Federal Ministry
of Transport and
Digital Infrastructure

ETHICS COMMISSION

AUTOMATED AND CONNECTED DRIVING

REPORT
JUNE 2017

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Ethics Commission

Automated and Connected Driving

Appointed by the Federal Minister of
Transport and Digital Infrastructure

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I. Introduction

Throughout the world, mobility is becoming increasingly shaped by the digital revolution. The „automation“ of private transport operating in the public road environment is taken to mean technological driving aids that relieve the pressure on drivers, assist or even replace them in part or in whole. The partial automation of driving is already standard equipment in new vehicles. Conditionally and highly automated systems which, without human intervention, can autonomously change lanes, brake and steer are available or about to go into mass production. In both Germany and the US, there are test tracks on which conditionally automated vehicles can operate. For local public transport, driverless robot taxis or buses are being developed and trialled. Today, processors are already available or are being developed that are able, by means of appropriate sensors, to detect in real time the traffic situation in the immediate surroundings of a car, determine the car‘s own position on appropriate mapping material and dynamically plan and modify the car‘s route and adapt it to the traffic conditions. As the „perception“ of the vehicle‘s surroundings becomes increasingly perfected, there is likely to be an ever better differentiation of road users, obstacles and hazardous situations. This makes it likely that it will be possible to significantly enhance road safety. Indeed, it cannot be ruled out that, at the end of this development, there will be motor vehicles that are inherently safe, in other words will never be involved in an accident under any circumstances. Nevertheless, at the level of what is technologically possible today, and given the realities of heterogeneous and non-connected road traffic, it will not be possible to prevent accidents completely. This makes it essential that decisions be taken when programming the software of conditionally and highly automated driving systems.

The technological developments are forcing government and society to reflect on the emerging changes. The decision that has to be taken is whether the licensing of automated driving systems is ethically justifiable or possibly even imperative. If these systems are licensed – and it is already apparent that this is happening at international level – everything hinges on the conditions in which they are used and the way in which they are designed. At the fundamental level, it all comes down to the following questions. How much dependence on technologically complex systems – which in the future will be based on artificial intelligence, possibly with machine learning capabilities – are we willing to accept in order to achieve, in return, more safety, mobility and convenience? What precautions need to be taken to ensure controllability, transparency and data autonomy? What technological development guidelines are required to ensure that we do not blur the contours of a human society that places individuals, their freedom of development, their physical and intellectual integrity and their entitlement to social respect at the heart of its legal regime?

II. Procedure adopted by the Ethics Commission on Automated and Connected Driving

The Ethics Commission on Automated and Connected Driving, which was appointed by the Federal Minister of Transport and Digital Infrastructure, held its constituent meeting on 30 September 2016. It is a committee comprising experts from a wide range of disciplines, headed by Dr Udo di Fabio, a former Federal Constitutional Court judge and now a professor at the University of Bonn. The Commission‘s brief is „to develop the necessary ethical guidelines for automated and connected driving.“ Its members are drawn from the fields of philosophy, jurisprudence, social sciences, technology impact assessment, the automotive industry and software development. The issues and problems resulting from the brief were allocated to five working areas. A working group, chaired by a member of the Commission, was established to address each of the working areas. The Ethics Commission met in plenary session at five meetings, held at the Federal Ministry of Transport und Digital Infrastructure in Berlin. It worked independently and freely. At an additional event, the Commission conducted test drives in automated and connected experimental vehicles from various manufacturers.

Working Group 1, „Situations involving unavoidable harm“, was chaired by Professor Eric Hilgendorf. Issues related to the data generated by automated and connected vehicles were addressed by Working Group 2 („Data availability, data security, data-driven economy“), chaired by Professor Dirk Heckmann. Professor Armin Grunwald chaired Working Group 3 („Conditions of human-machine interaction“), which explored the human-technology interface. Working Group 4 („Consideration of the ethical context beyond road traffic“) addressed the technology of automated and connected driving in the context of other (connected) technologies and was chaired by Professor Matthias Lutz-Bachmann. The responsibilities for evolutionary systems were addressed by Working Group 5 („Scope of responsibility for software and infrastructure“), chaired by Professor Henning Kagermann.

External experts were consulted at a separate meeting held in January 2017. Each of the experts gave a short speech setting out their crucial points regarding the issues from the working areas and answered questions and comments from the Commission. Dr Tobias Miethaner (Director-General, Digital Society, Federal Ministry of Transport and Digital Infrastructure) provided information on the Federal Government’s objectives and activities in the field of automated and connected driving. Professor Julian Nida-Rümelin (former Minister of State, now at the Ludwig Maximilian University of Munich) gave a speech on ethical aspects concerning, inter alia, „dilemma situations“. Issues relating to data protection were addressed by Peter Büttgen (Head of Division at the Office of the Federal Commissioner for Data Protection and Freedom of Information). Adjunct Professor Markus Ullmann (Head of Division at the Federal Office for Information Security) addressed issues relating to cyber security. In his presentation, Professor Markus Maurer (Head of the Institute for Control Engineering, Braunschweig University of Technology) gave an account of technological and societal aspects of autonomous driving and Dr Joachim Damasky (Managing Director, Technology, German Association of the Automotive Industry) focused on human-machine interaction in his presentation. Professor Peter Dabrock (Chairman of the German National Ethics Council, Friedrich Alexander University of Erlangen-Nuremberg) and Professor Dieter Birnbacher (Heinrich Heine University of Düsseldorf) gave their opinions on ethical issues in the context of new technologies from other settings. The question as to responsibility in emerging systems was addressed by Professor Michael Decker (Karlsruhe Institute of Technology).

Composition of the Ethics Commission:

Professor Udo Di Fabio Chair	Holder of the Chair for Public Law (Constitutional Law Department) at the Friedrich-Wilhelm University of Bonn, former judge at the Federal Constitutional Court
Professor Manfred Broy	Founding President of the Centre for the Digitalization of Bavaria (ZD.B)
Renata Jungo Brüngger	Member of the Board of Management of Daimler AG, Integrity and Legal Affairs
Dr Ulrich Eichhorn	VW AG, Head of Research and Development
Professor Armin Grunwald	Head of the Institute for Technology Assessment and Systems Analysis (ITAS) at the Karlsruhe Institute of Technology (KIT) and of the Office of Technology Assessment at the German Bundestag (TAB)
Professor Dirk Heckmann	Member of the Bavarian Constitutional Court; Holder of the Chair for Public Law, Security Law and Internet Law at the University of Passau

Professor Eric Hilgendorf	Holder of the Chair for Criminal Law, Law of Criminal Procedure, Jurisprudence, Information and Computer Law at the Julius Maximilian University of Würzburg
Professor Henning Kagermann	President of the German Academy of Science and Engineering (acatech)
Auxiliary Bishop Dr Anton Losinger	Auxiliary Bishop of the Diocese of Augsburg, Chairman of the Board of Governors of the University of Eichstätt-Ingolstadt
Professor Matthias Lutz-Bachmann	Director of the Institute for Research in the Humanities and Social Sciences, Goethe University of Frankfurt am Main
Professor Christoph Lütge	Holder of the Chair of Business Ethics at Munich University of Technology
Dr August Markl	President of the ADAC (German Automobile Club)
Klaus Müller	Chairman of the Federation of German Consumer Organizations, Minister (ret.)
Kay Nehm	President of the Conference of German Transport Lawyers, Federal Public Prosecutor (ret.)

