Report on the Need for Research

Round Table on Automated Driving –

Research Working Group

by

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Research WG

Round Table on Automated Driving

1. Introduction

This document has been produced by the Research Working Group (WG) of the Round Table on Automated Driving set up by the Federal Ministry of Transport and Digital Infrastructure. With this document, the Research WG aims at describing the need for research on continuously active vehicle automation as fully as possible. It is aimed in particular at the orientation of future national research programmes in this area.

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The Research WG is divided into four sub-working groups which have been described as clusters, namely the human-machine interface, the area of functional validation (function, safety, validation cluster), the aspects of road infrastructure and traffic and social aspects. These sub-divisions are derived from the initial research work conducted by the Federal Highway Research Institute (BASt) on the legal consequences of increasing vehicle automation (BASt Report, Issue F83, Bergisch Gladbach 2012) because they permitted a classification of all research issues identified at that time. The sub-divisions have proved to be suitable during the course of the work and are also used in this brief summary as the top level of classification. The documents submitted as Annexes 1 to 4 have been included to provide supplementary information and greater detail and similarly refer directly to the division of work in clusters.

It can be said that automated driving is not a completely new phenomenon. Rather, it is the further development of advanced driver assistance systems with environment sensing. Low degrees of automation of continuously automating functions in particular are already frequently available on the market as advanced driver assistance systems and are used in road traffic (such as adaptive cruise control or ACC, or lane departure warning systems which have been an optional extra in mid-class vehicles for some years now).

Automated driving is a further development of advanced driver assistance systems with environment sensing.

Although research on automated driving, such as the EU project *Prometheus*, dates back to the eighties, international research activities since around 2010 have increasingly placed importance on automated driving. A high coordination of regional research primarily in the USA, within the EU and in Japan is to be observed here. It is therefore highly advisable to compare international activities in general and within the EU in particular for the orientation of future research projects.

The Round Table on Automated Driving focuses on the continuously automated functions to be expected in future. Functions of this type will permit the driver to transfer the task of driving (partly, depending on the respective degree of automation) to the machine (the vehicle). Since dependent on specific functional design, a large number of possible versions of division of labour between driver and machine is to be expected in principle. In order to standardise this steady rise in technical discussions, specific levels of continuously automated driving functions have been taken as basis for the work of the Round Table (see overview “Specification and Classification of Automated Driving Functions” as a result of the second plenary session of the Round Table, see Annex 5). This classification according to levels of automation (assisted, partly automated, highly automated, fully automated) is based on the following report and originates from a study of the project group entitled “Legal Consequences of Increasing Vehicle Automation” (Rechtsfolgen zunehmender Fahrzeugautomatisierung) (BASt Reports, Issue F83, Bergisch Gladbach 2012).

High automation systems are currently the reason for the special interest in the topic. The automotive industry intends to launch them to market in the coming years as the next level of development of continuously automated functions. Highly automated applications are intended to enable the driver to temporarily discontinue driving (completely). Whilst today drivers are required to attentively observe the traffic environment and the behaviour of their own vehicles at all times (whereby this also applies without restriction when using advanced driver assistance or partial automation), for the first time high automation represents a degree of automation which completely assumes the function of (mechanically) driving the vehicle. High automation still always requires the driver to resume control after a brief lead time as soon as requested to do so by the system.

A main challenge and difference compared with former applications starting from the level of high automation is to be found in the use of independent mechanical vehicle control.

The risks associated with the higher levels of automation should be pointed out: in cases of high automation, mechanical vehicle control for the first time has a direct effect – without the driver as permanently available fallback level. This places very high demands on the system function and is directly linked with the question of a new type of automation risk. In this respect decisive importance is attributed to designing the functions to be as safe as possible. Risks also arise in the cooperation between driver and machine: one conceivable limitation to safety in high automation is that the driver is still viewed to be a fallback level (when the system reaches its limits, for example). Cooperation between machine and driver must therefore work because otherwise new dangers arise. Aspects of suitably implementing cooperation will therefore be decisive if dangers are to be avoided. In addition to the goal of traffic safety already mentioned here, which forms an internal correlation between all research clusters, the maintenance and improvement of traffic efficiency (maintenance of the traffic flow, congestion avoidance) and acceptance of this development by society as a whole are additional higher ranking factors which may require research.

Risks of higher levels of automation depend on the specific implementation: system function and cooperation are decisive to achieve the higher ranking goals of traffic safety, improvement in traffic efficiency and acceptance.

The following four paragraphs explain the four topic clusters of the Research WG:

In contrast to the functions of continuous vehicle automation which have so far been available, new questions and requirements concerning the human-machine interface basically arise due to the temporary independence of mechanical control. Questions arise at the human-machine interface particularly in connection with the possibility of transferring control back to the driver and on the continuous awareness of the system status. These questions are of great importance for the safe use of any such functions. Work can be based on existing research results on advanced driver assistance systems here.

There is a great need for research on the human-machine interface. Work is based on existing research results.

Completely new requirements arise in the area of function, safety and validation. Until now the driver has permanently conducted parallel tasks, so that the systems available have trusted that the driver is immediately available for corrective intervention and to take over from mechanical control. This situation alters fundamentally with the introduction of high level of automation: the move away from the driver requires a mechanical independence of the control system which for the first time also calls for an independent technical level of control safety in view of the delay in the driver regaining control.

The requirements placed on functional validation alter fundamentally in view of mechanical independence.

As far as the area of road infrastructure and traffic is concerned, it can firstly be established that vehicle automation will impact all road categories in the long term. Nevertheless, a considerable share of the questions raised concerns applications which place special alternating requirements on vehicle and infrastructure due to the higher speeds driven or which implement even higher levels of automation. This may only be of restricted importance for first applications (in the sense of a compelling requirement). However, the urgency of addressing these topics involving changes which are only expected in the long term is justified by the distinctly longer lead times for changes in this area. It should also be emphasised that infrastructure measures support an introduction of automation technology and may therefore distinctly accelerate it overall.

Longer lead times for changes in the area of road infrastructure require alternating requirements to be addressed at an early date.

As explained in the introduction, social aspects are a high-ranking factor when considering the need for research. Accordingly, individual issues – such as ethical issues – are addressed in different sections of this summary. However, where these issues are described in greater detail thematically, a correlation arises between the independence of mechanical control and traffic safety. New possibilities of influencing also extremely time-critical situations raise far-reaching questions for value systems which are to be considered in the control decisions. Other further reaching issues of a social nature arise particularly with respect to higher degrees of automation which signify changes for the traffic system, the use of means of transport and so on. Specific changes are also to be viewed in this connection which arise specifically from the application of continuous automation in commercial vehicles. However, this also includes the aspect of the significance of vehicle automation for the future viability of the automotive industry as a whole which is a driver of this development.

Higher ranking social aspects refer, for example, to acceptance of and changes resulting from automated vehicles.

These working results of the Research WG since its first meeting in January 2014 are therefore geared to the interrelated nature of the need for research which extends distinctly beyond initial applications. Not all research issues must therefore necessarily be addressed immediately and not all issues are of significance for initial applications. However, long-term research projects and development cycles of around four years call for research topics to be defined at an early date so that the results may be incorporated into new functions. Individual issues can be correctly classified only in the knowledge of the overall picture so that the presentation in its current form is justified and expedient. At the same time, a number of subjects are defined in different working groups of the Round Table but from a different perspective. This is true particularly for the driver-vehicle working group. Both the driver-vehicle working group and the law working group directly (up to 2020) address upcoming implementation tasks, and less the requirements of further “automation generations” after 2020. The working status of this document reflects the issues foreseeable at the start of 2015.

Need for research is interrelated and is not relevant to first applications in its entirety.

The background to addressing automated driving would also be incomplete if it were not to highlight the potential of available technical developments: systems are already available on the market which operate in emergency situations and

– for example as emergency braking system – usually intervene beyond the driver's capacity and therefore reduce or even avoid accidents. By contrast, continuously active automation is not initially aimed at a direct gain in traffic safety in near-accident situations but is usually intended to improve driver comfort. Systems of this type give the driver the choice of transferring the control of the vehicle to the machine – initially possibly restricted to certain driving situations and road categories. To the extent that issues which are directly relevant to safety can be addressed by a suitable design of the systems, there is a chance to completely avoid human driving errors (due to fatigue, inattentiveness, failure to observe traffic rules, distraction in road traffic etc.). The opportunity is therefore to control the vehicle better than the driver, particularly in typically less challenging situations. A decline in the accident statistics may result from the extension of the area of application of continuous vehicle automation to be expected in the long term.

The potential of continuous vehicle automation for traffic safety is that vehicles can be controlled better mechanically than by drivers in minor situations.

This report is sub-divided into a short and a long version in accordance with the four research areas. The short version offers fast access to the results and provides an overview of the subjects. It is followed by the long version of the working results in the respective fields of research in Annexes 1 to 4 which are provided in particular with the intention of supplying a comprehensive documentation of the results of the Research WG and for reference purposes.

Structure of this Research Report.

2. Aspects of the human-machine interface (HMI)

If humans continue to be discussed as the prime cause of accidents in connection with the automation of driving, it should not be forgotten that current mobility is decisively based on the fact that the driver contributes his human skills to the traffic system. Humans as vehicle drivers are important for a stable traffic situation both in terms of the specific situation of use and the preparation for it as well as the period thereafter.

Highly automated driving differs distinctly from driver assistance.

Both in quantitative and qualitative respect, highly automated driving differs distinctly from driver assistance which has been in successful use since the nineties. The driver uses assistance systems only in part and is supported in performing driving tasks so that he continues to assume a supervisory role.

“One of the greatest challenges to highly automated multifunctional systems is the question of an integrated interaction concept. A similar development has already been established in aviation. In terms of their impact, the findings made in this area may only be transferred cautiously to the automotive field. On the one hand, the level of training, system dynamics and situation complexity differ greatly from each other. On the other hand, fundamental risks such as “mode confusion” or “pilot out-of-the-loop” may arise even with highly trained pilots and must certainly be monitored with drivers who have undergone less training. The system complexity behind a “mode confusion” can present a great challenge here.” (Bengler, K. & Flemisch, F., 2011)

The increasing automation of vehicle control promises substantial effects in the area of traffic efficiency and traffic safety in addition to a clear rise in comfort (see also Section 4.5).

The question is therefore which research activities in terms of cooperation between humans and machine (i.e. highly automated vehicle) and traffic are expedient to raise the potential of this technological approach whilst at the same time guaranteeing a stable system. Questions are also addressed which have been discussed in a similar way in connection with advanced driver assistance systems and which are now attributed greater significance. One example here is the interaction between skill, control and responsibility which is intimated with advanced driver assistance systems (e.g. ACC) and is intended to develop its full relevance in high automation.

Even at a higher level of automation, humans will be required to take over vehicle control at the system limits.

Man will play an important role in the vehicle even at the level of high automation in order to stabilise the situation at the system limits and also in the case of system errors. Contrary to an aircraft, a vehicle is a consumer good in the majority of cases. The success of automation and therefore also of the installation volume will greatly depend on the acceptance of the user and the practicability of the respective implementation.

