacks. The distinction between these attacks is an important safety aspect, as V2V communication often blindly relies on the secure connection between two vehicles. The time it takes a human to regain control of an attacked vehicle must be taken into account when calculating ASIL and subsequently the standardisation of ISO 26262.[36]

Katrakazas et al. defines the following problems and lists possible solutions. The violation of security-relevant systems or problems with the protection of private data in V2X communication make it necessary to encrypt the communication, message layering or the use of proxies. This also prevents misinformation about speed and position data within platoons. Unreliable communication can be counteracted by categorising threats and their effects. By continuously monitoring and analysing diagnostic data collected in autonomous vehicles, maliciously inserted information about traffic flow can be prevented.

[31] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.74-80.
[32] Wood et al. (2019): SAFETY FIRST FOR AUTOMATED DRIVING, p.21-23.
[33] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.81.
[34] ENISA (2019): GOOD PRACTICES FOR SECURITY OF SMART CARS, p.19-20.
[35] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.86.
[36] Ibid., p.87-89.

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Cybersecurity modules are often not considered in vehicle control. Compliance with security and privacy regulations at the hardware and software level is necessary.[37][38][39][40]

5.2 Legal Aspects

The legal framework is often only very slowly adapted to technical developments. In the case of automated driving, this is particularly the case at higher levels of automation. Here, it is the government's task to create an appropriate legal framework in order not to hinder progress across borders in Europe and to enable testing. The legal situation was explained using the hierarchical structure in legislation for a better overview.[41][42]

5.2.1 International agreements and conventions

Starting with international agreements and conventions, the Vienna Convention on Road Traffic of 1968 was discussed, which describes the minimum technical requirements for technical standards of vehicles. Of particular interest in the context of autonomous driving is the amendment published in 2016, which made amendments to Article 8 and Article 39 by adding §5bis. These amendments enable automated driving, provided that the driver is in the vehicle and can override or switch off the system at any time. However, the fact that a driver must be present is seen by many experts as an obstacle to the introduction of fully autonomous driving.[43] Despite the fact that Art 8 para 5bis speaks of a handover of the driving task (under certain circumstances) to an automated driving system, it can be assumed from the wording in the rest of the legal provision that a driver must monitor the driving task at all times and that driving systems up to SAE level 3 are therefore possible. Depending on the country in which the Vienna Convention on Road Traffic has been ratified, Art. 13 and Art. 8 are interpreted differently, resulting in different approaches. In countries such as Germany, Austria, France or Italy, where a change in the legal situation would be necessary, the proposed amendments presented in 4.1.1.3 were discussed.[44] It was concluded, that solving old problems often lead to new ones, and in the case of the Vienna Convention, which was drawn up at a time when autonomous driving was not conceivable, the only solution may be a complete overhaul of the legal text.[45]

[37] Katrakazas et al. (2020): Advances in Transport Policy and Planning, p.87.
[38] Ferdowsi et al. (2019): IEEE Transactions on Communications, Bd. PP,, p.2-4.
[39] Wang et al. (2018): Computer-Aided Civil and Infrastructure Engineering, Bd. 34,, p.4.
[40] Schoitsch et al. (2016): The Need for Safety and Cyber-Security Co-engineering and Standardization for Highly Automated Automotive Vehicles, p.1.
[41] Siemens (2020): Siemens Digital Industries Software, p.3.
[42] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.6.
[43] von Ungern-Sternberg (2018): Völker- und europarechtliche Implikationen autonomen Fahrens (2nd Edition), p.11.
[44] Eugensson (2016): Overview of Regulations for Autonomous Vehicles, p.4-5.
[45] Fußbroich (2019): Die völkerrechtlichen Vorgaben für das automatisierte Fahren, p.16-17.

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In addition to the VC, the UN/ECE regulations are particularly important for the approval of all types of vehicles. Among the large number of ECE regulations, the regulations for automated vehicles mentioned in chapter 4.1.2 are particularly relevant. This includes regulations 6 (Direction indicators), 13H (Brake systems of passenger cars), 48 (Installation of lighting and light-signalling devices) and 79 (Steering equipment). On the basis of the examination of the individual regulatory texts, it became apparent that although regulations 6 and 48 describe a "driver" in paragraph 1.1, according to experts, the absence of this driver is not in contradiction with the legal text.[46] In ECE Regulation 13H, which refers to the vehicle's braking system, emergency braking functions are explicitly defined as "automatically commanded braking" in paragraph 2.20.[47] The regulation in 5.2.1, which prescribes three independent braking systems, is also not in conflict with automated driving functions, in which automated braking or emergency braking functions in particular can be carried out by redundant electric motors.[48][49]

Regulation 79 is often defined in the literature as a key issue when it comes to the introduction of automated driving. After a series of revisions, the current version in 2.3.3 defines two different classes of "autonomous steering systems", parking assistants (2.3.4.1.1) on the one hand and lane change assistants (2.3.4.1.2-6) on the other. Since these systems, which can be approved, still require a driver to be present at all times, who is responsible for monitoring the driving task, level 3 driving systems are feasible according to SAE J3016. Regulation 79 can therefore be seen as one of the primary obstacles to the introduction of automated driving.[50][51][52]

5.2.2 Regulations and directives within the EU

The regulations and directives within the EU were described one level lower in the hierarchy in Chapter 4.2. These concern the Regulation on the approval of motor vehicles, Regulation (EU) 2018/858, the General Safety Regulation (EU) 2019/2144, the General Data Protection Regulation (EU) 2016/679, and the Guidelines of the EDPB, which also have a decisive influence.

Regulation (EU) 2018/858 defines the technical framework for the approval of vehicles of different types and refers to other EU-Regulations and ECE/UN regulations.[53] In order

[46] Lutz (2016): Automated Vehicles in the EU: Proposals to Amend the Type Approval Framework and Regulation of Driver Conduct, p.2.

[47] Fußbroich (2019): Die völkerrechtlichen Vorgaben für das automatisierte Fahren, p.11.

[48] UN/ECE (2018a): UN Regulation No. 13-H Revision 4, p.12.

[49] Lutz/Tang/Lienkamp (2012): Analyse der rechtlichen Situation von teleoperierten und autonomen Fahrzeugen, p.3-4.

[50] Böning/Canny (2021): Freiburger Informationspapiere zum Völkerrecht und Öffentlichen Recht, Bd. 1,, p.8.

[51] Lutz (2016): Automated Vehicles in the EU: Proposals to Amend the Type Approval Framework and Regulation of Driver Conduct, p.2.

[52] Dittmers (2019): Autonomous Driving - Overview of the Current Legal Framework, p.8.

[53] European Parliament, Council of the European Union (2018b): Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018, p.87-97.

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to drive technical progress, it is possible to approve vehicles intended for test purposes and using technologies that do not comply with the directive, either by type approval with the permission of the Commission, or by individual approval with the provision of alternative technical requirements.[54]

The General Safety Regulation (EU) 2019/2144 described in chapter 4.2.2 amends Regulation 2018/858 in certain areas and repeals some other regulations. Its main purpose is to promote general safety by increasing the safety requirements for vehicles within the EU, to take into account vulnerable road users such as cyclists or pedestrians, but also to create legal certainty.[55] As the transposition of the directive is not due until 6 July 2022, it is not yet possible to form an exact judgement on the quality of the transpositions of the individual member states. However, on the basis of the drafts published by the European Commission for the implementation of the regulation, conclusions can be drawn as to how the individual countries are proceeding with the implementation into national law. After reviewing the draft, a team of experts from "Digitaleurope" defined some points of criticism, for example, the lack of some important definitions, as detailed in SAE J3016 described in chapter 2.2.1. In the further course of Digitaleurope's analysis, comments are made on the topic of human monitoring and vehicle behaviour, as well as on the fail-safe strategy and the requirements for the human-machine interface (HMI).[56] These are based on a draft that can still be revised until the time of mandatory implementation.

The General Data Protection Regulation (EU) 2016/679 (Chapter 4.2.3) or "GDPR" plays a central role in autonomous driving due to the large amounts of data that is generated, transferred and stored. In Article 5, the GDPR defines various principles under which the non-automated, partially automated and fully automated processing of personal data is to be carried out. The principles basically aim at a responsible handling of data, which requires integrity and confidentiality, as well as processing in good faith. Transparency and accountability, as well as accuracy and purpose limitation are also important. Furthermore, care is taken to enforce data minimisation and storage limitation.[57]

In connection with automated driving, there are some possible risks with regard to data protection. These were listed in 4.2.3.2 and include risks from localisation data, sensor data, driver monitoring, communication and the accident data logger. Even though the GDPR does not specifically address autonomous vehicles, the legal provisions can also be applied to them and also offer corresponding exceptions for test operations. In order

[54] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.81-82.

[55] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.4-5.

[56] DIGITALEUROPE (2021): DIGITALEUROPE's comments on the draft Implementing Act on ADS, p.1-2.

[57] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.77-78.

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to minimise risks, various recommendations were listed in 4.2.3.3.[58][59][60]

On the basis of the GDPR, the European Data Protection Board (EDPB) established guidelines, which were published in a second, revised version on March 9, 2021. In addition to the GDPR, reference was also made to the ePrivacy Directive. The EDPB also lists risks with regard to connected vehicles, which are defined in paragraph 46 to 60. The risks regarding data protection and privacy of data include "Security of personal data", "Further processing of personal data", "Excessive data collection", "Lack of control and information asymmetry" and "Quality of the user's consent" are described in 4.2.4.1. The EDPB guidelines also contain recommendations on certain topics. These recommendations are primarily aimed at the vehicle manufacturers and suppliers of technical systems that act as data controllers or processors. These recommendations cover the categorisation of data, recommendations on the handling of biometric data, data protection by design, data protection by default, the local processing of personal data, and information to be provided to the data subject. The rights of data subjects, security measures and the transfer of personal data are also dealt with. A detailed explanation can be found in chapter 4.2.4.2.[61][62]

5.2.3 Legislation and regulation in Austria

At the national level, the main focus lies on the legal situation in Austria. Here, laws were considered that are specifically applicable in Austria and have not already been mentioned at a higher level. Since there is always some room for legislative improvement at the national level, this aspect is particularly interesting in terms of the progress for autonomous driving, since in contrast to the EU level, changes can still be made more easily here.[63] Legislation was specifically researched that has an influence on automated vehicles or that was specifically created for their use.

The legal situation regarding autonomous driving in Austria is relatively simple and not very far developed. The Motor Vehicle Act (KFG) described in Chapter 4.3.1 is one of the most important legal texts with its 33rd amendment. With the help of this amendment, which amended §102 KFG in paragraph 3a and 3b, autonomous driving became possible for the first time in Austria in 2016. These new legal foundations made test drives on public roads possible for the first time, but these sparsely worded legal

[58] Kunnert (2017): „Autonomes Fahren“ aus datenschutzrechtlicher Sicht, in Eisenberger/Lachmayer/Eisenberger (Hrsg), Autonomes Fahren und Recht (2017), 169, p.190-196.

[59] Böning/Canny (2021): Freiburger Informationspapiere zum Völkerrecht und Öffentlichen Recht, Bd. 1,, p.21.