III. Ethical rules for automated and connected vehicular traffic

1. The primary purpose of partly and fully automated transport systems is to improve safety for all road users. Another purpose is to increase mobility opportunities and to make further benefits possible. Technological development obeys the principle of personal autonomy, which means that individuals enjoy freedom of action for which they themselves are responsible.

2. The protection of individuals takes precedence over all other utilitarian considerations. The objective is to reduce the level of harm until it is completely prevented. The licensing of automated systems is not justifiable unless it promises to produce at least a diminution in harm compared with human driving, in other words a positive balance of risks.

3. The public sector is responsible for guaranteeing the safety of the automated and connected systems introduced and licensed in the public street environment. Driving systems thus need official licensing and monitoring. The guiding principle is the avoidance of accidents, although technologically unavoidable residual risks do not militate against the introduction of automated driving if the balance of risks is fundamentally positive.

4. The personal responsibility of individuals for taking decisions is an expression of a society centred on individual human beings, with their entitlement to personal development and their need for protection. The purpose of all governmental and political regulatory decisions is thus to promote the free development and the protection of individuals. In a free society, the way in which technology is statutorily fleshed out is such that a balance is struck between maximum personal freedom of choice in a general regime of development and the freedom of others and their safety.

5. Automated and connected technology should prevent accidents wherever this is practically possible. Based on the state of the art, the technology must be designed in such a way that critical situations do not arise in the first place. These include dilemma situations, in other words a situation in which an automated vehicle has to “decide” which of two evils, between which there can be no trade-off, it necessarily has to perform. In this context, the entire spectrum of technological options – for instance from limiting the scope of application to controllable traffic environments, vehicle sensors and braking performance, signals for persons at risk, right up to preventing hazards by means of “intelligent” road infrastructure – should be used and continuously evolved. The significant enhancement of road safety is the objective of development and regulation, starting with the design and programming of the vehicles such that they drive in a defensive and anticipatory manner, posing as little risk as possible to vulnerable road users.

6. The introduction of more highly automated driving systems, especially with the option of automated collision prevention, may be socially and ethically mandated if it can unlock existing potential for damage limitation. Conversely, a statutorily imposed obligation to use fully automated transport systems or the causation of practical inescapabilty is ethically questionable if it entails submission to technological imperatives (prohibition on degrading the subject to a mere network element).

7. In hazardous situations that prove to be unavoidable, despite all technological precautions being taken, the protection of human life enjoys top priority in a balancing of legally protected interests. Thus, within the constraints of what is technologically feasible, the systems must be programmed to accept damage to animals or property in a conflict if this means that personal injury can be prevented.

8. Genuine dilemmatic decisions, such as a decision between one human life and another, depend on the actual specific situation, incorporating "unpredictable" behaviour by parties affected. They can thus not be clearly standardized, nor can they be programmed such that they are ethically unquestionable. Technological systems must be designed to avoid accidents. However, they cannot be standardized to a complex or intuitive assessment of the impacts of an accident in such a way that they can replace or anticipate the decision of a responsible driver with the moral capacity to make correct judgements. It is true that a human driver would be acting unlawfully if he killed a person in an emergency to save the lives of one or more other persons, but he would not necessarily be acting culpably. Such legal judgements, made in retrospect and taking special circumstances into account, cannot readily be transformed into abstract/general ex ante appraisals and thus also not into corresponding programming activities. For this reason, perhaps more than any other, it would be desirable for an independent public sector agency (for instance a Federal Bureau for the Investigation of Accidents Involving Automated Transport Systems or a Federal Office for Safety in Automated and Connected Transport) to systematically process the lessons learned.

9. In the event of unavoidable accident situations, any distinction based on personal features (age, gender, physical or mental constitution) is strictly prohibited. It is also prohibited to offset victims against one another. General programming to reduce the number of personal injuries may be justifiable. Those parties involved in the generation of mobility risks must not sacrifice non-involved parties.

10. In the case of automated and connected driving systems, the accountability that was previously the sole preserve of the individual shifts from the motorist to the manufacturers and operators of the technological systems and to the bodies responsible for taking infrastructure, policy and legal decisions. Statutory liability regimes and their fleshing out in the everyday decisions taken by the courts must sufficiently reflect this transition.

11. Liability for damage caused by activated automated driving systems is governed by the same principles as in other product liability. From this, it follows that manufacturers or operators are obliged to continuously optimize their systems and also to observe systems they have already delivered and to improve them where this is technologically possible and reasonable.

12. The public is entitled to be informed about new technologies and their deployment in a sufficiently differentiated manner. For the practical implementation of the principles developed here, guidance for the deployment and programming of automated vehicles should be derived in a form that is as transparent as possible, communicated in public and reviewed by a professionally suitable independent body.

13. It is not possible to state today whether, in the future, it will be possible and expedient to have the complete connectivity and central control of all motor vehicles within the context of a digital transport infrastructure, similar to that in the rail and air transport sectors. The complete connectivity and central control of all motor vehicles within the context of a digital transport infrastructure is ethically questionable if, and to the extent that, it is unable to safely rule out the total surveillance of road users and manipulation of vehicle control.

14. Automated driving is justifiable only to the extent to which conceivable attacks, in particular manipulation of the IT system or innate system weaknesses, do not result in such harm as to lastingly shatter people's confidence in road transport.

15. Permitted business models that avail themselves of the data that are generated by automated and connected driving and that are significant or insignificant to vehicle control come up against their limitations in the autonomy and data sovereignty of road users. It is the vehicle keepers and vehicle users who decide whether their vehicle data that are generated are to be forwarded and used. The voluntary nature of such data disclosure presupposes the existence of serious alternatives and practicability. Action should be taken at an early stage to counter a normative force of the factual, such as that prevailing in the case of data access by the operators of search engines or social networks.