The research topics presented in the following are not prioritised in terms of importance. The discussion has shown that the content of the individual subjects is strongly interrelated. Knowledge of the state and availability of the driver is therefore an important condition in many research issues and is therefore placed at the beginning. The occupation with possible auxiliary activities can be investigated considerably better if this is done against the background or together with interaction concepts for cooperative vehicle control.

Only then would it appear expedient to address questions of validation, teaching and learning automation.

The order of the topics does not therefore indicate any form of prioritisation but recommends an order without overlooking the interrelated content of the individual subjects.

Knowledge of readiness to resume control is of great importance in the transition to a different degree of automation.

2.1. Driver states and readiness to resume control

Fundamental research and experience from plant and flight automation show that high degrees of automation lead to changes in concentration and vigilance. In view of the fact that drivers continue to play an important role despite high automation at least in the transition to a different degree of automation, knowledge of the availability is of great importance. Even in partially automated systems, the state of the driver plays an important role. It must be ensured that drivers go about their continuous monitoring task within the set framework. With respect to motion sickness, it would at least be desirable to consider the direction of view before and during manoeuvres. A high temporal priority is therefore to be placed on the development of technologies to measure the readiness to resume control; the potential of existing technologies to objectively evaluate the readiness to resume control should be estimated in order to keep drivers in or bring them back to the control loop. The conditions which must be satisfied for drivers to basically resume control over highly automated functions must also be assessed.

Driver states are to be systemised by developing a taxonomy.

It is to be assumed that despite high automation, transitions to other operational states will be made. It must therefore be examined how frequent changes in "mode" affect the readiness to resume control and its development. The availability of the drivers and the associated states should be systematised in terms of developing a taxonomy because currently all taxonomies of vehicle control refer to this in their descriptions.

Under which conditions the recognition of the readiness to resume control can be waived is also important. This could define the limits for early automated systems. Approaches should also be examined which react to inadequate reactions of the driver such that they initiate a manoeuvre to reduce risk (e.g. emergency stop). (See also Section 3).

The shaping of the human-machine interface is of great importance precisely in automation.

2.2. Interaction between interfaces

Technological development promises extensive functionalities. The significance of the human-machine interface will not diminish (see aviation, for example) because the requisite system transparency and mode awareness and faultless and fast interaction will become considerably more important. Therefore, both concepts for transferring the driving task to the vehicle and returning it to the driver must be investigated so that drivers may resume control over highly automated functions.

The degree to which and the manner in which the intentions of vehicle and the surrounding vehicles must be communicated are also to be investigated.

Design rules for suitable human-machine interfaces, possibly in the form of best practice examples, must be formulated.

Experience from aviation cannot simply be transferred. Specific research work is recommended.

Research results must be systematically included in international standardisation.

Suitable interaction technologies and system architectures must be developed and researched. It is also deemed necessary to address interaction concepts which support high degrees of automation and transitions through to manual or partially automated ones. The development of new interaction concepts is intended to support the migration from conventional vehicle control to new paradigms in order to make use of the existing experience of motorists.

This also includes the consideration of incorrectly initiated transitions because this rare case is also to be included in the equation.

It should generally be ensured that the results of these research activities are systematically incorporated in international standardisation. Different national requirements, differently worded standards, higher or contradictory internationalisation requirements must be avoided (e.g. activation of ACC systems, see also Section 3).

Communication between man as road user and automatically controlled vehicles will be necessary.

2.3. HMI for the social interaction with the external environment

Which information must be communicated and how in mixed traffic?

Communication between road users, in particular with weaker road users, but also between car drivers is an important part of the everyday traffic situation and a prerequisite for cooperation. Whenever the machine “car“ moves in the social space of “traffic“, there will be an interaction with other road users and the environment which can be selectively shaped by an HMI directed at the external environment. In particular, collision avoidance between two road users is based on these mechanisms. Automated road users must contribute to communication with respect to the conflict avoidance potential and also in terms of an efficient flow of traffic.

There is a need for research into the question as to the information (status of automation, planned intention, system status) which must or should be communicated. Another question refers to the minimum requirements to be placed on new signal images in order to guarantee fast perception and clear interpretation in conjunction with common signals (e.g. direction-of-travel indicator, brake light etc.). Special importance is attached here to the vehicle’s movement and the corresponding trajectories in addition to lighting equipment and other measures on the outer skin of the vehicle.

What has been banned so far is now allowed and could also be advisable?

There is also a further need for research into the requirements arising in mixed traffic (see also Section 4.4 of this summary). In addition to knowledge about the requisite information provided to the vehicle by the road infrastructure, the extent to which the road infrastructure must also recognise intentions of automation or the general system status must also be clarified.

2.4. Non-driving activities

The increase in automation permits drivers to engage in non-driving activities which could not be conducted parallel to manual driving or partial automation.

The properties of auxiliary activities must therefore be investigated which are suitable for this and may even positiviely influence the readiness to resume control.

The huge entirety of possible auxiliary activities should therefore be systematised in order to obtain design and application recommendations. It would be desirable to develop a manufacturer-independent specification of prototypical standardised auxiliary tasks for research situations. Auxiliary activities which do not depend on the vehicle must be also be considered (for example, reading a book, eating/drinking, devices not interconnected with the vehicle, so-called “nomadic devices”).

It must furthermore be investigated how a “driver” behaves during an auxiliary activity if the vehicle makes an emergency stop.

Whether a positive or negative list of auxiliary tasks is advisable should be clarified and which criteria are to be applied to the respective assignment.

The objective of this research is to obtain a technically mature proposal for an automation and interaction concept. It must be possible to apply this proposal to all classes of vehicle (M1-N3 [Directive 2007/46/EC with Annex XXIX]). The concept ensures two things: it is clear to the driver at all times whether and which non-driving activities he is entitled to engage in, and the overall driver-vehicle system guarantees a change to the safe side if a forbidden, non-driving activity is detected.

The statements made in Section 2.5 Design for practical use and avoidance of abuse are also relevant here.

2.5. Design for practical use and avoidance of abuse

Inappropriate interaction schemes for automation functions may cause great safety problems.

It is to be expected that errors of system conception and reliability as well as flexibility of technical equipment, but above all in use by the driver will arise. Operating mistakes are to be expected, e.g. in changing between vehicles, forgetting or incorrect activation of systems, attributing false competencies to the system analogous to the very frequently encountered misconception that an anti-lock braking system (ABS) shortens brake paths. It is imperative to research these types of errors (operating errors, omission errors, errors in reasoning) in order to counteract them through design measures.

Operation and the main and side effects must be adequately communicated.

Inappropriate interaction schemes for automation functions may cause great safety problems. This is why acceleration and brake pedal must always be arranged in the same way; this principle is maintained even with right and left-hand drives. A similarly all-inclusive HMI concept certainly has advantages when changing cars. It is not currently clarified how an optimised automation function is to look ergonomically and psychologically so as to be self-explanatory, clear and intuitive. Corresponding proposals must be applicable to all vehicles. Possibilities of differentiating may be considered which are desired by competitors and refer to different classes of vehicle (M1-N3 [Directive 2007/46/EC with Annex XXIX], but also different vehicle segments A-J [REGULATION (EEC) No. 4064/89]). The support of manufacturer-independent standardisation from the government side is necessary in order to avoid an excessively strong proliferation of inadequately coordinated versions (see aviation).

It is advisable to systematise possible auxiliary activities.

The design of corresponding manuals, teaching units, training elements or interactive user interfaces of the vehicle is not currently researched.

Acceptable and effective precautions must be taken to avert foreseeable abuse (sleeping for example).

A special type of error is the intentional error which means that the system is used for objectives for which it was not originally intended. Simulation studies show that drivers immediately start to engage in highly distracting activities. Studies on ACC demonstrate that the systems which have been designed to promote comfort or heighten driver arousal and the perception of risk are being abused. It is to be expected that a number of individuals and also others will test and overstretch the limits of the system. It is therefore quite conceivable that radical cyclists or pedestrians will deliberately stop vehicles automatically or that drivers - in an illusory state of security - will leave the entire braking process or avoidance manouevres to the vehicle. Acceptable and effective precautions must be taken to avert foreseeable abuse (sleeping for example). (See also Sections 2.1 and 2.2.).

2.6. Test methods

The controllability of the system by the driver and proof of this is a basic demand in connection with cooperative vehicle control.

The controllability of the system by the driver and proof of this continues to be a basic demand placed on high levels of automation. These include all cases of use and system errors and failures. Established test methods have not been designed for the new cases. The main difference comes from the altered requirements of the driving task which permits more pronounced freedoms (see 2.4. Non-driving activities). In addition, new degrees of freedom are produced when it is not necessary to continuously monitor the driving task. Existing test methods need revising and which methods for special aspects of highly automated driving are unsuitable and whether new approaches can be established must be investigated. The question here in particular concerns the methods which provide information on long-term aspects, learning and forgetting. A further example concerns methods to examine cooperation, namely for cooperative vehicle control and cooperation externally with other road users (see also Section 4.7 here). Existing assessment scales and indicators must be extended and their importance re-assessed. In addition to assessments of distraction and drowsiness, greater focus is being placed on aspects such as over-trust/over-compliance in particular.

User acceptance is an important success criterion if the potential of high automation is to be enhanced.

Existing conventions, such as the RESPONSE Code of Practice, should be addressed and adjusted to the specific issues of high degrees of automation.

User acceptance is an important success criterion if the potential of high automation is to be enhanced. Systems which are not purchased or not used due to lack of acceptance or inadequate suitability for use, cannot make any contribution to traffic efficiency and traffic safety. Manufacturer-independent factors must be identified (controllability, driving experience, acceptance).

This development of methods will benefit from or even require a system of coordinated and possibly standardised (use) scenarios.

It must generally be ensured that the results of these research activities are systematically incorporated in international standardisation to avoid unnecessary work through a standardised validation method and to be able to compare results at an international level (see also Section 2.9.).

2.7. Learning and training

The degradation of skills must be researched and how systems can be designed such that they permit training embedded in the driving task.

Whilst there are few signs of incorporating the use and function of advanced driver assistance systems in driving lessons, this could well prove to be expedient for highly automated vehicle control. In principle, this aspect has already been taken into consideration in the distinction between manual and automated transmissions. Selective driver assistance training is currently on offer here and there. In the same way as automatic aircraft control, the requirements placed on training and recurrent training must therefore be clarified in order to counter the possible effects from the degradation of skills. In addition to special training, it must in particular be investigated how systems can be designed such as to permit training to be embedded in the driving task. Investigations in which the mental models are studied and which teach drivers about the system function are necessary to selectively shape these models.

The effects of increasing vehicle automation on traffic flow, traffic safety and competence of drivers must be observed and assessed.

The social acceptance and previous experience of users in assisted and partially automated driving will accompany the gradual introduction of highly automated vehicle control over the years in terms of a social learning process against the background of a heterogenous vehicle fleet (see also Section 5).

2.8. Differences in people, influences on tasks

The use of effective advanced driver assistance systems through to highly automated systems calls for a precise analysis of the requirements placed on the behaviour of the driver and of the processes of information processing by the driver. The effects of increasing vehicle automation on the traffic flow, traffic safety and also driving skills of motorists must be observed and assessed so that a response can be made to possible developments by means of successive adjustments to driving licence regulations, driving training and the design of automation functions over the course of time.