[60] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.77.

[61] European Data Protection Board (2021): Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications Version 2.0 Adopted on 9 March 2021, p.15-22.

[62] Haselbacher (2020): jusIT - Zeitschrift für IT-Recht, Nr. 4, Bd. 2020/46,, p.10-11.

[63] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.5.

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texts were not sufficient to serve as a suitable legal basis for test drives of automated vehicles.[64][65][66] Problems arise mainly due to a lack of concretisation of the framework conditions regarding the exemption from driver duties and for the transfer of driving tasks to approved systems, as well as due to partially contradictory formulations of the legal text, as described in chapter 4.3.1.2.[67][68] Furthermore, there may be problems with the authorisation procedure for test drives, as well as for those affected in cases of damage in the context of test drives due to constitutional and simple legal problems. The form of action through blanket exemptions at ordinance level and notification obligations of vehicle operators make effective legal protection more difficult. In the interest of legal certainty, whether for the affected road users or the applicants for test drives, it is necessary to create a legal framework that provides clear foundations in conformity with fundamental rights.[69]

A constitutional solution to the aforementioned competence-law problems regarding driver obligations would be an exemption in the StVO. An "extension" of the term "driver" in the StVO to non-human road users in favour of test drives would be conceivable.[70][71] In order to solve the problems with the licensing procedure, these would have to be defined in the KFG, as well as the StVO, either as a decision variant or as a certificate variant. As a possible solution for a lack of legal stipulation, in addition to a possible integration of missing legal regulations (with regard to data processing, the requirements for test drivers or the design of approval procedures) into existing laws, a possible enactment of an independent law (e.g. AutomatFahrG) that combines regulations for test drives of automated vehicles can also be considered.[72]

Based on the 33rd amendment to the KFG, the AutomatFahrV was created, which refers specifically to the amended sections §102 para. 3a and b, as well as §34 para. 6 KFG. Special applications were defined, which according to §§7 to 9 AutomatFahrV range from autonomous minibuses and motorway pilots with automatic lane changing to self-driving army vehicles. Special driving assistants were provided for in §10 and §11 AutomatFahrV, which include highway assistants with automatic lane-keeping and parking assistants. Since the driver must be able to activate the "emergency system" at any time, autonomy

[64] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.7.

[65] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.147.

[66] Bundesministerium für Verkehr, Innovation und Technologie (2016): 33. KFG-Novelle.

[67] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.162-163.

[68] Lachmayer (2017b): Zeitschrift für Verkehrsrecht, Nr. a, Bd. 12,, p.517.

[69] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.166-167.

[70] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.93-94.

[71] Lachmayer (2017b): Zeitschrift für Verkehrsrecht, Nr. a, Bd. 12,, p.516-517.

[72] Ibid., p.517-518.

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level 3 is possible according to SAE J3016.[73][74] The AutomatFahrV is considered a central instrument for promoting automated driving in Austria, but according to Lachmayer it is a difficult task to develop because the legal basis was already insufficient at the beginning of its adoption. The conceptual problems of the KFG described in chapter 4.3.1.2 were carried over into the AutomatFahrV and led to an insufficient specification of the requirements. This is not surprising, since due to the tiered structure of the legal system, the lack of a legal basis cannot be corrected by an ordinance. Due to problems with the approval or licensing procedure, described in 4.3.2.1, some experts are of the opinion that the current version of the AutomatFahrV must be considered unconstitutional and unlawful and does not provide a constitutional basis for the operation and testing of automated vehicles on public roads. In order to enable testing on public roads and provide a legal basis for civil, regular use of autonomous vehicles, a variety of further legal regulations are still required.[75]

Data protection laws at the national level are strongly based on the EU General Data Protection Regulation and were therefore mostly addressed in chapters 4.2.3 and 4.2.4. It is worth mentioning that the AutomatFahrV specifically refers to special legal provisions for the use of accident data recorders. According to §5 para 1 AutomatFahrV, every vehicle must be equipped with such a data recorder during a test drive. As claimed by experts, however, there is no legal basis for such a requirement.[76]

Liability law at national level in Austria for the context of autonomous driving is mainly covered by ABGB - General Civil Code (chapter 4.3.4.1), EKHG - Railway and Motor Vehicle Liability Act (chapter 4.3.4.2), PHG - Product Liability (chapter 4.3.4.3) as well as by KFG - Liability Insurance (chapter 4.3.4.4). Liability for fault is standardised in the ABGB under §§1293ff and serves as the first starting point for liability issues. The person causing the damage is also responsible for the damage caused, therefore the first contact person is also the driver if he has not fulfilled his duty of care. However, depending on the degree of autonomy, this does not necessarily lie with the driver of the vehicle.[77][78]

The so-called "liability shift" is legally solvable with today's levels of autonomy (level 3-4), but poses a problem with higher levels of autonomy, especially in terms of provability.[79] The EKHG defines the strict liability of the owner, which under §5 para 1 EKHG defines that the owner is liable for the compensation of the damage. However, as only level 3

[73] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.25-26.

[74] AustriaTech (2017): Automatisiertes Fahren in Österreich - Monitoringbericht 2017, p.10.

[75] Lachmayer (2017a): Verkehrsrecht: Rechtsstaatliche Defizite der Regelungen zu Testfahrten, p.165-166.

[76] Ibid., p.164.

[77] Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.164.

[78] Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.9.

[79] Hey (2019): Die außervertragliche Haftung des Herstellers autonomer Fahrzeuge bei Unfällen im Straßenverkehr, p.243-245.

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vehicles are admissible under current law, liability remains with the driver under §6 para. 2 EKGH, as the driver is not released from his duty of care at these levels of autonomy.[80]

The Product Liability Act (PHG) defines under §5 para. 1 nos. 1-3 three different types of defects, which are divided into instruction flaws, fabrication flaws or design flaws. For better traceability, it can be advantageous to use "black boxes" that record the course of the accident. For the autonomous driving systems and vehicles that can currently be approved, the current legal framework is sufficient and there are no gaps. There are also special exemption conditions for testing new technologies. For new scenarios, the obligation to take out increased liability insurance can be beneficial.[81][82][83] In the future, an increasing degree of automation may lead to a shift in liability, away from negligence on the part of the driver and towards abstract strict liability on the part of the owner or manufacturer and product liability.[84]

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[80]Templ (2016): Manz, Bd. ZVR 2016/7,, p.12.
[81]Lachmayer/Eisenberger/Rehrl (2019): EXTRA LAW – MOBILITY Experimentierräume im Verkehrs- und Mobilitätsrecht, p.164-165.
[82]Templ (2016): Manz, Bd. ZVR 2016/7,, p.12.
[83]Cacilo et al. (2015): Hochautomatisiertes Fahren auf Autobahnen - Industriepolitische Schlussfolgerungen, p.140-141.
[84]Bundesministerium für Verkehr, Innovation und Technologie (2018): Automatisiertes Fahren auf Straßen mit öffentlichem Verkehr – Rechtliche Rahmenbedingungen im Vergleich, p.9-10.

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CHAPTER 6

Survey of experts

The situation of automated driving is constantly changing. In order to get a deeper insight into current and future scientific findings, experts in various fields were consulted. Below are the raw versions of the interviews that were used for the research.

6.1 Dr. Kurt Hofstädter

Interview Partner	Dr. Kurt Hofstädter; Director Digital Strategy Siemens AG Österreich
Date	08.03.2022
Time	14:30 - 15:30
Language	German
Location	Vienna
Communication	online conference

Was sind die Enabler des automatisierten Fahrens? 5G-Network, Edge-Computing, AI, neue rechtliche Rahmenbedingungen? Das erste ist ganz klar die Sensorik, man benötigt entsprechende Sensorik die das Umfeld entsprechend, möglichst komplex wahrnimmt, also einen sogenannten Digital Twin erstellt. Dazu gehören natürlich entsprechende Prozessoren, weil gigantische Datenmengen verarbeitet werden müssen. Ich habe das bei AVL List gesehen, dort konnte ich mit einem BMW autonom mitfahren durch Graz und konnte dort auf einem Bildschirm mitverfolgen was für Rechenoperationen notwendig sind damit das Auto fährt. Man sieht aber nur wenige Auswertungen, die Datenmengen die dahinter stecken sind gigantisch und dann daraus ein realistisches Ebenbild zu kreieren ist dementsprechend aufwendig. Später werden dann auch Car2Car und auch das gesamte Umfeld (intelligente Ampeln, Straßen, Kennzeichen, Schilder, etc.) benötigt. Es ist ein multikomplexes System das zusammenarbeiten muss und wichtig ist aber auch, dass ich neue Fahrzeuge und Infrastruktur auch mit neuer Technik ausrüsten muss, aber wir in den nächsten 10 bis 20 Jahren natürlich eine Umgebung haben wo der überwiegende Teil der Verkehrsteilnehmer, zwar abnehmend aber immer noch groß genug ist, die eine solche Sensorik nicht verbaut hat. Das heißt man kann nicht darauf vertrauen, dass wenn ich zu einer Stop-Tafel hinfahre das sich diese „meldet“ und sagt halt ich bin eine Stop Tafel sondern das Fahrzeug muss das erkennen, genauso auch die Car2Car Kommunikation wird noch lange nicht so funktionieren wie wir das wollen weil 99 % der Auto das schlichtweg nicht können.

Komar: Das habe ich in meiner Recherche auch so gesehen, da gibt es den Unterschied zwischen den sensor based vehicles und den cooperative and communication based vehicles. Wie Sie eben auch gesagt haben, bei den Sensor basierten Fahrzeugen ist das Problem, das die Umwelt kaum perfekt ist, also es da oft Verbesserungsbedarf gibt. Deshalb habe ich das auch in die Frage mitaufgenommen, bei der Vehicle2Vehicle Kommunikation und Vehicle2System ist die Übertragung äußerst wichtig auch aufgrund hoher Datenmengen, geringer Latenzzeiten und Verfügbarkeiten. Da würde ich eben auch das Edge Computing miteinbeziehen da die Prozessorleistung ja nicht zwingend im Fahrzeug sondern auch in Nodes außerhalb des Fahrzeuges geleistet werden kann.

Dr. Hofstädter: Beim Edge Computing ist natürlich eines wichtig, sie müssen das so nah wie möglich dorthin bringen wo es auch gebraucht wird. Edge Computing im Zusammenspiel mit der Cloud nützt hier nichts, wenn sie überlastet oder gerade nicht verfügbar ist Also man braucht im Edge Computing möglichst hohe Computerleistung dort wo dann die Bremsung stattfindet, wo also die Kommunikation stattfindet und 5G ist echtzeitfähig aber diese ist nur relativ gegeben. Die 5G Netze der Anbieter ist zwar echtzeitfähig aber nicht darauf ausgelegt. 5G und Echzeitfähigkeit muss man differenzieren. In Deutschland gibt es im 5G Netz zum Beispiel eine Industrie Bandbreite, diese ist zum Beispiel für Industriekunden reserviert.