16. It must be possible to clearly distinguish whether a driverless system is being used or whether a driver retains accountability with the option of overruling the system. In the case of non-driverless systems, the human-machine interface must be designed such that at any time it is clearly regulated and apparent on which side the individual responsibilities lie, especially the responsibility for control. The distribution of responsibilities (and thus of accountability), for instance with regard to the time and access arrangements, should be documented and stored. This applies especially to the human-to-technology handover procedures. International standardization of the handover procedures and their documentation (logging) is to be sought in order to ensure the compatibility of the logging or documentation obligations as automotive and digital technologies increasingly cross national borders.

17. The software and technology in highly automated vehicles must be designed such that the need for an abrupt handover of control to the driver ("emergency") is virtually obviated. To enable efficient, reliable and secure human-machine communication and prevent overload, the systems must adapt more to human communicative behaviour rather than requiring humans to enhance their adaptive capabilities.

18. Learning systems that are self-learning in vehicle operation and their connection to central scenario databases may be ethically allowed if, and to the extent that, they generate safety gains. Self-learning systems must not be deployed unless they meet the safety requirements regarding functions relevant to vehicle control and do not undermine the rules established here. It would appear advisable to hand over relevant scenarios to a central scenario catalogue at a neutral body in order to develop appropriate universal standards, including any acceptance tests.

19. In emergency situations, the vehicle must autonomously, i.e. without human assistance, enter into a "safe condition". Harmonization, especially of the definition of a safe condition or of the handover routines, is desirable.

20. The proper use of automated systems should form part of people's general digital education. The proper handling of automated driving systems should be taught in an appropriate manner during driving tuition and tested.

IV. Outcome of the discussions and unresolved issues

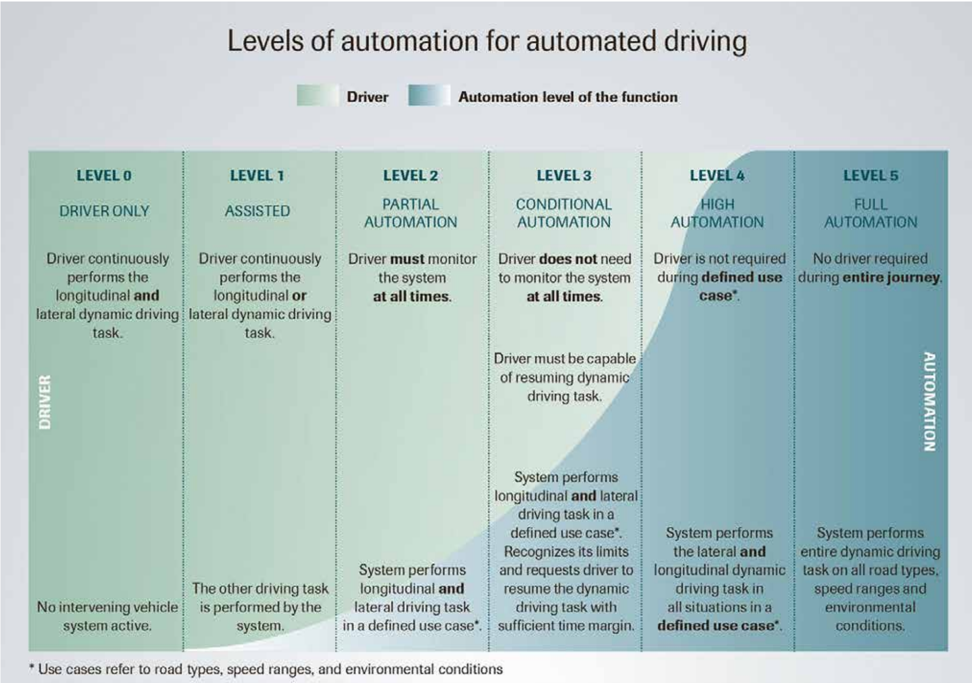
1. The licensing of automated driving systems as a risk decision

1.1 Levels of automated driving

Ethical questions arise primarily in connection with the deployment of conditionally automated and highly automated driving systems and for self-driving vehicles.

Figure 1: Levels of automation

source: VDA



The Ethic Commission‘s considerations focus on Levels 4 and 5 of the degrees of automation of automated driving. Starting at Level 4, the driver can hand the complete driving task to the system in defined use cases. These use cases describe the type of road, the speed range and the environmental conditions. Self-driving vehicles are emerging as the final level of development, Level 5. Here, the vehicle can perform the entire driving task for which it was developed completely alone, on all types of road, in all speed ranges and in all environments. In this case, the term „autonomous vehicles“ is also used.

The Commission is working with assumptions which, given the current state of the art, are not yet or at least not sufficiently available in a commercially viable form. Situations in which the technology has all the information it requires in order to, for instance, perform a reliable accident impact assessment, including any trade-offs between different harm scenarios, do not currently exist, or at least not in the shape assumed in the text book case. Nevertheless, ethical judgments are made, especially with regard to a clearly emerging future, which, given the non-linearity of an extremely dynamic development, for instance with regard to artificial intelligence and levels of connectivity, tend to be too limited rather than too far-reaching.

1.2 Growing mobility opportunities, more safety but also residual risks of fully automated transport systems

The shift from originally human-controlled actions to technological systems is not a new phenomenon. The debate surrounding the advantages and disadvantages of introducing new technological systems was conducted in the 19th century in the case of the railways and was also apparent in the early 20th century. The subject here was a technological development that we have taken for granted for a long time – the electronically controlled lift. The introduction of an electronic version of the lift meant initially not only the loss of jobs but also gave rise to a fear of system failures. Today, the electronic lift, despite the occasional malfunction, is on the whole one of the safest and most intensively used means of mass transport in the world.[1] An example such as this, which would appear to be marginal, shows just how much any scepticism arising with regard to autonomous driving should be expected and considered normal. Nor should it be dismissed as naive criticism of technology. Because road transport is part of the lifeblood of modern societies. Here, mobility manifests itself as an opportunity and as a risk.

1 Hancock. *Ergonomics* (2014), pp. 449, 454; https://www.welt.de/print-wams/article101802/Sicherstes-Verkehrsmittel-der-Welt.html (last retrieved on 6 May 2017).

Autonomous driving, for both driver-based and driverless systems, offers a wide range of new possibilities for users. It is expected to significantly reduce the likelihood of an accident. For users, it promises more convenience, less physical and mental stress and significant time gains. In terms of equity of access too, autonomous driving can enhance general well-being if self-driving cars enable people who do not possess the ability to drive a motor vehicle to make active use of the roads and the boundaries between the public and private carriage of passengers on the one hand and private transport on the other hand become blurred. Thus, under the current conditions, people with reduced mobility can enjoy better inclusion as a result of new mobility paths and integrate into the life of society.