Absent or inconsistent eye contact or gestures in automated driving may lead to misunderstandings in urban scenarios.

It should be investigated whether different effects arise for different age groups. For example, how do children and young people deal with automated vehicles and what is the situation with older people? Which role is played, for example, by the willingness to take risks, gender and reason for driving as well as traffic experience?

Above all weaker road users will continue to participate in road traffic without communicating with the vehicles, and the effects of incorrect communication (hand signs, eye contact and similar) must be investigated. On motorways the issue is initially still of little relevance. However, it must be investigated in detail before automated vehicles are used also in urban scenarios.

It will be necessary to examine the special consequences arising for commercial traffic, i.e. for commercial vehicles, coaches, public transport, lorries, courier drivers, taxis, rescue vehicles. If these professional groups are taken from the duty to monitor, the probability is high that they will be given other work tasks or the driving and resting times can be influenced and the driving task altered. The need for safety when transporting people is also usually higher than self-drive trips. (See also Section 5).

2.9. Standards

The preparation of these findings and their incorporation at a national and international level should be promoted and supported by the public sector. The rigour with which international and national standardisation activities are being advanced by other industrial nations primarily in the area of vehicle automation with respect to design, safety and operations should not be underestimated.

Decisions of funding and structural policy in connection with standardisation activities are urgently recommended.

Requirements and methods must be standardised.

3. Function, safety, validation

3.1. Overview

The focus of the function, safety and validation cluster is on the validation of automated driving functions. Validation here refers to aspects of the other clusters within the Research WG. Relevant references are therefore inserted at these interfaces.

During the work in this cluster, top topics were identified that had been derived from the research questions in the long version. These will be described in the following sub-chapters, arranged in order of their priority for the introduction of highly automated and fully automated vehicles.

3.2. When is the technology safe enough?

From the point of view of functional safety and validation, new challenges arise when the driver is permanently or temporarily no longer available as overseer and fall-back level as is the case with highly and fully automated driving. Intensive research is needed to clarify how proof of safety can be delivered.

Measure of safety for automated vehicles must be defined.

In order to establish legal certainty for the companies involved, it must be clarified in advance when highly and fully automated vehicles are safe enough for them to be accepted by society. To date, no measure of safety has been defined and established against which the performance of automated vehicles can be assessed. When preparing the requirements, developers in companies have no recourse to a corresponding established state of the art. The performance of the human driver is also insufficiently known. It is generally unclear whether, if valid studies were available, they would be suitable as a reference for automated vehicles.

3.3. Validation of technology, software and algorithms

To date, no generally accepted test methods exist using which automated vehicles can be validated in an economically viable manner and transferred to volume production.

Research is needed into test methods to prove safety.

Current validation methods rely on intensive driving trials, and existing safety concepts depend on people as the fall-back level. If the human is temporarily or completely absent as overseer, failure probabilities for the automation systems are needed which can no longer be validated under commercially acceptable conditions in the driving trial. Experts are largely agreed that new test procedures and continuous test methods need to be researched, developed and authorised to validate future highly and fully automated vehicles (see Section 4.7). Furthermore, there are no suitable measurement procedures for validating the environment sensor system.

3.4. Migration-capable interaction between man and machine

Interaction between human drivers and automated vehicles is necessary.

Intensive studies are required into the cooperation between road traffic vehicles controlled by people and those controlled by machines.

Traffic researchers are agreed about the importance of communication and cooperation between human road users especially at low speeds. Studies on assisted vehicles have shown that drivers who are supported by simple assistance systems change their behaviour in such a way that this affects cooperation with other road users. In highly or fully automated driving mode, automated vehicles must cooperate with other road users in mixed traffic consisting of vehicles driven by people, vehicles driven by people supported by assistance systems, and mechanically driven vehicles.

The technical systems must be designed so that a safe interaction between man and machine is possible.

The cooperation between the driver and the technical system inside a vehicle is addressed specifically by the human-machine interface cluster (see Section 2). It is crucial here not to think about cooperation merely in isolation, i.e. not just human-vehicle cooperation or vehicle-vehicle cooperation, but rather to understand, shape and optimise the overarching cooperation networks between several people and several automated vehicles in an interdisciplinary manner based on sufficient appreciation of individual types of cooperation. It must be considered here that the alternative concept to cooperation, i.e. competition such as for increasingly scarce space for movement, for safety and living spaces, is similarly a man-made pattern of behaviour. This should not be promoted by unadjusted technology or even manifested in the sense of a "built-in right of way" resulting from automation technology; instead it can be harmonised using suitable technology and developed towards cooperation. It should be remembered that, due to assistance and automation, traffic systems are clearly on an accelerated but probably decades-long migration through to a hopefully stable plateau, and that they must be safe at all times, i.e. in any acceptable ratio of old and new technology. The migration capability of increasingly automated and complex cooperation networks composed of people and vehicles should be systematically researched and validated by means of prospective design and examination using simulation and small fleets of vehicles.

It is important not to ignore the technological hurdles that exist for cooperation between automated and non-automated road users. The awareness of a need to cooperate and refusal to cooperate on the part of other road users and the expression of a need for cooperation by the automated vehicle must be reliably implemented in the automated vehicles.

3.5. Value systems for automated vehicles

A value system for automated vehicles to weigh up "actions" must be explored and implemented.

Value systems for automated driving must be explored and implemented in automated vehicles.

Human drivers repeatedly weigh up competing interests and values to maintain the safety of road users and the efficiency of the traffic system. In doing so they consciously accept a transgression of rules: a driver will cross a solid line on the road if by doing so he can avoid an accident (see Section 5.2).

The value system of an automated vehicle becomes particularly clear in dilemma situations when an accident is certain to occur and it is necessary to weigh up which road user should benefit or be disadvantaged by influencing the accident events. Developers must implement such decisions in automated vehicles. So far there has been insufficient research into how this can be done.

3.6. Risk versus benefit of the technology

The benefit of automated vehicles must be weighed up against the risk.

Systematic investigations are being made into the benefit of automated vehicles alongside research and development, which also form the basis for discussions on the risk/benefit analysis.

Research into assistance and automation systems for motor vehicles has for many decades also been motivated by the desire to increase safety for road users. Systematic studies into benefits with a focus on road safety are therefore an important foundation for the assessment and further development of assistance and automation systems (see Section 4.5). The benefits of automation systems for road users and society will play a decisive role in the societal discussion about which of the risks caused by these systems are acceptable. There is a need to maintain today's level of safety in road traffic and to increase it successively.

3.7. Technologies, algorithms and methods

As in the past, great efforts must continue to be made to conduct research into technologies, algorithms and methods for the safe automation of driving functions and bring these to market maturity.

Research and further development of technologies require more funding.

Assistance systems have become possible through intensive research and development work into the environment sensor system, actuators and suitable algorithms for machine cognition, decision-making and carrying out actions. Germany today assumes a leading position in the area of advanced driver assistance systems because vehicle manufacturers have invested in this area in good time - at a pre-competition level in alliances with state assistance and at a competitive level together with system partners.

Consistent further research and development in the specified technical subject areas at a pre-competition level under the leadership of public funding bodies and in competitive alliances is the essential prerequisite for maintaining the current competitive position. Leading world software corporations will be among those to enter the growing competition for automated vehicles.

The development and validation of highly and fully automated vehicles is a great technological and social challenge which requires the joining of many forces. It is particularly important not to underestimate the efforts required to explore systems for machine cognition to a level which is still to be defined (see above) and to bring them to market maturity.

4. Road infrastructure and traffic

4.1. Overview

The need for research in the road infrastructure and traffic cluster is set out below. The cluster is concerned with the role of the road environment in connection with the introduction of automated driving; in addition to the structural infrastructure, this also includes the transport and information-based infrastructure as well as other influences such as weather. Furthermore, the cluster will address the effects on road safety and on traffic and environmental efficiency. Finally, strategic aspects will be identified, and a procedure for system introduction developed.

Interfaces with other clusters will be mentioned here with reference to the cluster concerned, but will not be dealt with in depth. The findings of the road infrastructure and traffic cluster will result, for example, in the need for research and/or action at the highest level, the legal level.

The most urgent need for research lies in the reciprocal requirements between vehicles and the road infrastructure and in their possible gradual implementation in the various equipment/penetration levels. Estimating the impact of automated driving on road safety and on traffic and environmental efficiency is also extremely important, as is the possible distribution of roles in the cooperative infrastructure and vehicle network. Equally important is the description of the information-based infrastructure, and in particular standardisation and data representation.

4.2. The term road environment

Here, the term road environment encompasses all elements required for automated driving that are not present on the vehicle.

The term “road environment” in this context should be consciously defined in a broad manner and contain all elements required for automated driving that are not present on the vehicle. In addition to the structural, traffic-related and information-based infrastructure, external influences such as the weather will also be examined below.

The structural infrastructure comprises the road as a structure. Traffic infrastructure includes all mechanisms that impact on the traffic situation by means of prohibitions, requirements and information, and which have the necessary prerequisites, for example with respect to data processing. The information-based infrastructure contains the data provided for automated driving and all mechanisms for generating and updating these data, for data transmission and direct (bi-directional) communication.

4.3. Functions of automated driving

Firstly, the applications of automated driving and the resultant traffic effects will be determined.

Firstly, the functions of automated driving should be determined using scenarios. These result from foreseeable applications such as the traffic congestion or motorway system as examples of medium-term applications of automation, and, for example, the transmission of the basic data to the vehicle needed for highly automated driving. The effects of a gradual penetration taking account of existing solutions for traffic management should be considered simultaneously. The need for research set out here likewise incorporates the specification of relevant traffic conditions and applications for automated driving.

4.4. Requirements arising from the interaction between the road environment and vehicles

The potential functions and data services may result in direct and reciprocal requirements for both road infrastructure and vehicles**:** one key question here is whether and, where applicable, which infrastructure requirements can be derived with a view to safe operation on the roads for the different degrees of automation and applications. It is currently unknown which information needs to be provided on the infrastructure side as a prerequisite for automated driving, taking into account the degree of automation and necessary redundancies, and the quality and availability of this information. There is furthermore a need for research into whether there are environmental conditions, infrastructure elements and topologies that are particularly suitable or unsuitable for high degrees of automation, and what features these are characterised by. Requirements arising from existing traffic management solutions should be taken into account in these considerations; in many cases they are based on the enforcement of the road traffic regulations in the Highway Code.

The requirements concerning the road environment should be determined under consideration of the degree of automation.

Suitable topologies and elements must be identified.

A scenario-based consideration should firstly be undertaken that examines the predicted rates of equipping vehicles with highly automated functions. These should be placed in relation to different road categories under consideration of expected traffic trends. Above all it is necessary here to consider the extent to which traffic management strategies and measures can be integrated in highly automated vehicles. The requirements for (technical) components that underpin the operation of high automation in the infrastructure/vehicle interface area must also be determined.

A sustainability concept for the infrastructure (embedding in future systems) should also be incorporated.