Sehen Sie eine Zukunft in der Nutzung der Blockchain als shared ledger? Bitcoin funktioniert so, dass das Wissen auf alle Rechner verteilt ist, dann ist nicht einer praktisch der der die ganzen Daten hat. Andererseits wiederum, wenn Sie sich mit BitCoin eine Leberkässemmel kaufen und auf 100000 Rechnern dieser Welt der Schlüssel verteilt ist, dann können Sie sich ausrechnen, was eine Transaktion kostet, zum Beispiel alleine an Energieverbrauch und wenn die Transaktion ein Vielfaches ist klaffen die Transaktion kosten und der Transaktionnutzen weit auseinander und da muss man dann auch überlegen welche Dinge dürfen auf keinen Fall jemandem anderen bekannt sein. Das Problem ist dann mit den privaten Daten die zum Beispiel von einem Servicetechniker bzw. einer Firma überwacht werden, ob Sie zum Beispiel ihre Pläne einhalten, ob sie unerlaubte Pausen machen, arbeitsrechtliche Themen. Also bei der Blockchain habe ich noch keine Meinung in welche Richtung es da gehen wird, ob der Nutzen einer Blockchain so groß sein wird das die Nachteile, also der doch sehr große hohe technische Aufwand dem gerecht wird.

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Wie kann den Gefahren bei schlechtem Wetter (technisch) begegnet werden? Schwierig, mit meinem Dienstwagen, kann ich relativ gut von Wien bis ins hinterste Murtal mit dem Auto relativ gut autonom fahren. Am Semmering ab etwa 130-140, würde ich noch nicht auf die Idee kommen hinten zu sitzen und das Auto fährt dann von selber, weil es immer wieder passiert, dass das Fahrzeug ein wenig aus der Spur kommt und dann schreibt es, bitte übernimm.

Komar: Dahin gehend möchte ich etwas anmerken. In diese Richtung habe ich auch schon recherchiert und bin zu der Konklusion gekommen, dass bis Level 3 (SAE J3061) es eine Operational Design Domain gibt. Das ist ein Bereich, in dem das System funktionieren soll und muss. Diese Domain, also dieser Bereich ist je nach Level unterschiedlich, deswegen kann es eben sein, dass bis zu Level 3 zum Beispiel bei Schlechtwetter es außerhalb dieser Domain liegt und dann muss das Fahrzeug den Fahrer auffordern das Fahren wieder zu übernehmen. Da kommt es halt dann wieder auf das Level an, weil bei Level 4 oder Level 5 sich der Fahrer dann nicht mehr um das Geschehen kümmern muss. Laut dieser Definition ist es aber auch derzeit rechtlich nicht möglich, aber da ist dann wieder die Frage wie würde man es technisch regulieren. Da gibt es wieder andere ISO Normen z.B. 21448 (Road vehicles — Safety of the intended functionality ("Sicherheit der Sollfunktion")), da geht es darum, dass solche Gefahrensituationen bei der Konstruktion eines Fahrzeuges miteinkalkuliert werden müssen. Das ist bei höheren Autonomisierungsgraden schwierig und da habe ich auch noch keine Antwort dazu gefunden und nun ist meine Frage, gibt es dazu überhaupt eine Antwort.

Dr. Hofstädter: Also meine Erfahrung ist, im Zuge meiner beruflichen Tätigkeit, ist bis Level 3 und bis zu meinem Dienstwagen. Im Prinzip funktioniert es sehr gut. Die Radarfunktionalität ist gegeben, er erkennt rote Ampeln und Stop-Tafeln meistens, er erkennt aber auch Stoptafeln für die Seitenfahrbahn schräg stehen. Das bedeutet aber das man noch wesentlich mehr Logik einbringen muss. Wenn ein Fahrzeug auch nur wenig in die Fahrbahn reinragt, erkennt der Wagen das als stehendes Fahrzeug und leitet eine Notbremsung ein. Alle diese Fehler darf es bei Level 4 nicht mehr geben. Das nächste sind Baustellenbereiche. Bei einer Fahrt Richtung Mariapfarr wurde die Autobahn verlängert und da kommen auf einmal Kreisverkehre und Baufahrzeuge. Die Fahrbahn ist auf 30 bis 40 Meter komplett verschlammt und Schotter ist auf der Straße. Also zu erkennen ist da nichts mehr, also das Level 3 Auto erkennt da auch nichts mehr. Das Level 4 Auto muss das alles in Echtzeit erkennen und logisch reagieren. Die Entwicklung der letzten 20 Jahre war beachtlich. Vor 20 Jahren haben wir gesagt wir brauchen noch 20 Jahre und je näher wir diesen 20 Jahren gekommen sich, umso weiter ist das Ziel der nächsten Level eigentlich gesteckt. Die Herausforderungen pro Level immer mehr und mehr, ich muss Ihnen eines sagen ich kann mir Level 4 jetzt schon kaum vorstellen. Als Beispiel es beginnt jetzt Schneefall und die Sensoren vorne werden verdeckt. Die kann man natürlich alle beheizen, die können aber schmutzig sein, das kann man nicht wegheizen. Das müsste man wieder permanent spülen. BMW zum Beispiel ist hier deutlich besser geworden also beim Radar. Das hat zu Beginn bei leichtem Schneefall, dickere Flocken schon aufgegeben. Ich kann hier aus eigener Erfahrung sagen, das passiert jetzt nur mehr

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kaum, aber trotzdem, um es sich hier quasi auf der Rückbank gemütlich zu machen fehlt es doch noch an einigem, außer eventuell 10-fach redundante Sensorik, dass egal was ausfällt man noch ein Backup hat. Level 3 kann man noch optimieren, Level 4 wird schwierig und Level 5 kann ich mir derzeit noch gar nicht vorstellen mit der momentanen Sensorik die wir haben, auch wenn Elon Musk dauernd davon fantasiert, das ist meines Erachtens nach weit von der Realität entfernt. Ich kenne momentan keine Technik mit der man das realisieren kann.

Was ist notwendig um die Ziele der Cyber-Sicherheit nach SAE J3061 zu erreichen, welche Rolle spielt 5G Network für einen "Echtzeit" Schutz? Das ist wie jede andere Cybersecurity Frage, speziell wenn sie mit AI in Kontakt ist. Ich habe einen sehr interessanten Vortrag vor etwa 2 Jahren gehört von Kollegen von der TU München. Die haben uns gezeigt, wie einfach man, wenn man sich auskennt einbrechen kann ins Autonome fahren und der künstlichen Intelligenz Dinge beibringen kann. Die haben das Auto gehackt und haben demonstriert, wenn man auf die STOP-Tafel einen Aufkleber draufklebt wird die STOP-Tafel in 90 Prozent der Fälle immer noch als STOP-Tafel erkannt aber eben in 10% der Fälle als Tempo 100 Tafel. Das bedeutet das jeder zehnte Fußgänger vom Fahrzeug erfasst wird. Man braucht da nicht viel Vorstellungskraft was das in Wien bedeutet. Die Kollegen haben mir dann erklärt, dass die Systeme nicht permanent online sein müssen. Industrie Prozesse zum Beispiel sind auch nicht permanent am Netz. Ich wüsste keine Methode heute zu sagen das kann man durch die Industrie abwehren. Natürlich ist die Industrie permanent dran noch besser zu werden. Aber wenn selbst die großen IT-Konzerne à la Google gehackt werden oder jetzt zum Beispiel auch die Ukraine Krise wo man auch davon ausgehen kann das Hackangriffe von Russland aus ausgehen. Da muss ja einer dabei sein, der wieder ein Schlupfloch findet. Systeme kann man quasi nur durch eine Entkopplung sicher machen, also das ein permanenter Internetzugriff nur auf gewisse Teile des Fahrzeuges herrscht, alle Sicherheitsrelevanten Teile dürfen einfach nicht am Internet hängen und müssen komplett autonom sein. Das ist in der Industie üblich, muss jetzt auch auf das automatisierte Fahrzeug übernommen werden.

Wie sehen Sie die rechtliche Situation des autonomen Fahrens in Österreich? Besonders in Bezug auf Level über 3? Da habe ich aktuell keine Idee dazu. Minister Leichtfried hat damals in seiner Zeit gewisse Dinge freigegeben, in der Steiermark eine Teststrecke zum Beispiel, wo das jetzt trainiert wird. Das Problem ist halt, beim Menschen weiß man, dass er gewisse Gefahrensituationen schlichtweg nicht im Griff hat, zum Beispiel wenn Sie jetzt bei Glatteis ins Schleudern kommen und Sie haben da eine Dame mit einem Kinderwagen, dort eine Kindergruppe, hier noch eine Gruppe mit Kindern und und und; da weiß man der Mensch beherrscht das nicht. Dann passiert etwas und der Mensch ist daran schuld. Es gibt viele Situationen im Leben wo man sagt da gibt es ein Risiko. Bei einem Flugzeug zum Beispiel weiß man auch das die Software nie 100-prozentig ausgetestet sein kann und alle Fehler verzeiht. Ein gewisses Restrisiko gibt es auch bei Dingen des täglichen Lebens, Bahn fahren zum Beispiel.

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Dieses Restrisiko nehmen wir aber in Kauf da wir uns sonst gar nicht mehr bewegen können. Das Problem bei Level 4 ist das man Software hierfür zertifizieren muss und diese Software muss ja beweisen was sie wann macht. Dort harkt es derzeit. Denn welche Behörde soll abnehmen, dass man jetzt Pensionist gegen Frau mit Kind „opfern“ oder Schulbus gegen ein einzelnes Kind. Das was die Menschheit nicht beherrscht kann die Software auch nicht. Die Software ist um ein Vielfaches besser als der Mensch, aber sie hat Kausalitäten und diese muss eine Behörde abnehmen.

Komar: Das ist diese typische Dilemma Situation, die man beim autonomen Fahren hat. Welche Entscheidung trifft das Fahrzeug jetzt und vor allem wer ist dann schuld, die Haftungsfrage ist bei so hoch- bzw. Vollautomatisierten ist sehr komplex, weil da gibt es den sogenannten Liability Shift wo dann die Schuld nicht mehr beim Lenker des Fahrzeuges ist, sondern dann Richtung Hersteller geht, der das dann wieder Richtung Software Hersteller weitergibt und so weiter. Das ist gerade bei über Level 3 einer der Kernpunkte, die es noch zu lösen gilt.

Dr. Hofstädter: Und dann, wenn künstliche Intelligenz noch diese Entscheidungen trifft, dann passiert es und Sie können der Behörde nicht einmal sagen warum es passiert ist.

Was sind Ihrer Meinung nach die größten rechtlichen/technische Problemstellungen? Aktuell und in Zukunft? Komar: Ich darf hier vielleicht etwas anmerken, zu sensor und communication based vehicles. Für geringe Distanzen gibt es aktuell 2 Standard. Den ITS G5 und den Cellular Vehicle to Everything Standard. Der eine basiert auf WLAN und der andere auf 3GPP bzw. LTE oder 5G je nach Ausführung. Das Problem das ich dabei realisiert habe ist, dass beide auf dem 5,9 GHz Band laufen und nicht nur nicht kompatibel sind, sondern untereinander auch Störungen verursachen können.