On the other hand, there are still considerable risks in road traffic which, especially in mixed operations involving all five levels and in combination with other road users or other parties affected by road users, will continue to arise. If a harmful event in road traffic cannot technologically be completely ruled out, questions of liability and monitoring as well as dilemmatic conflict decisions in actual traffic situations will result as automated driving systems are increasingly deployed. The malfunctioning of connected systems or external attacks cannot be completely ruled out. Such risks, although rarely occurring, are inherent in complex systems. Nevertheless, from a purely utilitarian point of view, the advantages of autonomous driving in terms of increased mobility, enhanced safety and time gains outweigh prima vista the risks inherent in the systems. However, a consideration of the ethical context will also ask how, and to what extent, humans are to be allowed to surrender themselves to their technical artefacts, what boundaries have to be drawn and what control arrangements are required.

1.3 Human freedom of choice in dilemmatic conflict situations

Academics devote much time to the discussion of solutions to „dilemmatic situations". Preceding this discussion is the elemental question as to how much freedom of choice we are willing or allowed to transfer to programmers or even self-learning systems in the first place if, in Kantian ethics, the freedom of the individual to enjoy the right of moral self-determination forms the basis of an existence determined by reason. May existential dilemmatic decisions be anticipated at all in abstract/general terms and taken in advance by technology?

The following example can serve to illustrate this:

The driver of a car is driving along a road on a hillside. The highly automated car detects several children playing on the road. The driver of a manual vehicle would now have the choice of taking his own life by driving over the cliff or risking the death of the children by heading towards the children playing in the road environment. In the case of a highly automated car, the programmer or the self-learning machine would have to decide what should be done in this situation.

The problem associated with the decision to be taken by the programmer is that he might take the „correct" ethical decision for the human in conformity with the basic consensus but this decision remains an external decision which, moreover, does not intuitively capture a specific situation (with all the benefits and drawbacks of intuitive/situational behavioural control) but has to appraise a situation in abstract/general terms. In the case of an intuitive decision, the individual (in this case the driver) will either accept the risk of his own death or not.

Ultimately, therefore, the programmer or machine would, *in extremis*, be able to take correct ethical decisions on the demise of the individual human being.[2] Taken to its logical conclusion, humans would, in existential life-or-death situations, no longer be autonomous but heteronomous.

This conclusion is problematic in many respects. On the one hand, there is the danger of the state acting in a very paternalistic manner and prescribing a „correct" ethical course of action (to the extent that the programming prescribes this). On the other hand, this would be antithetical to the value system of humanism, in which the individual is at the centre of all considerations. A development of this nature thus has to be viewed critically.

2 Cf also. Lin. *Autonomes Fahren*, pp. 69, 77.

1.4 Dilemma situations

Dilemma situations are characterized by the fact that an automated vehicle has to decide which of two evils it necessarily has to perform. These cases are already familiar in a legal context as the „trolley problem“. [3] What is problematical about dilemma situations is that they involve decisions that have to be taken from out of a specific individual case and considering various factors. Specific normalizations such as „damage to property to take precedence over personal injury“ thus appear possible in dilemma situations, but as an abstract/general rule they raise doubts in cases in which, for instance, the result of damage to property could be an oil spill from a road tanker or the collapse of the power grid of a metropolitan region.

3 Welzel. *ZstW* (1951), pp. 47, 51.

Given the diversity and complexity of the different conceivable scenarios, abstract/general rules such as damage to property to take precedence over personal injury run up against the problem that it is not possible to normalize all situations.

It is not possible to systematically comply with the premise of minimizing personal injury unless an assessment of the impact of damage to property is attempted and possible resultant personal injury is factored into the behaviour in dilemma situations.

Nevertheless, in this case the Commission decided to take a decision and established a specific normalization (see also ethical rule 7). This can be justified by the fact that a solution that appears plausible from a technological perspective, offers the greatest potential for reducing accidents in most cases and is technologically feasible is to be preferred to a solution that is not yet feasible given the current state of the art.

1.5 Protection of life to enjoy top priority

On our scale of values, the protection of human life is a summum bonum. In the event of unavoidable harm, it enjoys unconditional priority. In the trade-off between damage to property and personal injury in the context of appraisable consequential damage, this results in preference always being given to damage to property over personal injury.

1.6 No selection of humans, no offsetting of victims, but principle of damage minimization

The modern constitutional state only opts for absolute prohibitions in borderline cases, such as the ban on torture relating to persons in state custody.[4] Regardless of the consequences, an act is mandated or prohibited absolutely because it is intrinsically already incompatible with the constitutive values of the constitutional order. Here, there is, exceptionally, no trade-off, which is per se a feature of any morally based legal regime. The Federal Constitutional Court's judgment on the Aviation Security Act [5] also follows this ethical line of appraisal, with the verdict that the sacrifice of innocent people in favour of other potential victims is impermissible, because the innocent parties would be degraded to mere instrument and deprived of the quality as a subject. This position is not without controversy, either in constitutional law [6] or ethically [7], but it should be observed by lawmakers.

4 Second sentence of Article 104 (1) of the Basic Law.

5 Federal Constitutional Court 115 (118 ff.) – *Luftsicherheitsgesetz*, judgment of 15 February 2006 – 1 BvR 357/05.

6 See only Josef Isensee. AöR (2006), pp. 173–192.

7 Niklas Luhmann. *Gibt es in unserer Gesellschaft noch unverzichtbare Normen?* (1993)

In the constellation of damage limitation that is programmable beforehand within the category of personal injury, the case is different to that of the Aviation Security Act or the trolley dilemma. Here, a probability forecast has to be made from out of the situation, in which the identity of the injured or killed parties is not yet known (unlike in the trolley dilemma). Programming to minimize the number of victims (damage to property to take precedence over personal injury, personal injury to take precedence over death, lowest possible number of persons injured or killed) could thus be justified, at any rate without breaching Article 1(1) of the Basic Law, if the programming reduced the risk to every single road user in equal measure. As long as the prior programming minimizes the risks to everyone in the same manner, it was also in the interests of those sacrificed before they were identifiable as such in a specific situation. The situation is similar in, for instance, the case of immunization. Here, too, statutorily imposed compulsory vaccination results in a general minimization of the risk without it being known beforehand whether the vaccinated person will belong to the group of the (few) harmed (sacrificed) parties. Despite this, it is in the interests of everyone to be vaccinated and reduce the overall risk of infection.