4.5 Road safety and traffic efficiency

There is a substantial need for research in terms of the effects of automated driving on road safety and traffic efficiency, and on the environment. The traffic flow could be modelled as one condition for determining the effects of automated driving, taking account of different rates of equipping vehicles, in particular concerning the mixed traffic during introduction, and the various classes of roads. In order to assess the traffic flow under the new conditions and to establish possible (macro) economic potential, it is necessary to examine how previous traffic models could be adapted to the equipment rates for automated vehicles.

Assessment of the potential of automated driving with respect to increasing road safety, improving traffic efficiency and reducing environmental pollution is required.

These investigations form the basis for a scenario-based consideration of future road capacities and traffic services. The effects on road safety and environmental efficiency should also be examined here.

Since automated driving can only be introduced gradually, it is essential to consider mixed traffic during the various expansion stages. The question which also arises here is whether and in what way traffic is affected by automated vehicles communicating their status externally. Other road users can then see whether or not the vehicle is in automatic mode. It is not merely the guarantee of road safety and of traffic and environmental efficiency that are important here, but also the acceptance by users. This is fundamental to a rapid increase in the equipment rate and thus also for system expansion.

4.6 Requirements placed on information technology

Among other things, the requirements determined can form the basis for a description of the information technology infrastructure necessary for high automation. As well as the technical description, the focus here must also be on the development of a corresponding system architecture for high automation and fundamental data structures for a harmonised representation of the data needed for high automation. Aspects for guaranteeing system safety must also be considered.

Standards are needed for information technology.

Data security and data protection must be obligatory.

The requirements placed on data and data transmission must be established in terms of standards, quality and security, but also on content. It must also be possible to guarantee reliability.

It is necessary to clarify the question of responsibilities, i.e. who - in terms of a role model - is responsible for the information technology or individual elements of it.

4.7 Test methods

New test methods must be developed to guarantee the functionality and reliability of the system. As no references are available here as yet, there is also a need for additional research in this regard, which will principally be formulated by the function, safety, validation cluster (Section 3).

4.8 Handling emergencies and system failures

It is also necessary to examine the handling of system failures (e.g. transfer to a safe operating state) and the behaviour of highly automated vehicles in special or emergency situations. Since there are no reference systems, a need for research also exists here. Emergency management, the system behaviour in the case of failures and suitable test methods should in particular be examined. This subject area will be dealt with in the function, safety, validation cluster (Section 3).

4.9 Strategic aspects and role models

For this new system to be developed in a structured manner and operated safely, strategic aspects must be discussed from the outset: previous roles must be redefined in the light of changed requirements, new cooperative ventures may be useful and new stakeholders required.

New technologies can lead to new cooperative ventures and changed role allocations.

New cooperation models should be developed.

As an introduction, migration and integration strategies should be developed and an analysis of the status quo performed. The integration into existing systems, the opportunity for expansion and the expense involved must be examined or estimated.

A possible business model should be developed for subsequent operation.

5. Social aspects

The expected transition to “highly and fully automated” vehicles in road traffic (“highly automated” and “fully automated” according to the definition of BASt in 2012) is not only an enormous technical challenge; it simultaneously implies what is likely to be a profound change to the entire traffic system. This system is embedded in social values and norms, political and economic objectives, legal stipulations and agreements as well as in the everyday practices of road users. In view of this, it is especially necessary to discuss social aspects:

The move to highly and fully automated driving will be almost impossible without social acceptance.

- *All* road users are affected by the introduction of highly and fully automated vehicles. A high degree of acceptance at a societal level and which goes beyond pure user acceptance is the prerequisite for the successful implementation of the new vehicles. This applies to vehicles used in passenger transport and commercial transport.
- In order to be able to estimate the possible effects of introducing highly and fully automated vehicles as reliably as possible, concepts for implementation must be developed early on and tested in scenarios. Specific aspects concern vehicle control, legal issues, vehicle operation, infrastructures and the form of interfaces with other modes of transport. The necessary decisions for this must be made in advance of the implementation of highly and fully automated vehicles on public roads. Part of these concepts must be the interaction between the automated road traffic and those systems (transport, politics, the law, economy, society) in which road traffic is embedded.
- The impact at the level of the transport system and society must be regarded holistically and presented transparently and openly in the communication between politics, the economy and citizens. The automation of light commercial vehicles and trucks as part of the change to a highly and fully automated system must also be taken into consideration.

Effects and benefits of automated driving can be experienced both at the individual and societal level.

- The highly and fully automated vehicle produces data and needs data just to guarantee permanent technical safety. Technical and legal stipulations for this are needed, to which currently hardly any attention is being paid, also with respect to their acceptance.
- Increased networking creates possibilities for integrating highly and fully automated vehicles in the transport system in a novel way, for example as part of the development of “new mobility concepts” or new logistics concepts. Possibilities for optimising traffic are thus linked in various respects.
- Currently there is a lack of concrete ideas about the demands on the “drivers” of automatically driving vehicles. The question in the long-term regarding increasingly automated driving is whether drivers lose their ability for self-determined driving.
- Participating in road use involves a high degree of communication with other road users, and understanding and predicting their behaviour. In the process social rules of conduct must be applied, which might become lost as a result of automated driving.

These observations have produced the following research subjects which focus on the social perspective and which are aimed at addressing and discussing the opportunities, possibilities and effects of automation in road traffic at an early stage.

5.1. Research status

Knowledge about the perception and evaluation of automated driving is currently only limited.

Research into social aspects of automated driving is currently only present to a limited extent. In addition to individual market-oriented surveys, there are approaches such as those found in the "Villa Ladenburg" project from the Daimler und Benz-Stiftung (Maurer et al.: "Autonomes Fahren im Straßenverkehr der Zukunft" [autonomous driving on the roads of the future] – forthcoming publication), which on the one hand tackle socially relevant aspects of automated driving, and on the other hand empirically extrapolate the expectations and hopes as well as the fears and concerns of road users. The few studies that have looked at the acceptance aspects of automated driving communicate a very heterogeneous picture in general, that ranges from enthusiastic agreement to a basic resistance to the idea of handing control of the vehicle control system over to a robot. Among other things, the work in the "Villa Ladenburg" project illustrates the necessity of highlighting the assessment of concrete substitution scenarios by road users in addition to general acceptance.

5.2. Research issues

Subject 1: What expectations and fears are there with regard to automated driving?

From the current, still very rudimentary status of research into the social aspects of automated driving and the other unanswered questions formulated above, the "Social Aspects" sub-group of the Research WG identifies a need for research in three subject areas:

Subject 1: Possible drivers of social and individual acceptance of automated driving.

The objective is to identify possible expectations (including benefits), but also fears and thus obstacles to highly and fully automated vehicles. Ideally this should take place in the form of monitoring. Going beyond a quantitative approach, it would appear important to record the everyday context of conventional car use much better than has previously been the case, so that the approaches for the comparatively fast and visibly beneficial deployment of highly and fully automated vehicles can be identified. Moreover, the acceptance of automated vehicles in commercial transport must also find its way into the research.

Subject 2: How can automated vehicles become part of the traffic system?

Subject 2: Change to the traffic system as a result of automated road vehicles.

The following scenarios are conceivable during the introduction of highly and fully automated vehicles in road traffic:

- Change to the choice of the means of transport due to the reassessment of journey times
- Change to the available transport through the redefinition of private and public transport.

This leads to a number of questions specifically related to passenger transport:

- How will the automation of motorised individual transport change the choice of the means of transport?
- How do the attitudes to driving and practices of car use change as a result of the introduction of automated vehicles?

The scenarios in commercial transport should initially focus on long-distance traffic and also take aspects such as the working situation of the driver into consideration; in the medium term, scenarios for (urban) delivery traffic should also be taken into account.

This results in questions that affect road traffic as a whole:

- How does the traffic system change as a result of the introduction of highly and fully automated road vehicles? (also see Section 4.5)
- How can and should the use of highly and fully automated vehicles be implemented in the traffic system?

Subject 3: What “ethics” are expected from the “car” machine?

Subject 3: What does the “car” machine need to be able to do to be on the road in an ethically acceptable manner?

The question of whether or how ethical principles can be “implanted” into a machine combines the software-based issues such as the resolution of dilemma situations and issues concerned with ideas about the ethics of machinery and robots in different groups of society. Important aspects from a legal and from a cultural and social science view are as follows:

- Attitudes towards machines/robots
- Expectations and fears regarding the functions and mode of operation of such machines/robots and the ensuing influence on their acceptance
- Conditions of acceptance of errors by machines: What errors? What machines?
- The occurrence of dilemma situations when handling machines and overcoming these.

Annex 1:

Aspects of the Human-Machine Interface

- Long version -

by

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The questions listed in the following were formulated during the workshop of experts. In view of the fact that as few changes as possible were made to the original contributions, less formal wording is also used.

Driver states and readiness to resume control

Assessment and development of technologies to measure driver availability
How can the performance/vigilance of the driver during automated driving be assessed to best bring him back to the control loop?
Define psychophysical limits to performance in the monitoring of partial automation
Can the driver maintain concentration during a longer automated trip?
Which requirements must be satisfied to permit the driver to resume control over the highly automated functions?
Can the driver handle the frequent change in "mode"? How can he be supported here?
Which driver states must be identified?
Examination of anxiety reactions
Situation awareness + system awareness of the driver/passengers

Designing the human-machine interface

Formulation of the design rules for the HMI
Development of arbitration concepts
Design of man/machine cooperation in high degrees of automation
Design of transitions in changing modes
Necessary feedback for high degrees of automation
Manufacturer-independent operating concepts/interactions
What do suitable HMIs look like?
Which HMI standards are necessary? (rented car scenario, rare use)
Which requirements must be satisfied for drivers to resume control of highly automated functions?
Can the driver handle the frequent change in "mode"? How can he be supported here?
Less reliability -> greater concentration; more reliability -> more acceptance
What do take-over strategies look like?
What is to be done to facilitate a driver take-over?
How can the driver be brought back to the control loop, e.g. at the limits of the system? -> Key word: transfer from vehicle to driver
Transfer from vehicle <-> driver; take-over from vehicle <-> driver

Non-driving activities

How/according to which rules do we permit non-driving activities?
Is an auxiliary activity good or bad?
How does a "driver" (auxiliary activity) behave if the vehicle performs an emergency stop?
What are the correlations between performing non-driving activities and possible impairments to the primary driving task (ability to take over the driving task at short notice) by the driver at automation level 3?

Desired use and avoidance of abuse

Does the driver keep to the task of monitoring the trip or abuse the support? (In the case of partial automation)
Use of the systems to their limits e.g. in cases of tiredness
User expectations on the system versus real function of the system

Test methods for HMI

Test methods for – driving experience; - acceptance; - usability
Which scenarios are to be used to validate controllability?
Which factors of automated driving affect the driving experience and acceptance?

Learning and training

Requirements placed on training for automated driving
Does the driver unlearn the ability to drive himself?
Which mental models does the driver create on system function? How can they be "shaped"?
Which steps of social acceptance and learning/previous experience of the user accompany the gradual introduction of automated driving functions (over years)?