Dr. Hofstädter: Meiner Meinung nach sollte das Auto immer noch funktionieren, wenn man in irgendeinem Alpental mit geringem Netzempfang ist. Das man zum Beispiel stufenweise abfällt, also von Level 5 auf Level 4 und dann auf Level 3 und ab dann muss der Fahrer ja eh selbst wieder übernehmen. Also ein Auto ohne Lenkrad wir es so nie geben, was ist wenn man in der Tiefgarage kein Netz hat, dann bekommt man das Auto ja nie wieder aus der Garage raus wenn man selber gar nichts machen kann. Die ganzen Frequenzen und Überlappungen sind problematisch, das ist unbestritten. Je höher Sie in der Frequenz gehen, desto kleiner werden die Zellen. Im Gegensatz zur Langwelle wo man mit einer Sendung um die ganze Welt kommt. Sie kommen mit 5G nur etwa 50 bis 100 Meter. Somit benötigen Sie mehr Antennen für dieselbe Netzabdeckung. Alle diese Antennen haben natürlich wieder eine Störanfälligkeit. Und nicht nur die Antennen, sondern generell die Hardware und wir kommen dann in solche Größenbereiche das rein statistisch immer etwas kaputt sein wird. Und man sieht das zum Beispiel in einem Automobilwerk, dort haben wir etwa 1.000 Roboter und etwa 100.000 Sensoren. Da gibt es eigene Teams die schauen das dort alles funktionier und Störungen in kürzester Zeit behoben werden. Das muss man dann auch flächendeckend für Europa haben. Das sind alles wieder Infrastrukturkosten und technische Kosten und ein Auto muss ja immer noch

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einen Preis haben, den man sich auch noch leisten kann. Das muss auch im Einklang bleiben, sonst können sich Autos nur mehr die obersten 10% der Bevölkerung leisten. Dann hat es aber auch keinen Sinn. Das heißt die Sicherheit und der Komfortgewinn muss in Relation zu einem ökonomischen Preis stehen und zu den sozialen Möglichkeiten einer Volkswirtschaft. Um auf Ihre Frage aber zurückzukommen. Die Inkompatibilität wird nicht viel besser werden. Elon Musk z.B. wird sich von Volkswagen zum Beispiel nicht viel reinreden lassen. Ganz im Gegenteil der wird sich von niemandem dreinreden lassen und die werden alle ihre eigenen Systeme haben. Die EU wird eigene Systeme haben mit der Europäischen Cloud und GAIA-X, die werden unter europäischem Recht funktionieren. Im Gegensatz zum US-Recht wo der Staat jederzeit auf alle Daten Zugriff hat. Es wird immer unterschiedliche Normen geben Die Autos müssen aber all diesen Normen entsprechen und wie Sie richtig sagen die können sich durchaus gegenseitig stören. Aber umgekehrt, überlegen Sie einmal wie viele Stecker man dafür braucht um einen Fön in ganz Europa zu verwenden. Eisenbahnwesen zum Beispiel in ganz Europa, hier als Untergruppe U-Bahnen in Europa. Es gibt in Europa keine 2 vergleichbaren U-Bahnen, weder die Schienen noch die Tunnel-Durchmesser. Aber nein, man baut nicht von einer U-Bahn 10.000 Stück sondern 300 verschiedene Modelle.

Komar: Es ist vielleicht noch einfach das auf europäischer Ebene zu Standardisieren. Aber wenn man jetzt überlegt, Fahrzeughersteller gibt es auf der ganzen Welt. Da müsste ja der amerikanische Fahrzeughersteller mit dem japanischen und dem deutschen zusammenarbeiten und sich auf eine Sache einigen.

Dr. Hofstädter: Es gibt hier Standardisierungs-Komitees. Hier ist China sehr auf dem Vormarsch, die eigenen Normen einzuführen. Viele afrikanische Staaten schließen sich den chinesischen Normen an um damit die Dominanz der europäischen Standards zu schwächen. Also ich sehe hier eher Markttendenzen der Differenzierung.

Komar: Es gibt ja, wie sei bereits gesagt haben, das European Interoperability Framework, die EIF von 2017, die für die Konformität von solchen Standards sorgt. Da habe ich auch gelesen, dass das zwar vorgesehen ist, aber auf einen gemeinsamen Nenner ist man noch immer nicht gekommen, wie Sie schon sagten. Das wird sich noch länger ziehen.

Wie sinnvoll ist es z.B. örtlich die SAE Level zu beschränken, z.B. Innenstadt kein Level 5? Dr. Hofstädter: Da bin ich nicht genug in die Materie vertieft, aber das wird so nicht funktionieren, dass jeder Level überall funktioniert. Zum Level 5 das wird vielleicht auf Autobahnen funktionieren, aber nicht in Seitengassen im ersten Bezirk. Sie werden es vielleicht noch erleben. Level 5 kann aus heutiger technischer Sicht eh noch nicht erreicht werden.

Komar: Rein aus der Definition dieser SAE Norm, unterscheidet Level 4 und Level 5, dass bei Level 4 die Vollautonomität auf eine bestimme Design-Domain beschränkt ist also z.B. von auf die Autobahn Auffahren bis von der Autobahn Abfahren. Und bei Level 5 gibt es keine Beschränkung, dass heißt einsteigen und aussteigen.

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Dr. Hofstädter: Also Level 4 kann ich mir noch vorstellen, weil 4 würde ja auch erreicht werden, wenn ich einen Kilometer auf der Autobahn definiere auf dem die Fahrzeuge Vollautonom fahren dürfen. Level 4 für ganz Österreich stelle ich mir schwierig vor und Level 5 wüsste ich nicht wie.

Darf es zu einem (regionalen) Verbot kommen, selbst ans Steuer zu gehen? z.B. wenn die Wahrscheinlichkeit für einen Unfall automatisiert geringer ist. (z.B. bei Schulen) Dr. Hofstädter: Das werden die Automobil-Hersteller nicht machen. Die Haftungen dahinter sind viel zu hoch, die werden diese Verantwortung lieber immer dem Fahrzeugführer geben.

Was ist Ihre Meinung zum Liability Shift bei autonomem Fahren in höheren Autonomisierungsgraden und wie kann diesem begegnet werden? Komar: Das gilt bei höheren Autonomitätsgraden, bei Level 3 hat man das Problem eh nicht, weil ja da noch der Fahrer immer reagieren muss und immer aufgefordert werden kann ans Steuer zu gehen, das heißt er darf seine Überwachsungspflicht ohnehin nicht vernachlässigen, wenn er das macht, ist ohnehin der Fahrer schuld. Ab Level 3 ist es dann die Frage.

Dr. Hofstädter: Man muss andere Techniken dann nutzen. Techniken die da vielleicht schon etwas weiter sind. Nehmen wir die Luftfahrt zum Beispiel. Wenn heute ein Pilot fliegt, fliegt er ja praktisch vollautomatisch aber im Landeanflug muss er selber übernehmen, weil die Systeme nicht sicher genug sind. Also in der Höhenkontrolle kann er Probleme bekommen, wenn der Gegenwind stärker wird aber wenn der Gegenwind abflacht oder wenn der Rückenwind stärker wird, muss der Pilot das selbst in der Hand haben. Trotzdem, wenn ein Pilot fliegt, sind viele der Systeme autonom. Der weiß ja nicht, wenn er etwas macht wie jetzt die gesamten Systeme darauf reagieren und arbeiten. Die können kaputt sein, aber statistisch sind die immer noch besser als wenn der Pilot das selber überwachen würde. Beim Auto hat man das ja auch zum Teil schon. ABS-Systeme zum Beispiel. Wenn Sie ein guter Autofahrer sind, können sie selber besser Bremsen als jedes ABS-System. Trotzdem verwendet man ABS-Systeme weil es wiederum statistisch besser bei einer Notbremsung ist, als wenn man darauf vertraut, dass der Fahrer richtig reagiert.

Wie sehen Sie die Zukunft der privaten Daten, wo hört Sicherheit auf und wo fängt Datenschutz an? Wer oder was darf/soll überwacht werden und mit wem darf geteilt werden? Dr. Hofstädter: Es ist schwierig, weil im Prinzip haben wir eine dichte an Daten die wir permanent abgeben von uns und ich habe alle Systeme bei mir abgedreht, die Ortungsfunktionen etc. und meine Kollegen schmunzeln dann immer etwas und fragen: „Darf ich Ihnen zeigen was Sie alles an Daten abgegeben haben?“ und dann zeigen die mir wieder wo ich die ganze letzte Woche überall herumgefahren bin, bei welchem Billa ich einkaufen war, wann ich meine Mutter besucht habe, wo ich war obwohl ich alles abgedreht habe. „Ja sie haben das abgedreht, aber das da drinnen können Sie gar nicht abdrehen und auslesen kann man es trotzdem.“ Ich glaube wir haben

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uns daran gewöhnt das sehr viel sowieso abgefragt wird, trotzdem glaube ich, müssen wir darauf achten, wo unsere Daten landen (betrifft auch GAIA-X). Wir wissen ja nicht was in 30 Jahren ist. Da werden Sie noch mitten im Berufsleben noch stehen und da kann es sein, dass es einen Wettbewerb unter den Nationen gibt das alle Idee von Ihnen natürlich geschützt sein müssen. Also wir brauchen sowieso sichere Daten und daher gibt es jetzt die GAIA-X Initiative. Momentan weiß ich keine Lösung. Bei uns gibt es die DSGVO wo man zu allem zustimmen muss. Da haben Sie X-Seiten da müssen sie Hackerl setzen und wenn Sie die nicht setzen, sind Sie nicht mehr Teil einer sozialen Gesellschaft. Das heißt die, die man treffen will, hat man gar nicht getroffen. Sie müssen ja eh nicht zustimmen, aber wenn Sie nicht zustimmen haben Sie nichts mehr, kein Google mehr gar nichts mehr. Deswegen stimmen Sie zu.

Komar: Also nur der Vollständigkeit halber, es gibt in dieser Automat-Fahr Verordnung einen Paragraphen, der Fahrzeuge die Testfahrten durchführen, dazu verpflichtet, einen Datalogger an Board zu haben, eine rechtliche Basis gibt es dafür allerdings nicht.

Dr. Hofstädter: Das ist auch wieder so eine Sache, der rechtliche Rahmen in Österreich ist sehr vage und dünn gesät in diesem Zusammenhang. Die Polizeifahrzeuge in Österreich haben so etwas verbaut, da hat es natürlich gewerkschaftliche Probleme gegeben, weil da auch natürlich alles auslesbar ist, ob er wirklich auf Streife gewesen ist oder beim Essen war. Privat gibt es das nicht. Manche Arbeitgeber haben es verbaut, da hat es auch gewerkschaftliche Probleme gegeben. Wenn Sie das privat machen haben Sie natürlich schon auch Vorteile, dass wenn irgendeine unvorhergesehene Situation können Sie wenigstens beweisen das Sie es nicht waren. Andererseits kann Ihnen dann die Versicherung in vielen Fällen vorwerfen, dass Sie fahrlässig gehandelt haben. Das ist eine Abwägungssache.