However, the Ethics Commission refuses to infer from this that the lives of humans can be „offset" against those of other humans in emergency situations so that it could be permissible to sacrifice one person in order to save several others. It classifies the killing of or the infliction of serious injuries on persons by autonomous vehicles systems as being wrong without exception. Thus, even in an emergency, human lives must not be „offset" against each other. According to this position, the individual is to be regarded as „sacrosanct". No obligations of solidarity must be imposed on individuals requiring them to sacrifice themselves for others, even if this is the only way to save other people.

A different decision may have to be taken if several lives are already imminently threatened and the only thing that matters is saving as many innocent people as possible. In situations of this kind, it would appear reasonable to demand that the course of action to be chosen is that which costs as few human lives as possible. Here, the Commission has not yet been able to bring its discussions to a satisfactory end, nor has it been able to reach a consensus in every respect. It thus suggests that in-depth studies be conducted. [8]

8 On the whole set of issues, see:
Dieter und Wolfgang Birnbacher. ‚Automatisiertes Fahren'. *Information Philosophie* (December 2016), pp.8–15;
Nida-Rümelin/Hevelke in *Jahrbuch für Wissenschaft und Ethik*, p. 1 ff;
Eric Hilgendorf. Autonomes Fahren im Dilemma. ‚Überlegungen zur moralischen und rechtlichen Behandlung von selbsttätigen Kollisionsvermeide-systemen'. idem. (ed.), *Autonome Systeme und neue Mobilität.* (Baden-Baden, 2017), pp.143–175;
Jan C. Joerden. , Zum Einsatz von Algorithmen in Notstandslagen. Das Notstandsdilemma bei selbstfahrenden Kraftfahrzeugen als strafrechtliches Grundlagenproblem'. in: Eric Hilgendorf (ed.), *Autonome Systeme und neue Mobilität.* (Baden-Baden, 2017), pp. 73–97;
Günther M. Sander, Jörg Hollering, Strafrechtliche Verantwortlichkeit im Zusammenhang mit automatisiertem Fahren', in *NStZ* (2017), pp. 193–206.

If the position set out here is followed, it results in the following problem. Can manufacturers be held accountable, and if so to what extent, for injuries inflicted or even deaths caused by automated systems, which are classified as a „wrong“? It should therefore be pointed out that collision avoidance systems are governed by the same principle as airbags or seat belts. Death caused an airbag inflating improperly remains a wrong, but the manufacturer will not be held liable for it if they have done everything that might be reasonably expected to minimize such risks. The installation of automated systems is thus permissible and does not result in special liability risks if the manufacturers do everything that might be reasonably expected to make their systems as safe as possible and, in particular, minimize the risk of personal injury.

1.7 Self-protection to take precedence over the protection of others or self-protection to have lower priority?

The guiding principle of humanism, which now enjoys universal consensus, is founded on the individual equipped with special dignity. It would not be compatible with this guiding principle if we were to impose on an individual, who is established in advance in his role of driver or user of a motor vehicle, obligations of solidarity with others in emergencies, including sacrificing his own life. For this reason, self-protection of the person is not per se subordinate to the protection of innocent parties. Nevertheless, the fundamental principle is that those involved in mobility risks must not sacrifice those who are not involved (ethical rule 9).

2. Taking animal welfare interests into account

The starting point when discussing this issue must be – what status do animals enjoy in our society? Purely intuitively, we will deal with (highly developed) animals differently than we deal with property. [9] This is supported by the theory of animals as sentient beings. This sentience of animals makes them creatures that are worthy of protection and imposes on humans the duty to preserve these creatures, as part of creation, from harm, even though animals cannot be given the same status as humans. Priority must therefore be given to preventing personal injury, including over the interests of animal welfare. If, however, personal injury can be ruled out, the protection of highly developed animals should always have priority over simple (calculable) damage to property. [10]

9 Article 20 a of the Basic Law and Article 90 a of the Civil Code make it possible to continue to apply *mutatis mutandis* the provisions governing property to animals but award animals a separate status to that enjoyed by property.

10 The special status enjoyed by animals is also illustrated by the way in which ethics is actually fleshed out in the judicial sphere, for instance section 1 of the Animal Welfare Act, which sets out the principle of non-harming and the avoidance of suffering and pain in animals.

3. Overruling by humans

In the case of conditionally automated driving, it is possible for the driver to use the highly automated mode for parts of the journey without having to intervene. Ethical conflicts arise when it comes to the following question. To what extent should voluntary resumption of control by the driver be ruled out? Is there an ethical obligation on the driver not to drive himself if this contributes towards enhancing safety? Or, conversely, should ultimate responsibility remain with the human until accidents can be ruled out with complete certainty?

One manifestation of the autonomy of human beings is that they can also take decisions that are objectively unreasonable, such as a more aggressive driving style or exceeding the advisory speed limit. In this context, it would be incompatible with the concept of the politically mature citizen if the state wanted to create inescapable precepts governing large spheres of life, supposedly in the best interests of the citizen, and nip deviant behaviour in the bud by means of social engineering. Despite their indisputable well-meaning purposes, such states of safety, framed in absolute terms, can undermine the foundation of a society based on humanistic and liberal principles. Apparently voluntary schemes can also have a similar impact, such as the „pay as you drive“ model for private insurance policy holders. Decisions regarding safety risks and restrictions on freedom must be taken in a process of weighing-up based on democracy and fundamental rights. There is no ethical rule that always places safety before freedom.

4. Technology in the case of divided responsibilities

Accountability for driverless systems that are being used for their intended purposes lies with the manufacturer and operator. In all other cases involving partially or highly automated driving systems, there are issues relating to the delimitation of accountability and liability. If responsibilities are divided, and taking into account the fact that the driver can override the system, the human-machine interface must be designed such that it is clear who is driving the vehicle at any point in time. This also includes the possibility of handing over control to the human driver if the technical system can no longer guarantee safe driving. However, an abrupt handover would result in the driver no longer being able to derive any benefit from conditionally automated driving. In this respect, therefore, an appropriate transitional period must be preserved. In emergencies, the control required to transition to a minimal risk condition must, by way of exception, remain with the vehicle if there is no time left to hand over to the human driver, if this will preserve a maximum level of safety for users and other parties involved.

5. Legal requirement to use fully automated transport systems?

Looking ahead to the future of automated and connected driving, the Commission also addressed issues not yet topical today relating to compulsory automation should technical systems prove to be superior to human driving. Would it be advisable for lawmakers to completely shape mobility and drivetrain designs on an area-wide and cross-system basis or, conversely, do the ideas of subsidiarity and the liberal idea of an association of subjects enjoying the autonomy of the individual require that the designs assert themselves on the market in competition and the state only ensures the necessary regulation and legal certainty? Does the automation and connection of road vehicles threaten to produce a social paternalization boost if drivers are no longer able to bypass the automated and connected transport systems by taking decisions of their own and traffic flows are comprehensively controlled?