Differences in people, influences on tasks

Professional versus private use and differences in tasks
What effects do differences in personality have, in particular: perception of locus of control?

HMI-relevant content of standards

Active contributions to international standardisation (e.g. ISO)
Terminologies
Standards for assessment methods
Design standards

Annex 2:

Function, Safety, Validation

- Long version -

by

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Report by the

"Function, Safety, Validation" (FSV) Cluster

as part of the Round Table on

"Automated Driving"

of the Federal Highway Research Institute (Bundesanstalt für Straßenwesen)

Third version of the long version as preparation for the 6th meeting on 5 March 2015

Markus Maurer (Spokesman)

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Version dated 13. August 2015

Contents

1. Aim of the document

The results of the meetings of the “Function, Safety, Validation” (FSV) sub-working group, part of the Research WG of the Round Table, led by the Federal Highway Research Institute (Bundesanstalt für Straßenwesen - BASt), are explained in this document. This long version deals with presentation and explanation of the current research questions regarding the use of automated vehicles in public road traffic and simultaneously reflects the progress of discussions during the various meetings of the working group. This documentation of the work in the working group therefore contains all remarks, suggestions and results arising from discussions.

The document includes a brief description of how research questions are presented, as well as a detailed description of the research questions and corresponding framework conditions. The research questions will be arranged and presented by cluster.

2. Structure of the description of research questions

Research question: The complete wording of the research question

Explanation: A brief explanation of the content of the research question.

Main cluster: The main cluster responsible for the research question. Main clusters are:

- Human-Machine Interface (HMI)
- Social aspects (SA)
- **Function, Safety, Validation (FSV)**
- Road infrastructure and traffic (RIT)

Only the research questions of the FSV main cluster will be considered in this document. For this reason the cluster will not be named in the questions.

Further main cluster: A further, secondary main cluster that is responsible for the research (HMI, FSV, RIT, SA).

Secondary cluster: The other secondary categorisation of the research question within the main cluster. Categorisation here takes place by topic in a total of 13 clusters.

Summary for project comparison: An overarching question for easier alignment of existing activities and projects that may include other questions in addition to the current research question.

Remarks: Further remarks about the research question and special features

Funding opportunities: Funding bodies which are among those that come into question for these research questions. A detailed explanation of these can be found in Section 4 “Funding possibilities” of this report section.

Current and planned projects/activities: Activities separated according to the company/association/ministry etc. executing them. A detailed explanation of the projects can be found in Section 5 “Projects and research activities” of this report section.

3. Research questions

3.1. "Function, customer benefit" cluster

This cluster contains questions regarding the benefit of automated vehicles. In addition to individual benefits, the interaction between automated vehicles is questioned.

3.1.1. Question F1

Research question: How is it possible to prove the efficacy of autonomous driving in terms of driving safety and efficiency?

Explanation: It is claimed that a high degree of automation in vehicles contributes to road safety and traffic efficiency. In the case of advanced driver assistance systems it has so far been extremely difficult to examine the effect of such impact because only in very rare cases are successful accident-preventing and efficiency-boosting assistance interventions documented. This question also applies to automated vehicles.

Further main cluster: SA

Secondary cluster: Function, customer benefit

Summary for project comparison: None

Remarks: None

Funding opportunities: FAT

Current projects/activities:

- IP AdaptIVe SP7, 2014-2017, European level (no DAI involvement in SP7)
- Project outline on this subject was discussed on 9.7.2014 in the German Automotive Research Association (Forschungsvereinigung Technik - FAT). No results are available as yet.

3.1.2. Question F2

Research question: How do different degrees of automation interact?

Explanation: It is to be expected that the degree of automation of vehicles will increase incrementally. As a result there will be mixed traffic comprising manually driven vehicles and vehicles with varying degrees of automation. The question arises as to what the interaction between all road users will look like.

Further main cluster: RIT

Secondary cluster: Function, customer benefit

Summary for project comparison: None

Remarks: Later (it will only be possible to answer the question following longer term studies into mixed traffic)

Funding opportunities: None known

Current and planned projects/activities: None known

3.2. "Ethical questions" cluster

Research questions concerning the ethical aspects for the operation of automated vehicles were formulated in this cluster. Since automated vehicles are developed by people, transport people and animals and interact with them in road traffic, an anticipatory consideration of the ethical aspects may be necessary.

3.2.1. Question F3

Research question: What is an acceptable "reasonable" risk? (The opposite of unreasonable risk in ISO 26262)

Explanation: Automated vehicles are operated with a certain risk. The question to address is how big this risk may be for use in public road traffic to be deemed safe for passengers and other road users.

Further main cluster: SA

Secondary cluster: Ethical questions

Summary for project comparison: None

Remarks:

- Important, where? (The question is whether this is a safety-related or an ethical question)
- Also see ID F1, or ISO 26262

Funding opportunities: Response IV

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety
- Partially in the aFAS project

3.2.2. Question F4

Research question: How must various "transgressions of rules" (e.g. infringements of the Highway Code (StVO), accidents involving damage to property, accidents involving personal injury) be prioritised and implemented?

Explanation Different "rules" apply in road traffic. In some situations it may be necessary to transgress one or more rules to prevent or reduce personal injury. How can this be directly implemented taking the StVO into consideration?

Further main cluster: SA

Secondary cluster: Ethical questions

Summary for project comparison: None

Remarks:

- Sensitive
- Can be integrated in UR:BAN

Funding opportunities: DFG

Current and planned projects/activities: None known

3.2.3. Question F5

Research question: Which aspects must apply to a behavioural decision in dilemma situations?

Explanation: There are situations in which personal injury can no longer be avoided. These require a decision to be made between different “injuries”. Which relevant aspects must be taken into consideration to make a decision in such situations?

Further main cluster: SA

Secondary cluster: Ethical questions

Summary for project comparison: None

Remarks: None

Funding opportunities: DFG

Current and planned projects/activities: None known

3.3. “Safety, general” cluster

This cluster contains questions that are aimed generally at the safety of automated vehicles. Among other things, the questions concern terminology, framework conditions and applicable standards / laws as well as influencing factors and necessary information for safe operation.

3.3.1. Question F6

Research question: Definition of a uniform vocabulary

Explanation: A uniform vocabulary makes sense to permit common understanding by all participating bodies.

Further main cluster: None

Secondary cluster: Safety, general

Summary for project comparison: None

Remarks: None

Funding opportunities: 4th Transport Research Programme

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety
- Preparation of a glossary planned in Ko-HAF
- Legal consequences of increasing vehicle automation

  BASt Report F 83

  Tom M. Gasser, Clemens Arzt, Mihiar Ayoubi, Arne Bartels, Jana Eier, Frank Flemisch, Dirk Häcker, Tobias Hesse, Werner Huber, Christine Lotz, Markus Maurer, Simone Ruth-Schumacher, Jürgen Schwarz, Wolfgang Vogt, “Legal consequences of increasing vehicle automation” project group

  (see http://www.bast.de/DE/Publikationen/Berichte/unterreihe-f/2013-2012/f83.html)

3.3.2. Question F7

Research question: Which standards and development principles are relevant?

Explanation: Numerous standards and established approaches for development already exist in the automotive sector and particularly in the driver assistance area. Which of these are also relevant to automated vehicles?

Further main cluster: None

Secondary cluster: Safety, general

Summary for project comparison: None

Remarks: None

Funding opportunities: Possibly aFAS

Current and planned projects/activities:

- Functional safety is the main focus of aFAS
- ISO 26262 further development in VDA AK 26

3.3.3. Question F8

Research question: Which factors have an impact on safety?

Explanation: In road traffic and in the technical vehicle system, many factors may have an influence on the operational safety of automated vehicles. What are these?

Further main cluster: None

Secondary cluster: Safety, general

Summary for project comparison: Which factors influencing the safety of automated vehicles exist?

Remarks: Summarise with F9

Funding opportunities: Response IV

Current and planned projects/activities:

- ISO 26262 further development in VDA AK 26

3.3.4. Question F9

Research question: Which information is relevant to the safety of a system? (Internal, external, other)

Explanation: Much information accrues in connection with road traffic and the technical vehicle system. Which of this information is relevant to operational safety and is therefore necessary?

Further main cluster:

Secondary cluster: Safety, general

Summary for project comparison: Which factors influencing the safety of automated vehicles exist?

Remarks:

- Summarise with F8

- Within the development responsibility of the OEM

Funding opportunities: None known

Current and planned projects/activities: None known

3.3.5. Question F10

Research question: How creative may a vehicle guidance system be?

Explanation: The possible processes for artificial intelligence in a decision-making vehicle have certain room for manoeuvre. How creative may an automated vehicle be within this room for manoeuvre?

Further main cluster: HMI

Secondary cluster: Safety, general / cooperation

Summary for project comparison: None

Remarks: Special question

Funding opportunities: DFG

Current and planned projects/activities:

- VDA AK 26

3.4. “Safe state, degradation” cluster

A safe state is the objective during the journey as well as in dangerous situations and hazardous events. It must be possible to maintain/achieve a safe state at all times. Among other things this can take place through degradation, i.e. a reduction in the scope of performance.

3.4.1. Question F11

Research question: How is a “safe state” defined?

Explanation: Until now no definition has existed for the safe state of an automated vehicle on public roads. There has been no research into the properties a state must have to be deemed safe.

Further main cluster: SA

Secondary cluster: Safe state, degradation

Summary for project comparison: Properties, detection, anticipation, maintaining and achieving a safe state?

Remarks: None

Funding opportunities: BASt

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety
- Ko-HAF, national level, BMWi
- Partial aspects in aFAS and Ko-HAF
- ISO 26262 further development in the VDA AK 26
- Research project FE 82.0570/2012

3.4.2. Question F12

Research question: How can a safe state be maintained?

Explanation: The operational safety of an automated vehicle changes constantly and there are always different courses of action. If a vehicle is in a safe state and the situation changes, the question arises about actions to maintain a safe state.

Further main cluster: None

Secondary cluster: Safe state, degradation

Summary for project comparison: Properties, detection, anticipation, maintaining and achieving a safe state?

Remarks: None

Funding opportunities: BASt

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety
- Ko-HAF, national level, BMWi
- Partial aspects in aFAS and Ko-HAF
- ISO 26262 further development in the VDA AK 26

3.4.3. Question F13

Research question: How can a safe state be achieved?

Explanation: The operational safety of an automated vehicle changes constantly and there are always different courses of action. If an event takes place that puts the vehicle in an unsafe state, the question arises about actions that can achieve a safe state.

Further main cluster: None

Secondary cluster: Safe state, degradation

Summary for project comparison: Properties, detection, anticipation, maintaining and achieving a safe state?

Remarks:

- Central to highly automated driving

Funding opportunities: FAT also Ko-HAF / BMWi

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety
- Ko-HAF, national level, BMWi
- Partial aspects in aFAS and Ko-HAF
- ISO 26262 further development in the VDA AK 26

3.4.4. Question F14

Research question: How can the current state be assessed?

Explanation: An automated vehicle moves in a continuously changing environment. In order to determine the safety of the current state, methods must be found that facilitate an assessment of the current state.