Wie stellen Sie sich die Zukunft des autonomen Fahrens vor? z.B. 10 Jahre?
Dr. Hofstädter: Also die nächsten 5 Jahre kann man ganz gut überblicken. Die Systeme werden einfacher, stabiler, besser einfach noch praxistauglicher und ich meine, ich blicke jetzt einmal zurück und auf die letzten 40 Jahre. Da war es noch so, da ein permanenter Lenkeingriff notwendig war, permanentes Gas, die Bremse war ohne Bremskraftverstärker da war Autofahren noch richtig Arbeit und wenn man studiert hat und kein Geld hatte, hat der Beifahrer die angelaufene Scheibe von innen geputzt. Dann hatte ich mein erstes Auto das teilautonom war und jetzt eines das ein ganz gutes Level 3 hat. Sie müssen nicht permanent auf alles achten und die Geschwindigkeit regeln, man muss nicht permanent regeln, man hat eine ganz andere Sicherheit mit ABS und anderen Sicherheitssystemen. Also man steigt nach 4 bis 5 Stunden wesentlich erholter aus als früher nach 2 bis 3 Stunden mit wesentlich höherer Sicherheit und ich glaube das diese Systeme alle noch besser, noch sicherer, noch komfortabler werden, es kommt hier und da noch ein Helfer dazu. Die Sprachsysteme haben sich auch deutlich verbessert. Vor 2 Generationen war die Antwort auf ein Sprachkommando immer: „Meinten Sie?“ „Nein“ „Meinten Sie?“ „Nein“. Also es war nicht brauchbar. Ich meine heutzutage von 100 Kommandos werden 99 korrekt verstanden. Auch das ist Komfort, weil wenn ich unterwegs bin und mir etwas

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angehört habe von meinem Smartphone und dann dem Fahrzeug Radio Ö3 sage und es schaltet um. Wenn man mit 130 KM/H unterwegs ist, ist das Komfort und Sicherheit. Ich glaube da wird einfach jedes Auto ein wenig besser und durch die Fahrzeuge im Luxussegment, die oft Technologieträger sind, wird die Hardware und Software so günstig, dass immer mehr einfachere Fahrzeuge das auch haben. Und darum geht es ja, es geht ja nicht darum das das teuerste Prozent der Fahrzeuge noch sicherere wird, sondern dass alle Fahrzeuge die darunter angesiedelt sind sicherer werden. Da wird natürlich viel weitergehen, indem Spitzenprodukte jetzt in die breite aller Fahrzeuge reinkommen und dort sehe ich den riesigen Nutzen. Da ist natürlich noch eine Menge zu tun. Wenn alleine Fahrzeuge im mittleren Preissegment in 15 Jahre auf das Level kommen auf dem jetzt die Oberklasse ist dann hätte das volkswirtschaftlich einen Nutzen. Navigation als Sicherheitsmerkmal, ich bin noch mit der Landkarte am Schoß gefahren und habe gelenkt oder der Beifahrer hatten die Karte in der Hand. Wenn man da etwa 20 Jahre voraussieht, das sind in etwa diese Zeiten. Dann wird das was jetzt in der Oberklasse verbaut ist in allen Autos verbaut sein und das hat natürlich einen enormen Nutzen.

6.2 Univ.-Prof. Dr. Konrad Lachmayer

Interview Partner	Univ.-Prof. Dr. Konrad Lachmayer; Vizedekan der Fakultät für Rechtswissenschaften an der Sigmund Freud Privatuniversität Wien, Universitätsprofessor für Öffentliches Recht, Europarecht und Grundlagen des Rechts
Date	25.02.2022
Time	14:00 - 15:30
Language	German
Location	Vienna
Communication	online conference

Es wurde ein fachliches Gespräch im Umfang von 1h 30min mit Dr. Lachmayer geführt, welches bei der Recherche und Erstellung der Arbeit von großem Wert war. Für die Veröffentlichung des Transkriptes konnte leider keine Zustimmung erlangt werden, da es bei den mündlich gesprochenen Passagen zu einer unerwünscht starken Simplifizierung komplexer rechtlicher Themenkreise käme. Dennoch konnten durch viele hilfreiche Hinweise und Tipps gezielt Themengebiete bearbeitet werden. Folgende Fragen wurden diskutiert:

Wie sehen Sie die rechtliche Situation des autonomen Fahrens in Österreich? Besonders in Bezug auf Level über 3?

Was sind Ihrer Meinung nach die größten rechtlichen Problemstellungen? Aktuell und in Zukunft? AutomatFahrG?

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Wie sinnvoll ist es z.B. örtlich die SAE Level zu beschränken, z.B. Innenstadt kein Level 5?

Darf es zu einem (regionalen) Verbot kommen, selbst ans Steuer zu gehen? z.B., wenn die Wahrscheinlichkeit für einen Unfall automatisiert, geringer ist. (z.B. bei Schulen)

Wie sehen Sie die Zukunft der privaten Daten, wo hört Sicherheit auf und wo fängt Datenschutz an? Wer oder was darf/soll überwacht werden und mit wem darf geteilt werden?

Was sind die Enabler des automatisierten Fahrens? 5G-Network, Edge-Computing, neue rechtliche Rahmenbedingungen?

Wie stellen Sie sich Zukunft des autonomen Fahrens vor? z.B. 10 Jahre?

6.3 Dr. iur. Andreas Eustacchio LL.M.

Interview Partner	Dr. iur. Andreas Eustacchio LL.M.; Rechtsanwalt u.a. für Produkthaftungsrecht, Wirtschafts- und Unternehmensrecht, Europarecht, Telekommunikationsrecht und Rechtsberater zu Product-Compliance, contract design und automotive law
Date	05.05.2022
Time	15:30 - 16:30
Language	German
Location	Vienna
Communication	online conference

Wie sehen Sie die rechtliche Situation des autonomen Fahrens in Österreich? Besonders in Bezug auf Level über 3? Der rechtliche Status quo ist, (nach dem Wiener Übereinkommen, welches im Kraftfahrzeuggesetz umgesetzt ist) dass die Hände zwar nicht immer am Lenkrad sein müssen, aber die Kontrolle muss immer beim Fahrer liegen. Das ist so eigentlich unbefriedigend. Das ist meiner Meinung nach das rechtliche Problem, das erfordert eine Konzentration die eigentlich nicht vorhanden ist. Man wird ja verleitet, nicht aufmerksam zu sein auf gewissen Strecken. Also von daher halte ich das für nicht so günstig wie es im Moment ist, aber das liegt nicht nur am Recht. Man sagt ja sehr häufig, dass das Recht hinterherfährt. Sie sind ja an der technischen Universität, vielleicht ist die Technik und die Technologie noch nicht so weit, dass sie uns die Sicherheit vermittelt bzw. garantieren kann, die man eigentlich erwartet. Das ist meiner Meinung nach das Problem. Das ist auch ein technisches Problem, von Kameras,

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LIDAR, Erkennungssoftware und daher nicht nur ein rechtliches Problem, sondern auch ein Problem des Standes der Wissenschaft und Technik.

Komar: Die technische Seite wird in der Arbeit auch behandelt und wie Sie auch gesagt haben, sind einerseits die Sensoren andererseits auch die Technologie für die Vernetzung der Fahrzeuge auch noch nicht ganz geklärt, da geht es einerseits um den Grundsatz wie das Ganze vernetzt werden wird also entweder Car2Car oder mit einer Infrastruktur, das sind ja zwei verschiedene Ansätze und da gibt es auch unterschiedlichen Standards für die Funkverbindungen. Nicht nur, dass diese teilweise nicht kompatibel sind, sondern auch im Fall des WLAN und LTE-Standards, stören die sich gegenseitig auch.

Dr. Eustacchio: Ich glaube es hat keinen Sinn das man sagt man macht jetzt Level 4 und man prescht vor und dann passen wir das Recht an. Das geht eben nicht ohne Technologie. Jetzt zu sagen wir müssen das Recht ändern, wenn wir über die rechtlichen Fragestellungen noch nicht die Klarheit haben finde ich fahrlässig. Wenn jemand sagt „Lassen wird das doch einfach zu.“ Dann muss man aber auch in Kauf nehmen das es Unfälle geben wird. Wollen wir die, das ist die Frage, um es herunterzubrechen. Natürlich kann man sagen, es passieren doch jeden Tag schon Unfälle, na dann passieren halt da auch Unfälle, dann braucht man aber das neue System nicht. Entweder bringt es einen Mehrwert oder nicht.

Was sind Ihrer Meinung nach die größten Rechtlichen Problemstellungen? Aktuell und in Zukunft? Komar: Ich kann hier von dem berichten was ich schon gelesen habe im Zuge meiner Arbeit. Dr. Lachmayer ist der Auffassung, dass die aktuelle rechtliche Lage bezüglich AutomatFahrV, die auf dem Kraftfahrgesetz basiert, so zu beschreiben ist, dass es hier eine nicht ausreichende Spezifizierung der Anforderungen gibt und dass die problematische Ausstellung einer Genehmigung für Testfahrten eines der Hauptprobleme sind. Vielleicht haben Sie da eine andere Ansicht.

Dr. Eustacchio: Genau. Ich habe mich ja immer wieder auch ausgetauscht mit Dr. Lachmayer. Das eine ist sicher auch das Problem der Zulassung, welche Systeme müssen welche Sichererfordernisse erfüllen und ob man ein Zulassungssystem einführt. So ähnlich wie bei Medikamenten oder Impfstoffen. Diese müssen ja auch durch eine Behörde zugelassen werden und als sicher bewertet werden oder man sagt man macht hier eine Selbstzertifizierung. Wir haben das ja bei sehr vielen Produkten, z.B. MedizinprodukteGesetz oder NiederspannungsRichtlinie. Es gibt ja sehr viele Sondervorschriften auf europäischer Ebene, die den Herstellern eine Selbstzertifizierung auferlegen, das heißt die müssen das selbst evaluieren, eine Risikobewertung durchführen und dann eine Konformitätsbeurteilung am Ende machen und diese beinhaltet dann auch sehr häufig die CE-Kennzeichnung. Das heißt wiederum, man hat gewisse Mindeststandards erfüllt und bei Kontrollen kann man dem nachgehen und sagt, stimmt das, wo ist deine Risikobewertung. Das eine ist das Zulassungssystem im Vorhinein oder man lässt die Hersteller eine Selbstzertifizerung vornehmen. Ich meine, das ist ja heute auch nicht anders in der Automobilindustrie, dass die Hersteller in ihre Fahrzeuge auch Systeme verbaut haben, die dann im Rahmen der Typengenehmigung mitgenehmigt werden, aber wie jetzt ein