As an expression of their autonomy, human beings, who take responsibility for their own actions, are at liberty to avail themselves of technological possibilities. And one component of their freedom of action is also not to avail themselves of certain possibilities. The mandatory introduction of such systems would impose severe constraints on human beings‘ opportunities for development (including their enjoyment of driving). The mandatory introduction of autonomous systems cannot be justified solely by the general enhancement of safety by highly automated systems. [11]

11 See 1.2. above.

6. Technical assistance systems to assist or guide the driver

In Level 2 automated driving [12], humans have full control over their vehicle. Driver assistance systems warn and remind them of mistakes they may make if they are fatigued or display other lapses of concentration. The purposes of such non-binding reminders to the driver is to prevent accidents, and they are thus to the benefit of society. If, however, the machine no longer possesses admonitory elements but issues commands that have to be obeyed, this has to be viewed more critically, and possibly be the prerogative of legislative trade-off decisions. [13] One possibility, for instance, is that drivers would be unable to start their vehicle if they have not taken the required breaks after a long trip.

A comparable situation in the sphere of nursing care illustrates how this situation is to be appraised. An increasing number of carebots are in operation, which help patients requiring a high level of care by laying out their medications or assisting in examinations.

However, how should the situation be appraised if the robots no longer simply laid out the medication but forced the patients to take them, supposedly for their own good? [14] Such controls could deprive individuals of the right to take their own decisions. However, they must retain the right to decide themselves whether they get into their car despite being fatigued or whether they take the medication. Commands that have to be obeyed are no longer compatible with the concept of the autonomous human being.

7. No irreversible subjugation to technical systems

Another question is the subjugation of human beings to technological systems. If autonomous driving is not regarded as a stand-alone issue but as part of a development that is penetrating many spheres, such as the replacement of complex occupational profiles by robots [15], it is possible to arrive at the conclusion that technological development is irreversible. Especially with regard to the loss of human cognitive skills, not only concerning the ability to drive but also the performance of medical operations, it would appear that it is no longer possible to act autonomously in the case of high automation, because the skills required for this, which have to be constantly practised, have disappeared. [16]

12 For classification, see 1.1. (Figure 1).

13 For a general account of the issue of advancing automation and its benefit for society, see also: Hancock. *Ergonomics*, p. 449 ff.

14 Deng. *Nature*, 23, 25, (2015), describes the problems associated with carebots, retrievable online at: http://www.realtechsupport.org/UB/WBR/texts/markups/Deng_TheRobotsDilemma_2015_markup.pdf.

15 See also Eidenmüller. *Oxford Legal Studies Research Paper* (2017), pp. 1, 3, who describes this phenomenon in relation to the legal profession.

16 For a description of the negative consequences, see also Wolf. *Autonomes Fahren*, pp. 103, 105; Bainbridge. *Automatica*, p. 775 ff.

8. Dependence of society on technological systems

The increasing dependence on technological systems is peculiar to modern societies. This now relates to core areas of infrastructure, such as food, access to information and knowledge, health care and energy supply. Certain systemic risks are an inevitable consequence of this development. These range from an accidental failure to an increasingly emerging „cyber wars" strategy comprising targeted hacking. If the digital control of road traffic increases, a further key area of infrastructure would become subject to such systemic instability to a greater degree than in the past. [17] Nevertheless, such systemic susceptibility can be justified in utilitarian terms as long as the risks are deemed to be low. However, to prevent susceptibility to system failure, as a worst-case scenario, resulting from hacking, the cyber security of these systems has to be more strongly promoted by the manufacturers and the state. Here, the state has a protective mandate to ensure the integrity of these systems.

17 See also Grunwald. *Autonomes Fahren*, pp. 661, 673.

9. „Total" connectivity of infrastructure

If it is to be possible to control vehicles without permanent human decision-making based on the immediate situation, it is necessary to develop IT-based decision-making systems that can supplant those control stimuli (such as speed, direction of travel/steering movement or choice of route) generated in the current system by the driver for a targeted and collision-free journey. The centrepiece of such a system can be computers, such as those already installed in motor vehicles, but in this case with significantly enhanced functionality. Other integral components of automated vehicle control include sensors, cameras and additional technical aids, which are used in the respective vehicle to capture and process all traffic information relevant to control of the vehicle (especially on the carriageways, vehicles or obstacles in the vicinity). On this basis, it is conceivable that the system of automated and connected driving could be decentralized and – from the perspective of any given vehicle – made self-sufficient, as it were, in such a way that the targeted and safe automated vehicle control works solely on the basis of the information captured by and stored in the vehicle itself. However, a digital transport infrastructure is also conceivable that uses information that is outside the vehicle and is retrieved by the vehicle for control purposes. Here, we are talking about central traffic information servers (on which, for instance, permanently updated weather or carriageway condition data are available for download), as well as roadside information carriers or other vehicles which, for instance, transmit information relevant to vehicle control and road safety within the context of car-to-car communication and cannot be detected by the sensors or cameras of the receiving vehicle (for instance the end of a tailback over the brow of a hill).

If, therefore, it cannot be ruled out against this background that the development of automated driving is inextricably linked with the idea and concept of centralized vehicle control and the capture of all vehicles, the question arises as to the acceptable risk of the improper use of such centralized power structures. There should therefore be critical reflection on what is feasible against the background of what is appropriate, moderate and ethically justifiable. Automated and connected driving could result in the total surveillance of all road users. In the case of centralized traffic control, it has to be assumed that the freedom of the individual to move freely from A to B without being detected or observed could be sacrificed to digital transport infrastructure based on efficiency. Autonomous driving would be at the expense of autonomous everyday action. The gain in convenience and road safety could not then justify the loss of freedom and autonomy. Action is to be taken to counter such a development by promoting „privacy by design“ and fleshing out normative standards.

10. Utilization of data between security, personal autonomy and informational self-determination

10.1. Reconciliation of conflicting objectives

The aspect of data security takes on a new dimension as a result of autonomous driving. If the system is to operate smoothly, it is necessary to collect and process quantities of data from users. Lawmakers have to strike a balance between collecting data, which is necessary for functional safety, and ensuring informational self-determination.

The principles of data minimization and data avoidance, which are enshrined in European and German law, must be appropriately reconciled with road safety requirements and with regard to a level playing field in globalized wealth creation models. Beyond the aspect that is relevant purely to road safety, there are a wide range of interests on the part of government agencies regarding security and on the part of private sector companies regarding commercial purpose [18] Here, informational self-determination should not be understood in a one-sided manner within the context of privacy. It also means the freedom of users to decide whether they wish to disclose personal data.