Further main cluster: None

Secondary cluster: Safe state, degradation

Summary for project comparison: Properties, detection, anticipation, maintaining and achieving a safe state?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety
- Ko-HAF, national level, BMWi
- Partial aspects in aFAS and Ko-HAF
- ISO 26262 further development in the VDA AK 26

3.4.5. Question F15

Research question: How can a change in the state be anticipated?

Explanation: In addition to the reactive behaviour during events, it may be an advantage to anticipate the safety of the vehicle in future situations and take measures. The question arises as to how changes in the situation and thus the state of the vehicle can be predicted.

Further main cluster: None

Secondary cluster: Safe state, degradation

Summary for project comparison: Properties, detection, anticipation, maintaining and achieving a safe state?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Ko-HAF, national level, BMWi
- Partial aspects in aFAS and Ko-HAF
- ISO 26262 further development in the VDA AK 26

3.4.6. Question F16

Research question: How can functional limits be recognised?

Explanation: Automated vehicles with differing degrees of automation will have functional limits beyond which operation is no longer safe. The question arises about the methods enabling these limits to be recognised.

Further main cluster: None

Secondary cluster: Safe state, degradation

Summary for project comparison: Properties, detection, anticipation, maintaining and achieving a safe state?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Ko-HAF, national level, BMWi
- Partial aspects in aFAS and Ko-HAF
- ISO 26262 further development in the VDA AK 26

3.4.7. Question F17

Research question: How are risk and a safe state connected?

Explanation: The current operating risk could be a measure of the current state of an automated vehicle. The question therefore arises as to how the operating risk is connected to a safe state.

Further main cluster: SA

Secondary cluster: Safe state, degradation

Summary for project comparison: Properties, detection, anticipation, maintaining and achieving a safe state?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety
- Ko-HAF, national level, BMWi
- Partial aspects in aFAS and Ko-HAF
- ISO 26262 further development in the VDA AK 26

3.5. "Metrics for safety" cluster

Metrics that make a point about various aspects of the safety of automated vehicles are useful when assessing safety. Questions about the benefit and properties of metrics are pooled in this cluster.

3.5.1. Question F18

Research question: Can functional safety be measured?

Explanation: Functional safety as an abstract term would appear always to be dependent on the observer (in practice there are margins of discretion). The question arises as to whether the functional safety of an automated vehicle can be quantified so that it can be estimated equally by all participating bodies.

Further main cluster: None

Secondary cluster: Metrics for safety

Summary for project comparison: How can the safety of automated vehicles be evaluated?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety
- Partial aspects in Ko-HAF
- ISO 26262 further development in the VDA AK 26

3.5.2. Question F19

Research question: How can I measure the safety level (see man v system)?

Explanation: In road traffic we accept the different performance of people and the resultant risk. The question is whether and how it is possible to compare the performance of human drivers with that of technical systems.

Further main cluster: None

Secondary cluster: Metrics for safety

Summary for project comparison: How can the safety of automated vehicles be evaluated?

Remarks: None

Funding opportunities: DGUV

Current and planned projects/activities:

- Partial aspects in Ko-HAF
- ISO 26262 further development in the VDA AK 26
- PEGASUS

3.5.3. Question F20

Research question: Which metrics are suitable for an automated system to assess its own state?

Explanation: The automated system's own state changes continuously. Which metrics are available for assessing the safety and other properties of its own state? (Dysfunctional requirements e.g. when virtual/imagined targets are detected)

Further main cluster: None

Secondary cluster: Metrics for safety

Summary for project comparison: How can the safety of automated vehicles be evaluated?

Remarks:

- Summarise with F21,F22
- Not relevant – will be taken into consideration during development (e.g. functional safety, FMEA etc.)

Funding opportunities: BAUA/BASt

Current and planned projects/activities:

- Partial aspects in Ko-HAF
- ISO 26262 further development in the VDA AK 26
- PEGASUS

3.5.4. Question F21

Research question: Which metrics are suitable for an automated system to assess its own efficiency?

Explanation: The efficiency of an automated system changes continuously. What metrics are available for assessing efficiency?

Further main cluster: None

Secondary cluster: Metrics for safety

Summary for project comparison: How can the safety of automated vehicles be evaluated?

Remarks:

- Summarise with F20, F22
- Not relevant - will be taken into consideration during development (e.g. functional safety, FMEA etc.)

Funding opportunities: None known

Current and planned projects/activities:

- Partial aspects in Ko-HAF
- ISO 26262 further development in the VDA AK 26
- PEGASUS

3.5.5. Question F22

Research question: Which metrics are suitable for assessing current risk?

Explanation: The current operating risk of an automated system changes continuously. What metrics are available for assessing the risk?

Further main cluster: None

Secondary cluster: Metrics for safety

Summary for project comparison: How can the safety of automated vehicles be evaluated?

Remarks:

- Summarise with F20, F21
- Not relevant - will be taken into consideration during development (e.g. functional safety, FMEA etc.)

Funding opportunities: FAT

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety
- Partial aspects in Ko-HAF
- ISO 26262 further development in the VDA AK 26
- PEGASUS

3.5.6. Question F23

Research question: How can a “better than human” efficacy be demonstrated?

Explanation: For society to accept automated vehicles in road traffic, it would appear necessary for them to work “better than humans”. Can this be proven?

Further main cluster: None

Secondary cluster: Metrics for safety

Summary for project comparison: How can the safety of automated vehicles be evaluated?

Remarks: See F1, F3

Funding opportunities: None known

Current and planned projects/activities:

- Partial aspects in Ko-HAF
- ISO 26262 further development in the VDA AK 26
- PEGASUS

3.5.7. Question F24

Research question: When is a system safe enough?

Explanation: “Better than humans” is an imprecise statement. The efficiency and safety of an automated vehicle must achieve this, however. The question is when is a system safe enough, and is therefore regarded as being “better than humans”.

Further main cluster: SA

Secondary cluster: Metrics for safety

Summary for project comparison: None

Remarks:

- Reference to F3
- See F1, F3

Funding opportunities: None known

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety
- ISO 26262 further development in the VDA AK 26
- PEGASUS

3.6. "Security" cluster

In addition to (functional) safety, "security" also plays a key role. Because of the quantity of data processed in automated vehicles and the electronic control of the actuators, it is necessary to ensure that data are handled confidentially and safeguarded from external attacks.

3.6.1. Question F25

Research question: How can the vehicle guidance system be protected from external manipulation in terms of data integrity during communication from vehicle to vehicle and vehicle to infrastructure?

Explanation: Automated vehicles will not only communicate with each other, but also with infrastructure and possibly even with external operators via radio connections. The question is how these can be protected from unauthorised access and manipulation.

Further main cluster: None

Secondary cluster: Security

Summary for project comparison: Which security aspects exist for automated vehicles?

Remarks: Summarise with F26

Funding opportunities: BMVI

Current and planned projects/activities:

- TU9 / CN (BMBF) up to 2015 - secures C2X communication

3.6.2. Question F26

Research question: How can trust in data be achieved (integrity and authenticity)?

Explanation: As well as external manipulation, data obtained in a "regular" manner can also be erroneous, for example map material. The question is whether and how these data can be trusted?

Further main cluster: None

Secondary cluster: Security

Summary for project comparison: Which security aspects exist for automated vehicles?

Remarks: Summarise with F25

Funding opportunities: -

Current and planned projects/activities:

- TU9 / CN (BMBF) up to 2015 - secures C2X communication

3.7. "Architecture" cluster

An automated vehicle consists of an electronic (programmable) system, sensor technology, communication equipment and actuation system. Questions about the system architecture for such a system are formulated in this cluster.

3.7.1. Question F27

Research question: Which minimum requirements must the architecture for automated driving satisfy on-board and off-board?

Explanation: The overall system for an automated vehicle consists of on-board and off-board components, for example in the transport infrastructure. The aim of the question is to identify minimum requirements of the architecture so that this can contain on-board and off-board components and facilitate the necessary functional scope of an automated vehicle.

Further main cluster: RIT

Secondary cluster: Architecture

Summary for project comparison: What does a system architecture for automated vehicles look like?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety

3.7.2. Question F28

Research question: What does a system architecture for highly automated vehicles with good properties for testing look like?

Explanation: The implementation of functionality by means of a suitable system architecture is a necessary prerequisite for the operation of automated vehicles. In addition it must be possible to test this functionality. How can this be taken into consideration in a system architecture?

Further main cluster: None

Secondary cluster: Architecture

Summary for project comparison: What does a system architecture for automated vehicles look like?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety

3.7.3. Question F29

Research question: What does a possible redundancy concept look like and what demands are placed on it?

Explanation: Functional components are frequently implemented redundantly to permit a high availability of functionality. The question is whether and how a redundancy concept for automated vehicles can be realised.

Further main cluster: None

Secondary cluster: Architecture

Summary for project comparison: None

Remarks: Special question

Funding opportunities: None known

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety

3.7.4. Question F30

Research question: Which sub-systems of a vehicle guidance system are relevant to safety?

Explanation: A system for automated driving will consist of numerous sub-systems which in turn provide different functions. Not every sub-system will therefore be relevant to safety.

Further main cluster: None

Secondary cluster: Architecture

Summary for project comparison: None

Remarks: Special question

Funding opportunities: None known

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety

3.7.5. Question F31

Research question: Which tasks for communication technologies arise from functions and architecture?

Explanation: The communication between vehicles, between the vehicle and infrastructure and the vehicle and external operators must perform certain tasks. These arise from the functional scope and system architecture.

Further main cluster: None

Secondary cluster: Architecture

Summary for project comparison: None

Remarks: Special question

Funding opportunities: None known

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety

3.8. “Machine cognition and localisation” cluster

In order to operate, an automated vehicle must be able to locate itself in the world, on the road and in lanes. The stationary and dynamic environment must also be mechanically perceived. Questions dealing with this topic will be formulated in this cluster.

3.8.1. Question F32

Research question: Is reliable machine cognition possible? If so, how?

Explanation: The machine cognition of an open quantity of possible situations with numerous influencing factors is challenging. The question arises as to whether and how a machine cognition system can operate reliably.

Further main cluster: None

Secondary cluster: Machine cognition and localisation

Summary for project comparison: Monitoring and anticipation of the cognitive performance.

Remarks: None

Funding opportunities: BMWi: funding objective/product oriented; DFG: fundamental question; BMVi

Current and planned projects/activities:

- Ko-HAF, national level, BMWi
- EFA 2014 II (BMBF) just ended; environment recognition, localisation;
- SPP cooperatively interacting automobiles (DFG) from 2015
- UR:BAN (BMWi) up to 2016
- Ko-FAS (BMWi) up to 2013

3.8.2. Question F33

Research question: Are existing sensor principles adequate for driving automatically in all situations?

Explanation: The environment of a vehicle can be recorded using different sensor principles. It is not yet known whether the available sensor technologies are adequate for complete environment sensing. The algorithm should also be considered (hardware and software) in conjunction with this.