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Scheibenwischer konfiguriert ist oder wie eine Bremse funktioniert, das bleibt ja jedem selber überlassen. Beim autonomen Fahren könnte man ja sagen, dass das auch eine Möglichkeit wäre, wenn man von eben dem spricht, aber eben komplett autonom also ohne Infrastruktur dahinter, dann wäre das ein möglicher Ansatz. Das ist auch ein kulturelles Thema, dass man alles vorher prüfen lässt in Europa. Irgendeine Behörde muss das absegnen und dann glauben wir einfach, dass das gut ist und funktioniert. Auch um hier eine Brücke zu aktuellen Themen zu schlagen. Die Covid-19 Impfung, die EMA sagt auch, dass der Nutzen größer ist als das Risiko. Die EMA hat aber nie gesagt, dass die Covid-19 Impfung keine Nebenwirkungen hat. Da gibt es auch keine 100%ige Sicherheit, das ist bekannt. Wenn der Wunsch besteht, dass man eine behördliche Überprüfung einschiebt, dann befürchte ich halt, das ist aber meine persönliche Meinung, da geht es dann wieder eher darum wer welche Posten in der Behörde bekommt und wer welche Aufträge bekommt. Ob es um das Interesse geht, ob das ganze sicherer ist, weiß ich nicht. Hier gehen die USA einen anderen Weg, auch bei Covid-19, die haben hier eine Notzulassung ermöglicht und die sagen dann, wenn etwas passiert, haben wir einen Schadenersatzsystem, dass es uns auch ermöglicht mit punitive damages in den USA die Hersteller zur Verantwortung zu ziehen. Denken Sie jetzt nur an den VW Diesel Skandal, die waren da beinhart. Mich hat das immer gewundert das VW in den USA Milliarden zahlen musste und in Europa schleppend irgendwelche Gerichte ein paar Entscheidungen erlassen habe und sich ein wenig getraut haben VW auf die Finger zu steigen. Sie sehen da den Unterschied, hier ist man sehr restriktiv was Schadensersatzzahlungen angeht und da muss man sehr stark dafür kämpfen, während die in den USA Milliarden gezahlt haben. Da muss man sich schon fragen, ist der Konsument in den USA der wichtigere Konsument als der europäische? Aber um zurück auf den Punkt zu kommen mit der Zulassung. Ja, das ist alles schön und gut aber selbst wenn etwas passiert dann müssen wir uns eine Amtshaftung überlegen, weil die Behörde das ja zugelassen hat. Also auch eine Behörde wird keine 100%ige Sicherheit garantieren können. Wir sollten wegkommen von dieser Vorstellung einer 100%igen Sicherheit einer Behörde, das ist für mich nur ein Mehrverwaltungsaufwand und von dem haben wir vermutlich schon genug in Österreich.

Was ist Ihre Meinung zum Liability Shift bei autonomem Fahren in höheren Autonomisierungsgraden und wie kann diesem begegnet werden? Komar: Die Sache mit Level 3 ist ja geklärt, da ist ja quasi die Haftung des Fahrers aufgrund von Fahrlässigkeit abgedeckt. Aber bei höheren Autonomisierungsgraden geht die Frage der Haftung weg von der Fahrerhaftung, hin in Richtung der Gefährdungshaftung vom Fahrzeughalter bzw. weiter zur Produkthaftung. Wo hört das dann auf. Das wird meiner Meinung nach schwierig, wenn man irgendwelche Schäden hat und diese nachverfolgen muss.

Dr. Eustacchio: Das ist richtig was Sie sagen. Das eine ist zu sagen, also gut wir verschärfen die Haftung oder wir machen eine Liability Shift hin zum Hersteller. Ich habe heute ja die Möglichkeit den Hersteller zu klagen, nur der Geschädigte hat halt den Vorteil, dass er durch das Eisenbahn- und Kraftfahrzeughaftpflichtgesetz den Halter in die Haftung nehmen kann und dann parallel dazu die Versicherung. Das heißt die

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Versicherung des Halters deckt das und die kann sich dann am Hersteller regressieren. Das dient dem Opferschutz, das heißt der Geschädigte soll die Möglichkeit haben, dass sein Schadenersatz relativ schnell abgehandelt wird und er nicht langwierige Prozesse gegen den Hersteller führen muss. Das ist ja eigentlich Grundsätzlich in Ordnung, die Frage wird nur sein, wenn ich in meinem Fahrzeug jetzt bei Level 4 weniger Verantwortung habe, da ist dann noch die Frage wie weit reicht meine Verantwortung noch. Wenn das Auto wirklich selbst fährt und den Weg bahnt, ich habe das heute schon als Halter, ich habe auch kaum mehr Einfluss aufs ABS und auf sonstige Traktionskontrollen, aber trotzdem, wenn da etwas passiert, dann haftet der Halter, abgefedert durch die Versicherung. Also wenn man das weiterspinnt auf die Assistenzsysteme könnte man sagen, „Naja dann spielt das keine Rolle, dann hat man halt weiter die Halterhaftung." Ich glaube nur, dass es ein wirtschaftliches Thema gibt für die Versicherungen. Diese haben natürlich ein Geschäftsmodell mit der Pflicht-Haftpflicht-Versicherung. Jeder zahlt eine Prämie, die kann man sich halbwegs leisten, die Frage ist ob diese Prämienzahlung dann noch gerechtfertigt ist oder ob dann nicht die Hersteller sich selbst versichern müssten mit einem Vertrag zu Gunsten Dritter. Das heißt, die Hersteller schließen Versicherungen ab und geschützt ist dann sozusagen der Insasse, der selbst gar nicht mehr fährt. Die Frage ist nur, welche Aufgaben wird diese Person noch haben, wenn er dann einsteigt? Muss er trotzdem noch die Fahrtüchtigkeit haben, das Fahrzeug zu kontrollieren oder läuft das dann so ab, dass man auf einen Knopf drückt und das System selbst einen Systemcheck macht und sagt, ja alles in Ordnung, das Auto ist fahrtüchtig. Ist es damit belassen oder muss man dann noch einen Check von außen machen? Dann könnte man sagen, dass die Hersteller die Haftung übernehmen und sich versichern lassen. Es spricht nichts dagegen, das System jetzt so beizubehalten wie es jetzt ist, nur irgendwann wird man sich die Frage stellen, wenn ich heute in einem Taxi bin oder mit dem Zug fahre, muss ich als Insasse ja auch keine Versicherung abschließen. Wenn ich wirklich reiner Insasse bin, dann ist die Frage, bin ich dann überhaupt noch Halter des Fahrzeuges oder ist es sozusagen eine Dienstleistung die mir angeboten wird. Ich setz mich in ein Auto rein das halt frei ist, so wie bei AirBNB. Bin ich dann überhaupt verantwortlich, mich versichern zu müssen. Ich glaub das wäre dann schon sehr weit hergeholt, dass man sich noch zusätzlich versichern muss. Ich glaube irgendwann einmal müssen sich die Versicherungen und die Hersteller auch die Frage stellen. Wenn ich so etwas anbiete, dann habe ich eine Haftung, ich kann also nicht immer das Spiel spielen „Du hattest die Letztkontrolle und hättest da noch eingreifen können." Das wird dann nicht mehr funktionieren. Wenn man das als Massenprodukt auf die Straßen bringen will, muss man auch die abholen, die der Technik distanziert sind. Also nicht nur die digital natives, sondern man will ja auch die Leute ins Boot holen, die skeptisch sind und heute ist es so, dass es kein Gesetz gibt, das mir sagt für wie lange ich die Hände am Lenkrad halten muss. Jeder Hersteller stellt das anders ein, der eine sagt nach 20 Sekunden piept er, beim andere nach einer Minute und irgendwann muss man dann die Hände ans Lenkrad geben, weil sonst beginnt das Auto sich abzuschalten, auszurollen und stehen zu bleiben, aus Sicherheitsgründen natürlich. Meiner Meinung nach wird es so sein, dass man sagt, dieses Versicherungssystem lässt sich nicht mehr aufrechterhalten. Vielleicht werden sogar die Versicherungen sagen, dass

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die Schäden die dadurch auftreten, wenn jetzt so ein System durch einen Halterfehler ausfällt, ist es eine Person, aber wenn jetzt Systeme ausfallen die in der Konstruktion defekt sind oder fehlerhaft sind, dann ist die Schadensgeneigtheit eine viel größere und dann treten Massenschäden auch viel häufiger auf.

Komar: Ich bringe etwas zur Sprache, das in der AutomatFahrV festgelegt ist. Bei Testfahrten wird eine Blackbox in Fahrzeugen verlangt. Sehen Sie so etwas als realistisch bei normalen Fahrten in massetauglichen Fahrzeugen?

Dr. Eustacchio: Es gibt Versicherungen die so etwas anbieten und sagen, wir zeichnen dein Fahrverhalten auf und danach richtet sich dann auch die Prämienzahlung. Da muss ich natürlich einwilligen, denn das ist eine Datenschutzthematik. Theoretisch ist das denkbar, das ist zwar keine Blackbox, aber wir haben ja die Automatische Notfall Verordnung, wo auch aufgezeichnet wird und wenn etwas ist, wir automatisch einen Notruf abgegeben und die Blaulichtdienste wissen dann wo das Fahrzeug ist. Die Frage ist halt, ob da noch mehr aufgezeichnet wird. Das wäre durchaus denkbar. Da haben wir dann wieder das datenschutzrechtliche Problem, wem gehören die Daten und dann gibt es auch noch ein strafrechtliches Thema. Ich kann natürlich im Strafrecht die Aussage verweigern, wenn man sich dadurch selbst belastet. Wenn die Auswertung der Blackbox jetzt zu dem Ergebnis führen würde, dass ich da wirklich zu schnell gefahren bin und grob fahrlässig einen Unfall mit Körperverletzung verursacht habe, dann wäre das strafrechtlich relevant und dann ist die Frage ob des Grundsatzes, dass ich mich der Aussage entschlagen kann, auch auf die Blackbox zutrifft und man sagen kann, ich möchte nicht, dass die Blackbox ausgewertet wird. Aber das ist dann wieder eine Beweiswürdigung und dann sagt man „Ok schon, weil du das nicht möchtest wäre ein Indiz das du zu schnell gefahren bist, weil du hast ja nichts zu verbergen." Das wäre schon zivilrechtlich ein Problem und strafrechtlich muss man jetzt sagen will man nicht. Die Frage ist natürlich wem gehört die Blackbox und wer hat Zugriff auf die Blackbox. Das ist ein ziemlicher Datenschutzeingriff. Das andere Thema ist eine Dash-Cam, die ist ja eh schon nicht erlaubt bei normalen Fahrzeugen, aber es ist schon möglich bei den Testfahrten. Universitäre Einrichtungen und Forschungseinrichtungen dürfen ja auch personenbezogene Daten für Zwecke der Forschung verwenden. Das Alplab in der Steiermark fällt da nicht darunter, die dürfen solche Aufzeichnungen nicht machen, auch nicht bei testfahren bzw. wenn personenbezogene Daten generiert werden, müssen die sofort gelöscht werden. Es ist durchaus möglich, dass der Gesetzgeber sagt, er möchte eine Blackbox einführen. Die Frage ist dann nur, wer hat Zugriff auf die Blackbox und wem gehört die dann.

Wie sehen Sie die Zukunft der privaten Daten, wo hört Sicherheit auf und wo fängt Datenschutz an? Wer oder was darf/soll überwacht werden und mit wem darf geteilt werden? Komar: Wenn die Blackbox ab Stufe 4 oder 5 eingeführt werden würde, ist die Frage, wie die Zukunft der privaten Daten aussieht, also wo hört der Sicherheitsgedanke auf und wo fängt Datenschutz an. Gerade bei Level 5 hat der Fahrer ja die Fahraufgabe an das System übergeben und nach Definition auch die Aufgabe der

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Überwachung. Da ist dann die Frage, ob die Blackbox herangezogen werden kann, um herauszufinden wo der Schuldige ist.