18 For an account of the problems involved, see also Hornung. *DUD* (2015), p. 359 ff.

10.2. Solutions that meet the requirements of data processing and data utilization

The introduction of various automated procedures necessitates new solutions that meet the requirements of data processing and data utilization. Data protection and an environment conducive to innovation by no means represent insurmountable opposites. Rather, they generate reciprocal added value. Automated and connected driving thus requires data protection that is conducive to innovation and innovations that are conducive to data protection. In addition, innovative technologies can make effective data protection possible (privacy by design). In keeping with the data law principle of privacy by default, vehicles should, upon delivery, already have privacy-friendly factory settings that suppress the collection, processing and use of data that are not relevant to vehicle safety, unless these data are absolutely safety-critical, and until the driver actively enables these processes.

The premise here must be that users take a decision of their own volition on the use of their data. Here, informational self-determination must be seen not in a purely one-sided manner within the context of protection against intrusion. It also includes the possibility of the voluntary disclosure of data.

If, however, the use and processing of data is no longer clearly discernible by drivers and thus removed from their decision-making, the state must fulfil its constitutional protective mandate and ensure an appropriate and necessary level of protection for its citizens with regard to the protection of their data. Here, the state could assume responsibility to the effect that the necessary privacy-relevant procedures connected to data relevant to vehicle control are given democratic legitimacy in the form of a statutory justification. One part of this statutory enabling norm could also be a requirement that automated (and connected) driving functions be licensed. It would then only be possible for the vehicle to drive in automated mode if it is ensured that it obtains certain certificates and, when in operation, exchanges sufficiently pseudonymized condition data with other vehicles and the infrastructure. In addition, investment could be made in research into and the development of new technical anonymization solutions. This would require continuous observation to determine whether certain data have been sufficiently anonymized and, if necessary, the adaptation of these processes.

Finally, practical procedures and technical solutions should be found that enable drivers, keepers or users to be informed about the purposes and legal bases of data processing with regard to the use of data that are not relevant to control and to take appropriate decisions. Any consent that has to be given by other parties in the vehicle‘s surroundings, such as passers-by or other road users, also requires legally compliant approaches.

In addition, the progressive introduction of automated and connected driving should be monitored by independent testing institutes and relevant stakeholder groups such as consumer watchdogs. To meet transparency requirements (see ethical rule 12), fact-based awareness-building about the opportunities and risks of data use is required. The particular relevance of this derives from the fact that the manufacturers of automated and connected vehicles have to be able to or must access their vehicles and the associated data way beyond the point in time at which ownership is transferred, for instance within the context of necessary updates, product observation or for purposes of customer loyalty.

11. The problems associated with the scope of responsibility of software and infrastructure

11.1. Problem

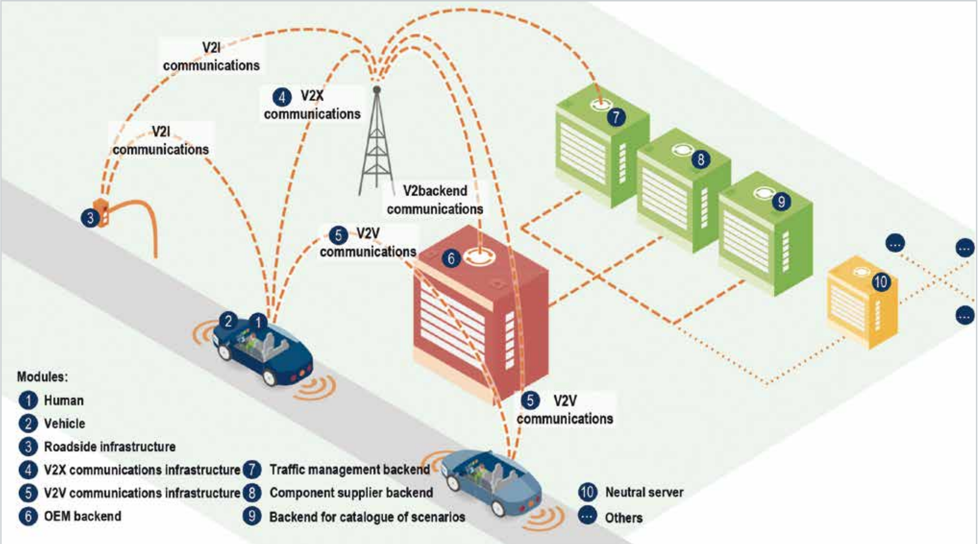
The introduction of automated and autonomous systems, both at the vehicle level and across systems in collaborative road traffic, raises the question as to who shoulders responsibility in the event of an accident. In this context, responsibility means the duty of a person to account for decisions taken by and attendant actions performed by the automated vehicle system and/or the software on which it is based, to assume liability and, if necessary, be willing to accept any legal consequences.

Today, the German system of liability assigns the risk of a road traffic accident in the final instance to the keeper or driver of the vehicle. In addition, the manufacturers are liable within the scope of statutory product liability. However, highly automated and fully automated vehicles are also subject to more far-reaching determinants (see Figure 2).

For this reason, not only the keepers and manufacturers of the vehicles but also the corresponding manufacturers and operators of the vehicle‘s assistance technologies have to be included in the system of liability sharing. The illustration provides an overview of the parties potentially responsible. It shows that liability and responsibility in connected mobility systems is shifted to the areas and players identified in the illustration and has to be divided up among them. In addition, a new definition is required of the duties of care to be observed by the manufacturers, suppliers and operators of components, software and data and by developers. Automated driving functions may not be deployed unless they are statistically safer than human drivers. With the shift of responsibility away from the driver/ keeper to the party responsible for the technological system within the context of product liability, the following question also has to be discussed. How much safer in statistical terms does a technological system have to be for it to be accepted by society and what methods will result in reliable confidence?

Figure 2: Modules in the overall architecture of cooperative road traffic [19]

19 Illustration based on Lemmer, K. (ed.). *Neue autoMobilität. Automatisierter Straßenverkehr der Zukunft* (acatech STUDY), (Munich, Herbert Utz Verlag, 2016)



Parties potentially responsible

1. Human being: drivers, vehicle keepers
2. Vehicle: OEMs, component suppliers, garages
3. Road infrastructure: public sector
4. V2X : communications infrastructure: communications network operators
5. V2V: OEMs
6. OEM backend: OEMs, IT service providers
7. Traffic management backend: public sector, etc.
8. Component supplier backend: level 1 suppliers, digital maps, etc.
9. Backend for catalogue of scenarios: state-certified body
10. Neutral server (interface with other services): IT service providers

The architectural illustration shows the wide range of different components that are present in collaborative road traffic. For each of the components, different players are responsible for quality assurance and the reliable transmission of data. Except in the case of V2V/V2X communications, the vehicle data are first transmitted to the OEM's backend. However, it is not the task of an ethics commission to recommend whether the backend should, as shown in the illustration, be operated by the OEM or by a neutral organization. Rather, it is part of parliament's responsibility for shaping public policy.