Further main cluster: None

Secondary cluster: Machine cognition and localisation

Summary for project comparison: Monitoring and anticipation of the cognitive performance

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Ko-HAF, national level, BMWi
- EFA 2014 II (BMBF) just ended; environment recognition, localisation
- SPP cooperatively interacting automobiles (DFG) from 2015
- UR:BAN (BMWi) up to 2016
- Ko-FAS (BMWi) up to 2013

3.8.3. Question F34

Research question: Which measures of quality for machine cognition are possible and necessary?

Explanation: The assessment of environment sensing is difficult because the environment sensors currently available are not sufficient for reliable perception. The question is then, what measures of quality for cognitive performance can be determined using environment sensing.

Further main cluster: None

Secondary cluster: Machine cognition and localisation

Summary for project comparison: Monitoring and anticipation of the cognitive performance

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Ko-HAF, national level, BMWi
- EFA 2014 II (BMBF) just ended; environment recognition, localisation
- SPP cooperatively interacting automobiles (DFG) from 2015
- UR:BAN (BMWi) up to 2016
- Ko-FAS (BMWi) up to 2013

3.8.4. Question F35

Research question: How can safety for open systems be achieved in terms of perception components and evaluating the situation?

Explanation: An assessment of the current performance, and in particular environment sensing and evaluating the situation, are necessary to determine the operating risk of an automated vehicle. The question here is how this performance can be determined for an open system where not all potential situations and events are known.

Further main cluster: None

Secondary cluster: Machine cognition and localisation

Summary for project comparison: Monitoring and anticipation of the cognitive performance

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Ko-HAF, national level, BMWi
- EFA 2014 II (BMBF) just ended; environment recognition, localisation
- SPP cooperatively interacting automobiles (DFG) from 2015
- UR:BAN (BMWi) up to 2016
- Ko-FAS (BMWi) up to 2013

3.8.5. Question F36

Research question: Can functional degradations in perception be detected in advance?

Explanation: To anticipate future risk, situations must be perceived and their development predicted. The question arises as to whether it is possible to predict the risk from the possible future development of perceived situations, based on environment sensing and suitable prediction procedures.

Further main cluster: None

Secondary cluster: Machine cognition and localisation

Summary for project comparison: Monitoring and anticipation of the cognitive performance

Remarks: None

Funding opportunities: Horizon 2020 MG.3.6-2015

Current and planned projects/activities:

- Ko-HAF, national level, BMWi
- EFA 2014 II (BMBF) just ended; environment recognition, localisation
- SPP cooperatively interacting automobiles (DFG) from 2015
- UR:BAN (BMWi) up to 2016

- Ko-FAS (BMWi) up to 2013

3.8.6. Question F37

Research question: The transition to cooperative systems requires highly accurate, absolute positions. Is a robust, highly accurate localisation of own position possible?

Explanation: For mutual localisation of road users and the transport infrastructure, it is essential to have a reliable absolute localisation in the world. The question is how this can be achieved.

Further main cluster: None

Secondary cluster: Machine cognition and localisation

Summary for project comparison: Monitoring and anticipation of the cognitive performance

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Ko-HAF, national level, BMWi
- EFA 2014 II (BMBF) just ended; environment recognition, localisation
- SPP cooperatively interacting automobiles (DFG) from 2015
- UR:BAN (BMWi) up to 2016
- Ko-FAS (BMWi) up to 2013

3.9. "Cooperation" cluster

Automated vehicles permit direct cooperation between road users and the transport infrastructure. The questions in this cluster are aimed at the possibilities and characteristics of cooperative behaviour. Cooperation here does not concern the cooperation between man and machine within a vehicle (see Human-Machine Interface cluster), rather the cooperation between vehicles in mixed traffic.

3.9.1. Question F38

Research question: What special requirements does the safety of cooperative systems have?

Explanation:

Further main cluster: HMI

Secondary cluster: Cooperation

Summary for project comparison: What are the properties and requirements regarding cooperation with and between automated vehicles?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Ko-HAF, national level, BMWi;
- AdaptIVe, European level
- Horizon 2020
- SPP cooperatively interacting automobiles from 2015
- Ko-FAS (BMWi) up to 2013

3.9.2. Question F39

Research question: What are the criteria for cooperative automated driving?

Explanation: Cooperative driving should offer advantages to all involved. The question arises as to the criteria governing cooperation in road traffic.

Further main cluster: HMI

Secondary cluster: Cooperation

Summary for project comparison: What are the properties and requirements regarding cooperation with and between automated vehicles?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Ko-HAF, national level, BMWi;
- AdaptIVe, European level
- Horizon 2020
- SPP cooperatively interacting automobiles from 2015
- Ko-FAS (BMWi) up to 2013

3.9.3. Question F40

Research question: What cooperation schemes are there?

Explanation: Numerous possibilities for cooperation are conceivable in addition to direct cooperation between two road users. There has not yet been any examination of which cooperation schemes exist on public roads and which are possible.

Further main cluster: HMI

Secondary cluster: Cooperation

Summary for project comparison: What are the properties and requirements regarding cooperation with and between automated vehicles?

Remarks: None

Funding opportunities: BMVi, DFG

Current and planned projects/activities:

- Ko-HAF, national level, BMWi;
- AdaptIVe, European level
- Horizon 2020
- SPP cooperatively interacting automobiles from 2015

3.9.4. Question F41

Research question: To what extent is cooperation possible (number of cooperating road users, convoy stability etc.)?

Explanation: It should be assumed that limitless cooperation is not possible. The extent to which cooperation may take place has not yet been investigated however.

Further main cluster: HMI

Secondary cluster: Cooperation

Summary for project comparison: What are the properties and requirements regarding cooperation with and between automated vehicles?

Remarks: None

Funding opportunities: Horizon 2020, DFG

Current and planned projects/activities:

- Ko-HAF, national level, BMWi;
- AdaptIVe, European level
- Horizon 2020
- SPP cooperatively interacting automobiles from 2015
- Ko-FAS (BMWi) up to 2013

3.9.5. Question F42

Research question: Can cooperation be reliably implemented?

Explanation: Cooperation in road traffic requires at least two cooperating partners who can communicate with each other in different ways. The question is whether cooperative behaviour can be implemented reliably via communication paths.

Further main cluster: None

Secondary cluster: Cooperation

Summary for project comparison: What are the properties and requirements regarding cooperation with and between automated vehicles?

Remarks: None

Funding opportunities: DFG, SPP

Current and planned projects/activities:

- Ko-HAF, national level, BMWi;
- AdaptIVe, European level
- Horizon 2020
- SPP cooperatively interacting automobiles from 2015
- Ko-FAS (BMWi) up to 2013

3.9.6. Question F43

Research question: What is the safety significance of automatic error compensation (errors made by other drivers)?

Explanation: In addition to direct cooperation, road users can also be forced to cooperate. The question is whether it is possible to compensate for the errors made by other road users using cooperative behaviour.

Further main cluster: HMI

Secondary cluster: Cooperation

Summary for project comparison: What are the properties and requirements regarding cooperation with and between automated vehicles?

Remarks: None

Funding opportunities: Ko-HAF

Current and planned projects/activities:

- Ko-HAF, national level, BMWi;
- AdaptIVe, European level
- Horizon 2020
- SPP cooperatively interacting automobiles from 2015
- Ko-FAS (BMWi) up to 2013

3.9.7. Question F44

Research question: How are human statements, for example the direction of travel indicator, interpreted?

Explanation: The cooperation between people frequently involves gestures. The question is whether and how these can be recorded and interpreted by machine cognition.

Further main cluster: HMI

Secondary cluster: Cooperation

Summary for project comparison: What are the properties and requirements regarding cooperation with and between automated vehicles?

Remarks: None

Funding opportunities: BMVi

Current and planned projects/activities:

- Ko-HAF, national level, BMWi;
- AdaptIVe, European level
- Horizon 2020
- SPP cooperatively interacting automobiles from 2015

- Ko-FAS (BMWi) up to 2013

3.9.8. Question F45

Research question: For which situations is centrally controlled cooperation more suitable than “peer-to-peer” cooperation?

Explanation: In addition to direct cooperation between vehicles, controlling the traffic flow from a central point using means of communication is conceivable. In which situations this can be better, in particular with reference to mixed traffic, has not yet been examined.

Further main cluster: None

Secondary cluster: Cooperation

Summary for project comparison: What are the properties and requirements regarding cooperation with and between automated vehicles?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Ko-HAF, national level, BMWi;
- AdaptIVe, European level
- Horizon 2020
- SPP cooperatively interacting automobiles from 2015
- Ko-FAS (BMWi) up to 2013

3.10. “Validation, approval, measurement engineering“ cluster

Questions concerning the testing and ability to test automated vehicles and their functions are formulated in this cluster. The measurement engineering required for this similarly is part of the cluster. Approval-related questions are also dealt with.

3.10.1. Question F46

Research question: How can the safety of autonomous vehicles (ASIL D) be checked/safeguarded?

Explanation: The procedures for testing advanced driver assistance systems appear to be reaching their limits in view of the higher degrees of automation. The question is therefore which procedures can be used to deliver proof of the safety of automated vehicles.

Further main cluster: None

Secondary cluster: Validation, approval, measurement engineering

Summary for project comparison: How can the safety of autonomous vehicles (ASIL D) be checked/safeguarded?

Remarks:

- Obstacle:
    - Lack of methods, tools and testing ground
    - Underdeveloped awareness on the part of (funding) bodies

Funding opportunities: None known

Current and planned projects/activities:

- Response IV
- IP AdaptIVe SP2, 2014-2017, European level
- Ko-HAF, national level, BMWi
- MotorBrain (BMBF) up to 2014: Approaches of functional safety of electric powertrains
- PEGASUS

3.10.2. Question F47

Research question: How can functional safety be proven?

Explanation: In addition to existing test procedures, the question of new methods and tools to deliver evidence of functional safety arises.

Further main cluster: None

Secondary cluster: Validation, approval, measurement engineering

Summary for project comparison: How can the safety of autonomous vehicles (ASIL D) be checked/safeguarded?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Response IV
- IP AdaptIVe SP2, 2014-2017, European level
- Ko-HAF, national level, BMWi
- MotorBrain (BMBF) up to 2014: Approaches of functional safety of electric powertrains
- PEGASUS

3.10.3. Question F48

Research question: How much “creativity” of a vehicle guidance system can be tested?

Explanation: Due to the room for manoeuvre of automated vehicles, it is conceivable that there could be unexpected solutions for situations which are nevertheless safe. The question arises as to whether and how these unexpected actions can be tested if these are unknown in advance.

Further main cluster: None

Secondary cluster: Validation, approval, measurement engineering

Summary for project comparison: How can the safety of autonomous vehicles (ASIL D) be checked/safeguarded?

Remarks: Special question

Funding opportunities: None known

Current and planned projects/activities:

- Response IV
- IP AdaptIVe SP2, 2014-2017, European level
- Ko-HAF, national level, BMWi
- MotorBrain (BMBF) up to 2014: Approaches of functional safety of electric powertrains

3.10.4. Question F49

Research question: How can uncertainty be modelled in test cases?

Explanation: Especially in environment sensing, information with a high degree of uncertainty is processed and the uncertainty from raw data is propagated through the various processing steps. It is therefore necessary for testing and simulation that these uncertainties are modelled.