Dr. Eustacchio: Auf den Levels haben Sie recht, hier wird nicht mehr ein mögliches Verschulden des Fahrers ausgewertet, denn der hat ja gar kein Verschulden, weil er keinen Einfluss mehr hat. Bei Level 4 könnte man diskutieren, weil hier doch ab und zu noch Eingriffe geschehen. Ein anderer Gedanke wäre, die Straßenverkehrsordnung sieht dann vor, ähnlich wie im Winter bei Kettenpflicht, „ab hier automatisiertes System ausschalten" zum Beispiel, dann würde sich die Blackbox auch gleichzeitig ausschalten. Denn der Zweck der Blackbox ist ja nur, um festzustellen, ob es ein Systemfehler war oder ein Dritter Schuld hat. Nur wenn der Mensch gar nicht mehr auf bestimmten Strecken die Fahraufgabe übernehmen soll, ist die Frage ob sich die Blackbox dann auf solchen Strecken einschaltet und auf anderen wieder abschaltet, wobei die Daten wieder auch im automatisierten Zustand verwertet werden. Wo man hin fährt sind ja auch personenbezogene Daten. Das hat datenschutzrechtliche Relevanz, wenn die Daten auf eine bestimmte Person rückverfolgbar sind. Das ist beim Datenschutz die Frage, ob die Daten mit „vertretbaren (finanziellen) Mitteln" rückverfolgbar sind, dann sind es personenbezogene Daten, welche in diversen Fällen nicht aufgezeichnet werden dürften. Es gibt auf Ebene der EU für nicht-personenbezogene Daten eine Schnittstelle einzuführen per Verordnung. Die Frage ist, ob man personenbezogene Daten und nicht-personenbezogene Daten überhaupt so schön trennen kann.

Wie sinnvoll ist es z.B. örtlich die SAE Level zu beschränken, z.B. Innenstadt kein Level 5? Denkbar ist natürlich alles, die Frage wird sein, ob ein Hersteller so ein Level in der Stadt sicher anbieten kann. Das ist dann natürlich auch eine Haftungsfrage, ob der Hersteller das will. Ich kann mir vorstellen, dass man sehr wohl Beschränkungen einführt, also dass nur auf bestimmten Strecken Level 5 möglich ist. Ich halte es für sinnvoll das auf Autobahnen zu machen, zum Beispiel dass eine Spur reserviert wäre. Bei Abfahrt würde das Fahrzeug wieder auf niedere Level zurückschalten.

Ein Punkt ist die Frage der Testungen, was will man erreichen? Jetzt gab es die Novelle zur AutomatFahrV, welche Usecases einziehen. Das Thema ist immer noch „cui bono", wem nutzt jetzt der Test was, und was ist das Ergebnis des Tests? Die Frage sollte nicht nur sein, „Wieso ist hier etwas passiert?", sondern auch bei knappen Fällen, „wieso ist hier knapp nichts passiert?". Ich weiß bis heute nicht, was mit diesen Tests der AutomatFahrV erreichen will. Für mich ist es natürlich auch eine Standortfrage und ein wenig eine Marketingfrage; Für die Automobilindustrie, kommt nach Österreich testen, wir haben eine AutomatFahrV bei uns. Man versucht ausländische Investoren anzulocken, weil man hier Testen kann, ob die Sinnhaftigkeit der Tests gegeben ist, ist fraglich. Wer testet die Ergebnisse aus? Was ist der nächste Schritt nach dem Test? Wer entscheidet das? Hier bräuchte es eine Zulassungsstelle, welche nach den Tests Entscheidungen fällt (zb. Jetzt darf es zugelassen werden). Diese Stelle fehlt.

Man kann das System einbauen, aber solange es die gesetzliche Regelung mit Level 3, 4, 5 haben, wird man auch beim besten System nur bei Level 3 bleiben und die Frage

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ist, kann das jemals (auch wenn es getestet wurde) auf Level 4 oder 5 gehoben werden, bzw. auf den Markt kommen. Also entweder man gibt das jetzt frei, man kann Level 5 verwenden, aber es muss im Vorhinein ausreichend getestet werden. Diese Tests müssen jedoch nach einem Standard festgelegt werden. Hierzu bräuchte es eine Normierung oder technische Standards, die sagen nach welchen Kriterien hier getestet werden muss und was das Ergebnis dann sein soll. Das fehlt mir in der AutomatFahrV.

Was sind die Enabler des automatisierten Fahrens? 5G-Network, Edge-Computing, neue rechtliche Rahmenbedingungen? Es gibt in Österreich natürlich auch eine praktische Handhabe, das ist diese automatische Einparkhilfe, welche verwendet werden darf und der automatische Spurhalteassistent. Ich habe da einen anderen Ansatz, da wir jetzt schon so viele Gesetzte haben (Anmerkung zu AutomatFahrG). Bei der Bescheinigung, welche von der AustriaTech ausgestellt wird, stellt sich die Frage, was diese für eine rechtliche Wirkung hat. Ist das jetzt ein Bescheid? Dann haben wir eigentlich kein rechtliches Gehör/Verfahren, wer muss eigentlich gehört werden? Eigentlich müssten ja Leute die dort auf der Straße fahren auch gehört werden und können Einspruch erheben. Aber das ist es ja nicht! Es ist offenbar kein Bescheid, sondern eine Bescheinigung. Da kann man natürlich diskutieren was das rechtlich sein soll und man könnte sagen, hier wäre ein Gesetzt angebracht. Ich als Industrieanwalt habe hier einen pragmatischen, praktikablen Zugang. Muss man es gesetzlich regeln? Ja natürlich, ich muss über das Wiener Übereinkommen, dem Österreich beigetreten ist, die Regelung so schaffen, dass der Mensch nicht mehr die Hände (nicht einmal zur Kontrolle) auf das Lenkrad geben muss, nicht einmal auf bestimmten Streckenabschnitten. Das Wiener Übereinkommen ist ja in Österreich im Kraftfahrgesetz umgesetzt, früher hieß es man muss die Hände immer am Lenkrad haben, heute nicht mehr. Außerdem gehört geregelt für wie lange hier ohne Hände gefahren werden kann, für manche Strecken mag 20 Sekunden bereits zu lang sein, für andere nicht. Man müsste das in Österreich vermutlich mit der Straßenverkehrsordnung verknüpfen, sodass man sagt, auf bestimmten Stecken können Autos, welche diese Systeme haben, dürfen diese Systeme auch einsetzen.

Komar: Die nicht ausreichende Spezifizierung der Anforderungen ist eines der Grundprobleme, welche ich in der AutomatFahrV ausmachen konnte.

Dr. Eustacchio: Mir wurde die neue Novelle vorab auch ausgehändigt, und da waren, wie Sie sagen, auch viele unbestimmte Teile. Ich habe dazu eine Stellungnahme abgegeben welche ich kurz heraussuche. Diese lautet wie folgt.

So sehr es nicht die Aufgabe der Novelle zur AutomatFahrV sein soll, jeden einzelnen Fall sowie die rechtlichen Folgen im Detail zu regeln, so sehr sollten die in der Novelle vorkommenden Spezifikationen konkret zu sein, um so für jene die Rechtsunsicherheiten im Rahmen zu halten, für die sie adressiert sind, die Stakeholder. Alternativ dazu könnte die Novelle aber jene Behördenstelle(n) benennen, die über die Gesetze zu wachen hat. Abgesehen davon findet sich auch in diesem Entwurf kein Wort zum verfassungsrechtlich verankerten Rechtsschutz, dem rechtlichen Gehör, sowie der verantwortlichen Instanz bei einer Ablehnung zum Testen. Weiters habe ich hier ein paar Begriffe herausgeholt,

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nämlich, es muss bei allen Anwendungsfällen klar sein, wie viel Kilometer verpflichtend im Vorfeld, real als auch virtuell, getestet worden sein muss. Wer überprüft nach welchen Kriterien die Ergebnisse dieser Tests, das heißt „ausreichend getestet“ und „für sicher empfunden“. Was versteht man unter „nachvollziehbarer Risikobewertung“, und was soll bei Risikobewertung untersucht werden. Will man mit der Verordnung, vergleichbar mit der „CE“ Kennzeichnung eine Selbstzertifizierung im Rahmen einer Beurteilung einführen, dann möge dies auch so dargelegt werden. Soll bei der nachvollziehbaren Risikobewertung eine rein technische Risikobewertung, der in einem Testgebiet zu testenden Fahrzeugen oder eines konkret zu testenden Systems erfolgen, will man diese Aufgaben externen Prüfinstituten als benannte Stellen übertragen, so möge dies im Entwurf deutlich gemacht werden. Ist dies die Zielrichtung, dann muss für die Adressaten ein Kriterienkatalog verfügbar sein, nach dem sie eine Risikobewertung vornehmen können. Meine Empfehlungen: Es ist meiner Erfahrung nach, als im Bereich Automotive beratender Rechtsanwalt, im sinne einer Sensibilisierung der beteiligten Stakeholder zu empfehlen, dass die Risikobewertung auch eine rechtliche Risikofolgenabschätzung umfasst. Mit dieser soll insbesondere auch auf die von den zu testenden Systemen ausgehenden Gefahren für die Umwelt, sowie unbeteiligte Dritte aufmerksam gemacht werden.

Das ist nämlich auch ein Thema, das im neuen Vorschlag der EU, der Produktsicherheitsverordnung enthalten ist, es geht hier also auch sehr stark auch um die Risikobeurteilung für die Umwelt und die Nachhaltigkeit.

Es hat sich in meiner Beratungspraxis gezeigt, dass viele Industrieunternehmen, die in der Entwicklung im Bereich des automatisierten Fahrens tätig sind, sich zwar möglicherweise des Risikos des Ausfalls oder Nicht-funktionierens ihrer Systeme bewusst sind, aber die rechtlichen Folgen und Gefahren im Zusammenhang mit unsicheren, gefährlichen und fehlerhaften IT-Systemen nicht richtig einzuschätzen in der Lage sind. Daher sollten die in den Paragraphen 7(a, b), 8(a), 9(a, b) in den jeweiligen Absätzen genannten Fahrzeugherstellern (Entwickler von Systemen, Forschungseinrichtungen, Verkehrsunternehmen, Betreiber von Kraftfahrlinien und Güterbeförderungsunternehmen) begleitend zu einer technischen Risikobeurteilung auch eine Beratung zur rechtlichen Risikofolgenabschätzung verpflichtend in Anspruch nehmen müssen. Jedenfalls sollte meiner Meinung nach mit Risikobewertung auch eine rechtliche Risikofolgenabschätzung mitgemeint sein. Weiters dann am Schluss: Weitere Begriffe die einer Konkretisierung bedürfen: Was ist ein adäquates Fahrsicherheitstraining? (§2 Abs. 3) Das System muss daher in der Lage sein, alle Fahrsituationen automatisch zu bewältigen. Nach welchen Kriterien und was ist mit „allen Fahrsituationen“ und dem Begriff „zu bewältigen“ gemeint? Was muss Bewältigt sein? Wenn nun dieses System in der Lage sein muss alle Situationen automatisch zu bewältigen, dann ist denklogisch nachfolgender Absatz 5 in Paragraph 3 eher obsolet, weil ich meine nach Absatz 4 kann es ja dann zu keiner dieser Situationen mehr kommen, da der Lenker die Notfallvorrichtung gar nicht mehr zu betätigen hätte.