11.2. How can the responsibility for software and infrastructure be fleshed out and split?

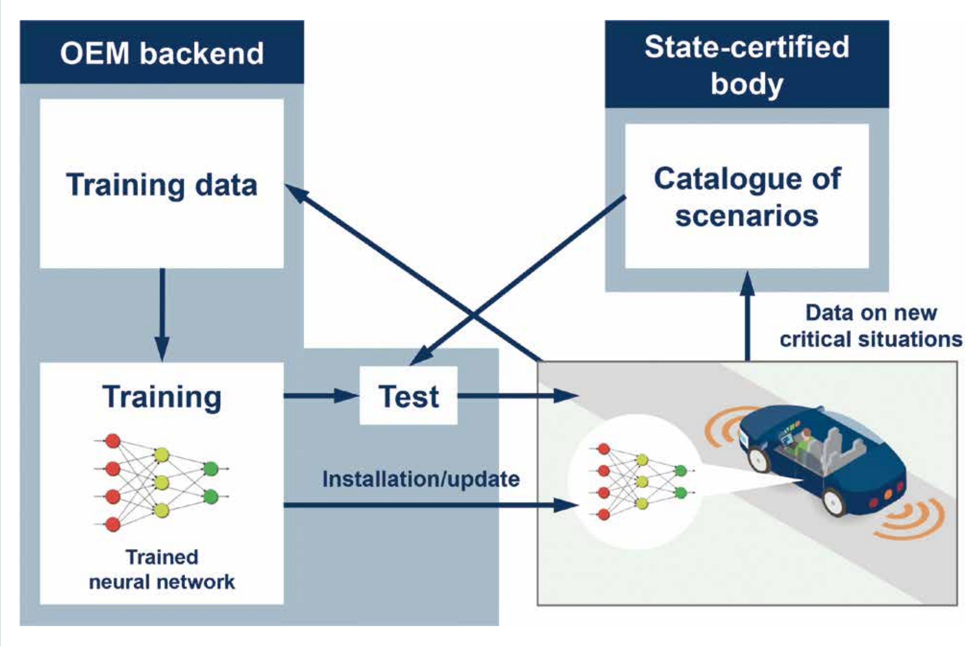
It follows from the architectural illustration that the manufacturers are responsible for the functional safety of the systems. If they are to meet this responsibility, they have to use and analyse certain datasets. Accordingly, the OEMs are responsible for all safety-related data (contents and quality) that are exchanged with the vehicle via the traffic-based information and communications infrastructure and via the OEM backend. If they use data from third-party providers, they are responsible for the quality and contents of these data. If they are to meet this responsibility, a check of the quality of incoming safety-related data from external third-party providers could be considered. This could take the form of certificates that have to meet certain security standards for the products.

These certificates should contain, in particular, evidence of confidence with regard to the quality guarantees. Thus, for instance, a map service provider should guarantee the consistency of the information provided on the maps with the degree of resolution in terms of time and space by means of a confidence threshold stipulated by the OEM. Likewise, statements on maximum latencies and integrity of the data transmitted by V2V and V2X communication should be combined with confidence statements.

However, the reliable transmission of data is not covered by the manufacturers' responsibility for liability and could thus be assigned to the telecommunications operators. They are responsible for the secure transmission of the data within the scope of the guarantees they have given. In any case, the provisions governing data privacy have to be observed within the context of product responsibility. When assigning responsibility and fleshing out the details, lawmakers in Member States and at European level will have to comply with European and constitutional protective mandates with regard to ensuring the integrity and confidentiality of such systems. As far as the collection of such data is concerned, manufacturers must comply with the regulatory framework and should submit proposals on its evolution from their perspective. New anonymization procedures for vehicle-related data should be developed.

To prevent errors and to ensure the safety of all road users, there should be an analysis of hazardous situations that are relevant to erroneous perception and behaviour by the vehicle. It would be technologically desirable for identified errors in the system to be forwarded by the manufacturers to a catalogue of scenarios, which would store these situations. These should be forwarded to an independent public institution (see ethical rule 8). The catalogue of scenarios described above could be designed such that it is constantly enlarged on the basis of real-life hazardous situations. One idea would be a backend database filled with information on situations in which erroneous interpretations of the actual surroundings were observed by the vehicle, resulting in the automated driving mode being deactivated. When fleshing out the system in practice, it will be necessary to identify what information will be required for the catalogue of scenarios.

Figure 3:
Establishment of a knowledge base on critical driving functions by end-to-end deep learning (own illustration).



Furthermore, the possibility of the vehicle also ensuring the safety of its driver without external connectivity should be considered. For everyday practice, a safety check can be suggested, which ensures that the unrestricted functionality of all on-board systems required for the automatic driving function, the connection with the backend and the successful installation of all critical software updates is checked. If an error occurs or if a critical update has not been installed, it should be indicated that the automation function concerned is not available.

11.3. To what extent can self-learning systems be deployed?

When various software programmes are used, a distinction has to be made between learning and self-learning systems. Learning systems are trained during development. Self-learning systems additionally improve themselves during operation. At present, not only learning systems (for instance object identification algorithms) but also self-learning systems (for instance adaptation of vehicle dynamics to drivers) are in use. Self-learning systems continuously update their knowledge base while in operation. However, this means that the knowledge bases of the individual vehicles would differ as operation increases. The Commission asked itself the following question. In what areas can such systems be licensed and who is ultimately accountable with regard to such systems?

With regard to the introduction of self-learning systems, the protection of the physical integrity of the users must enjoy top priority (see ethical rule 2). As long as there is not sufficient certainty that self-learning systems can correctly appraise situations and/or comply with safety requirements, the decoupling of self-learning systems from safety-critical functions should be prescribed. Given the current state of the art, the deployment of self-learning systems is thus only conceivable in the case of functions that are not directly safety-relevant. Here, deployment in the sphere of human-machine interaction could be possible, where it could, for instance, analyse the driver's personal driving mode and adapt to it. However, it should be borne in mind that such an analysis of an individual's driving mode would create the possibility of gaining and using data for purposes that are not directly relevant to the vehicle. Such use by permitted business models may be acceptable if the data sovereignty of the personal user is preserved (see ethical rule 15).

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