Davon unabhängig fragt sich, wie eine „kritische Situation“ zu verstehen ist und für wen muss es eine kritische Situation sein? Sollte für „kritische Situation“ nicht ein anderer Begriff verwendet werden, wie eine potentiell oder subjektiv konkrete drohende Gefahr?

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Zum Begriff der Notfallvorrichtung: Es wird zwar die Verpflichtung zur Betätigung der Notfallvorrichtung normiert, aber was soll durch das Betätigen der Notfallvorrichtung passieren. Soll das Fahrzeug in den sofortigen Stillstand übergeführt werden? Soll sich die Art der Notfallvorrichtung nach dem Notausschalter der EN ISO 13850 richten?

Zum automatisierten Parkservice: Auch da empfinde ich die Formulierung unkonkret, nämlich: Müssen diese dem Stand der Technik entsprechen und gegen unberechtigte Zugriffe von außen geschützte sein. „Stand der Technik", zu welchem Zeitpunkt? Der Stand der Technik ist nur der technische Mindeststandard, und kann oft zu wenig sein, daher würde ich das umformulieren: müssen die bei Verwendung des automatisierten Parkservice verfügbaren Stand der Wissenschaft und Technik entsprechen. Was die Formulierung im unberechtigten Zugriff von außen geschützt sein angeht, verweise ich auf den aktuellen EU Cybersecurity Act von 2019 (VO 2019 881 über die ENISA) und über die Zertifizierung der Cybersicherheit von Informations- und Kommunikationstechnik.

Weiters komme ich dann noch zur automatisierten Arbeitsmaschine, nämlich nach §9 b. Weshalb sieht §9 b die Möglichkeit der Nutzung der Kommunikationseinrichtungen zwischen Maschine und Infrastruktur nicht vor, dem in §9 a (automatisiertem Parkservice) aber schon. Diese sind einige Aspekte, welch einer weiteren Diskussion bedürfen. Das war meine Stellungnahme an das Ministerium vom 14.12.2021. Ich habe in der jetzigen Novelle aber nicht wirklich Antworten auf meine Fragen gefunden. Mir kommt vor, dass diese wagen Formulierungen absichtlich gemacht wurden, man will der Industrie scheinbar nicht auf den Fuß steigen. Man will das Testen in Österreich sicherlich fördern. In Ungarn wurde hier bereits eine ganze Rennstrecke für das Testen von autonomen Fahrzeugen aus dem Boden gestampft.

Die Use Cases kommen ja in die Verordnung hinein, weil die Industrie sagt, dass können wir jetzt schon. Das ist ja nicht umgekehrt so, dass man etwas zulässt, was es heute noch gar nicht gibt. Also wird diese Verordnung immer hinten nach sein.

Wie stellen Sie sich Zukunft des autonomen Fahrens vor? z.B. 10 Jahre? Ich habe hier einen Ausdruck im Kopf, von Henry Ford, wenn man die Menschen über die Zukunft fragen würde, würden diese sagen man solle 100 Pferde vor eine Kutsche spannen. Herausgekommen ist dann das Automobil. Ich denke, dass hier oft eine falsche Denkweise herrscht, da wir immer das Auto vor uns haben. Wir haben eine Infrastruktur, welche für das Auto konzipiert ist, also wird es schon in diese Richtung gehen. Kein Staat wird hier jetzt komplett neue Infrastrukturen schaffen. Sicherlich werden konkurrierende Standards zum Problem. Ich denke die Frage hängt davon ab, ob man die Menschen jetzt davon überzeugt. Automatisierte Systeme sollen einen Komfort bieten, aber auch eine Sicherheit und die Frage ist ob der Mensch (aus dem psychologischen heraus), bereit ist, diese Kontrolle abzugeben und ob er vertrauen aufbauen kann in diese Systeme. Wenn das aus technischer Sicht gelingt, dass ein Fahrzeug zumindest so sicher ist wie ein Mensch, dann kann ich mir schon vorstellen, dass man das dann akzeptiert. Allerdings, und das habe ich in meinem Podcast beim ÖAMTC auch gesagt, diese Fahrzeuge werden zu beginn sehr defensiv eingestellt sein. Wenn sie Objekte erkennen die ihnen im Weg

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stehen, werden diese eher auf die Bremse steigen und die Frage ist, ob der Vorteil der Fahrsicherheit unserem Wesen entspricht, nämlich dass wir auch schnell Fahren wollen. Der Mensch würde hier oft eine Aktion anders setzen als das Fahrzeug. Die Frage ist ob man in Zeiten wie diesen auch politisch gewollt ist, dass mehr Menschen im Auto sitzen, durch den Umweltgedanken will man die Menschen ja eher weg vom Auto, hin zu öffentlichen Verkehrsmitteln bringen.

Komar: Das kommt sicherlich auch auf die Umgebung an, in der Stadt ist das vielleicht einfacher, aber das autonome Fahren kann vor allem für ältere Bevölkerungsgruppen in ländlicheren Umgebungen eine Chance zur Mobilität sein.

Dr. Eustacchio: Das glaube ich auf alle Fälle, das können Möglichkeiten sein die „last Mile“ zu erreichen. Anderseits kann das den Interessen von anderen Interessengruppen entgegenstehen, Beispielsweise Taxi oder Uber. Dann kommt der große Aufschrei, da sitzt ja keiner im Fahrzeug und so weiter. Ich frage mich nur, ob ich meine Töchter in einen autonomen Bus setzen würde, wo keiner Aufpasst und wo es eventuell dazu kommen könnte, dass hier jemand belästigt und niemand etwas dagegen tun könnte. Das ist zwar alles mit Video überwacht, das hilft mir aber dann wieder nur im Nachhinein. Ich weiß nicht ob es hier nicht ganz angenehm ist, wenn da noch ein Busfahrer bzw. ein Mensch vorhanden ist, welcher eingreifen und reagieren könnte.

Ich vertrete sehr viele Industrieunternehmen und habe sehr viel mit Technikern und Ingenieuren zu tun, und was mir auffällt ist das diese Leute sehr stark Normen-getrieben sind. Das ist jetzt aus der rechtlichen Perspektive oft zu wenig, denn diese technischen Standards könnten durchaus unter der berechtigten Sicherheitserwartung sein. Das heißt, ich könnte dann trotzdem zur Verantwortung gezogen werden, weil dieser Mindeststandard ja nur ein „Mindest“-Standard ist. Ich versuche bei meinen Mandanten zu vermitteln, dass diese Standards eben nur Mindeststandards sind und es zu wenig ist, sich nur an diese zu halten. Vielfach wird der TÜV ja herbeigezogen, der TÜV ist aber eine private Einrichtung, und da wird auch gesagt „das hat der TÜV aber gesagt, dass das geht“. Dann kennt der TÜV aber die Judikatur nicht, denn es gibt dann Rechtsprechungen in bestimmten Bereichen, gerade bei der Sensorik, die vielleicht anderes sagen. Beispiel aus 2009, da ging es um einen BMW. Da ist ein Fahrer mit seinem BMW auf einen Randstein gefahren, im Schritttempo. Da ist der Airbag aufgegangen und hat den Fahrer an der Halsschlagader getroffen und dieser erlitt einen Herzinfarkt. Eigentlich hätte dieser Airbag ja nicht aufgehen dürfen, da bei Schritttempo ja keine Notsituation bestand, und da hat BMW aber argumentiert, dass man hier mehr Sensorik hätte verbauen können, dies aber aus Kostengründen nicht getan hätte. Da sagt der BGH dann aber, das wäre ein Konstruktionsfehler, weil das Fahrzeug zwar dem technischen Standard entsprechen würde, aber es wäre nach der Rechtsprechung zu wenig um diesen Unfall zu verhindern.

Hiermit will ich sagen, dass die Techniker nicht immer nur auf die Normen schauen dürfen, sondern auch die berechtigte Sicherheitserwartung berücksichtigen müssen. Hierfür muss eine technisch-rechtliche Risikofolgenabschätzung gemacht werden. Mir fehlt hier bei dem Ganzen die Sensibilisierung für den möglichen Schaden, es geht mir auch nicht darum nachher über eine Haftung zu reden, sondern es geht darum präventiv mögliche Schäden

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zu verhindern. Und das kann ich mir beim automatisierten Fahren jetzt überlegen, es kann immer noch sein, dass das Fahrzeug einen Fehler macht, das ist ja auch „ok“, aber dann muss vielleicht das Chassis, oder sonst was, so konzipiert sein, dass der Insasse stärker geschützt ist, als er das heute ist. Man muss dann irgendwo eine Sicherheit einbauen und sich das ganze System anschauen. Im englischen gibt es die Begriffe von Safety und Security. Safety ist sozusagen die Sicherheit des Produktes und Security die Sicherheit das von außen niemand eingreift. Hier ist das viel deutlicher. Ich darf also nicht nur die funktionale Sicherheit anschauen (der Sensor funktioniert, der Airbag geht auf), sondern muss auch die System Sicherheit beachten. Wenn es zu einem Problem kommt, muss ich das Fahrzeug in eine Situation bringen bei der für den Fahrer als auch die Umgebung keine Gefahr ausgeht. Erst wenn all diese Faktoren berücksichtigt werden, kann es dazu kommen, dass derartige Systeme in den Straßenverkehr kommen.

Wenn ein Fahrzeug ein Problem hat, muss das Fahrzeug so konfiguriert sein, dass es sehr schnell auf den Pannenstreifen zum Beispiel gebracht wird. Heute haben wir aber die Verpflichtung, dass ein Warndreieck in einem gewissen Abstand aufgestellt wird. Wie mache ich dann das, wenn ich keinen „Fahrer“ habe, muss das dann der Insasse machen? Oder muss das dann per Car-to-Car Communication machen? Muss das Fahrzeug dann andere Fahrzeuge warnen? Wenn das alles funktiniert kann ich mir schon vorstellen, dass man irgendwann derartige Fahrzeuge auf die Straße bringt.

Komar: Das ist auch ein Safety Concept welches ich behandelt habe, welches auch in der ISO 26262 von 2018 behandelt, dass man weg von fail-safe behaviour hin zu fail-degraded oder fail-operational behaviour hingeht. Das würde bedeuten, dass das Fahrzeug dann eben rechts ranfährt oder bis zur nächsten Abfahrt mit verringerter Geschwindigkeit fährt. Das gehört beim Entwicklungsprozess mit einbezogen.

Dr. Eustacchio: Richtig, wenn man das schafft, dann kann man auch ein Vertrauen erzeugen, dass immer notwendig ist bei solchen Produkten.

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