Further main cluster: None

Secondary cluster: Validation, approval, measurement engineering

Summary for project comparison: How can the safety of autonomous vehicles (ASIL D) be checked/safeguarded?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Response IV
- IP AdaptIVe SP2, 2014-2017, European level
- Ko-HAF, national level, BMWi
- MotorBrain (BMBF) up to 2014: Approaches of functional safety of electric powertrains
- PEGASUS

3.10.5. Question F50

Research question: Development of test procedures for sensor technology & algorithms, extension (e.g. X-in-the-loop)

Explanation: The existing sensor technology for monitoring tests and algorithms to be used for tests would appear to be inadequate for testing automated vehicles. The question of new test procedures arises.

Further main cluster: None

Secondary cluster: Validation, approval, measurement engineering

Summary for project comparison: How can the safety of autonomous vehicles (ASIL D) be checked/safeguarded?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Response IV
- IP AdaptIVe SP2, 2014-2017, European level
- Ko-HAF, national level, BMWi

- MotorBrain (BMBF) up to 2014: Approaches of functional safety of electric powertrains
- PEGASUS

3.10.6. Question F51

Research question: Kilometres v number of scenarios

Explanation: In the previous “proven in use” evidence, a high number of kilometres was driven in road tests, thereby proving safety. The question is whether this amount of driving can be reduced using other test methods, for example a validated simulation or a clever selection of test scenarios.

Further main cluster: None

Secondary cluster: Validation, approval, measurement engineering

Summary for project comparison: How can the safety of autonomous vehicles (ASIL D) be checked/safeguarded?

Remarks:

- Special question
- “Proven in use” will not be possible with autonomous driving, therefore an alternative must be found. One example is incrementally, whereby one releases the systems at a low degree of automation. The approach could be discussed in the ISO AK.

Funding opportunities: None known

Current and planned projects/activities:

- Response IV
- IP AdaptIVe SP2, 2014-2017, European level
- Ko-HAF, national level, BMWi
- MotorBrain (BMBF) up to 2014: Approaches of functional safety of electric powertrains
- PEGASUS

3.10.7. Question F52

Research question: Which requirements apply for a test facility for fully automated vehicles?

Explanation: A complete test facility for automated vehicles would presumably go further than previous test centres. Inner-city scenarios in particular appear to be difficult. The question of the requirements of a test facility (e.g. a testing ground) therefore arises.

Further main cluster: None

Secondary cluster: Validation, approval, measurement engineering

Summary for project comparison: How can the safety of autonomous vehicles (ASIL D) be checked/safeguarded?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Response IV
- IP AdaptIVe SP2, 2014-2017, European level
- Ko-HAF, national level, BMWi
- MotorBrain (BMBF) up to 2014: Approaches of functional safety of electric powertrains
- PEGASUS

3.10.8. Question F53

Research question: How can simulation be validated?

Explanation: A possible means for testing automated vehicles is simulation. However until now there have been no adequate possibilities for validating simulation such that the simulation results determined would also have been achieved in the real world.

Further main cluster: None

Secondary cluster: Validation, approval, measurement engineering

Summary for project comparison: How must a simulation environment for automated vehicles be designed? Also see: How can the safety of autonomous vehicles (ASIL D) be checked/safeguarded?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Response IV
- IP AdaptIVe SP2, 2014-2017, European level
- Ko-HAF, national level, BMWi
- UR:BAN (BMWi) up to 2016
- PEGASUS

3.10.9. Question F54

Research question: Transfer of actually measured scenarios to simulation scenarios

Explanation: To automate tests, the possibility exists to transfer actually measured scenarios to a simulation environment. The question arises as to how this can be achieved.

Further main cluster: None

Secondary cluster: Validation, approval, measurement engineering

Summary for project comparison: How must a simulation environment for automated vehicles be designed?

Remarks: Special question

Funding opportunities: None known

Current and planned projects/activities:

- Response IV
- IP AdaptIVe SP2, 2014-2017, European level
- Ko-HAF, national level, BMWi
- UR:BAN (BMWi) up to 2016
- PEGASUS

3.10.10. Question F55

Research question: Development of simulation methods for virtual validation

Explanation: The question is whether and how a simulation environment could serve as evidence of reliability in the real world.

Further main cluster: None

Secondary cluster: Validation, approval, measurement engineering

Summary for project comparison: How must a simulation environment for automated vehicles be designed? How can the safety of autonomous vehicles (ASIL D) be checked/safeguarded?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Response IV
- IP AdaptIVe SP2, 2014-2017, European level
- Ko-HAF, national level, BMWi

- UR:BAN (BMWi) up to 2016
- PEGASUS

3.10.11. Question F56

Research question: How do I refer to a reference?

Explanation: A reference is usually drawn on to evaluate systems. The question that arises is how to reference a reference if this already uses what is technically feasible in order to reference systems.

Further main cluster: None

Secondary cluster: Validation, approval, measurement engineering

Summary for project comparison: How must a simulation environment for automated vehicles be designed?

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- Response IV
- IP AdaptIVe SP2, 2014-2017, European level
- Ko-HAF, national level, BMWi
- UR:BAN (BMWi) up to 2016
- PEGASUS

3.10.12. Question F57

Research question: Approval

Explanation: After a successful test, automated vehicles must be approved for road traffic. This leads to the question of an approval process for automated vehicles.

Further main cluster: None

Secondary cluster: Validation, approval, measurement engineering

Summary for project comparison: None

Remarks: The Vienna Convention was updated in April 2014. The matter is now up to the UN ECE working groups.

Funding opportunities: None known

Current and planned projects/activities:

- Response IV
- IP AdaptIVe SP2, 2014-2017, European level

3.11. "Servicing" cluster

As a result of the increasing complexity, there is an increase in the servicing work on the sensor system, computer hardware and software. Corresponding questions are formulated in this cluster.

3.11.1. Question F58

Research question: How can regular updates of functions be ensured?

Explanation: Due to the installation of surround sensors, it is conceivable that new functions could be provided by means of software updates. It is moreover possible for faults to be rectified using updates. The question is how these updates can be imported and checked.

Further main cluster: None

Secondary cluster: Servicing

Summary for project comparison: None

Remarks: None

Funding opportunities: None known

Current and planned projects/activities: None known

3.11.2. Question F59

Research question: Ability to test long-term behaviour (development + function during the general inspection)

Explanation: During the general inspection, the vehicle is inspected to ensure it is working safely. This may also include an inspection of the systems for automated driving. The question arises about the need and implementation of the ability to test safe functionality.

Further main cluster: None

Secondary cluster: Servicing

Summary for project comparison: None

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- From 2017 the inspection of function will take place as part of the general inspection (test run, inspection of condition and function using the Adapter+ general inspection)

3.12. “Standardisation” cluster

Questions arise for the standardisation cluster in view of a cross-border use of automated vehicles.

3.12.1. Question F60

Research question: Is a new international standard for safety requirements necessary and possible? (Different highway code, different mentality of road users)

Explanation: Automated vehicles should be sold internationally and then used in various countries after purchase. Owing to different highway codes and practices in road traffic, the question of an international (global) standard for the behaviour and safety of automated vehicles arises.

Further main cluster: None

Secondary cluster: Standardisation

Summary for project comparison: None

Remarks: None

Funding opportunities: None known

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety

3.12.2. Question F61

Research question: What are the relevant contents of standardisation?

Explanation: Not only highway codes, but also radio standards, signs and many other topics affect automated vehicles. In view of a cross-border use of a vehicle, the question arises as to the subject areas that must be subjected to standardisation.

Further main cluster: HMI

Secondary cluster: Standardisation

Summary for project comparison: None

Remarks: None

Funding opportunities: Horizon 2020 MG.3.6-2015

Current and planned projects/activities:

- ISO TC22 SC3 WG16 Functional safety
- UR:BAN (BMWi) up to 2016

3.13. "Special questions" cluster

Special questions that do not fit directly in one of the previous clusters are collated in this cluster. The questions are mostly aimed at specific versions of functions or technologies.

3.13.1. Question F62

Research question: Interaction in a varying environment, dynamic lane allocation.

Explanation: Automated vehicles will be operated in changing road networks. For example there are lanes that can be driven in changing directions according to the required use. It is therefore necessary for automated vehicles to cope with this varying environment.

Further main cluster: None

Secondary cluster: Special questions

Summary for project comparison: None

Remarks: None

Funding opportunities: None known

Current and planned projects/activities: None known

3.13.2. Question F63

Research question: Business v private use liability + programming according to company standards

Explanation: Different liability questions arise for the business and private use of automated vehicles. These must be considered in detail and clearly regulated. The question also arises as to how the programming of automated vehicles must and can take place according to company standards and applicable statutory regulations if automated vehicles are deployed in companies.

Further main cluster: SA

Secondary cluster: Special questions

Summary for project comparison: None

Remarks: None

Funding opportunities: None known

Current and planned projects/activities: None known

3.13.3. Question F64

Research question: Will it be necessary in future to no longer look at and evaluate the vehicle as sub-systems, but rather as a complete system.

Explanation: Modern vehicles contain ever more electronic systems. Frequently their functions are only considered in isolation. Also during approval, complex electronic systems are looked at and evaluated individually according to the applicable statutory regulations (e.g. R79, R13, R13H etc.).

Further main cluster: None

Secondary cluster: Special questions

Summary for project comparison: None

Remarks: Similarly a subject for the ECE working groups.

Funding opportunities: None known

Current and planned projects/activities: None known

Funding opportunities

The funding opportunities for projects are listed below with the research questions that have arisen when collating research questions. A detailed description will not be provided here.

- Funding bodies
  - Federal Highway Research Institute (Bundesanstalt für Straßenwesen - BASt)
  - Federal Institute for Occupational Safety and Health (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin - BAuA)
  - Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur - BMVI)
  - Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie - BMWi)

    Funding objective/product oriented
  - German Research Foundation (Deutsche Forschungsgemeinschaft - DFG)

    Fundamental questions
  - German statutory accident insurance
  - German Automotive Research Association (Forschungsvereinigung Automobiltechnik e.V. - FAT)
- Funding programmes
  - Federal government: 4th transport research programme (planned)
  - DFG: priority programme (SPP) for cooperatively interacting automobiles
  - EU: Horizon 2020
  - SIFOP

4. Projects and research activities

The following completed and ongoing projects are concerned at least in part with research questions. A detailed project description will not be provided here.

4.1. Completed

- Legal consequences of an increase in vehicle automation, BASt report F 83,
  Tom M. Gasser, Clemens Arzt, Mihiar Ayoubi, Arne Bartels, Jana Eier, Frank Flemisch, Dirk Häcker, Tobias Hesse, Werner Huber, Christine Lotz, Markus Maurer, Simone Ruth-Schumacher, Jürgen Schwarz, Wolfgang Vogt, "Legal consequences of growing vehicle automation" project group
  (see http://www.bast.de/DE/Publikationen/Berichte/unterreihe-f/2013-2012/f83.html)
- EFA (Energy-efficient driving) 2014 II (BMBF) just ended; environment recognition, localisation;
- Validation strategies for advanced driver assistance systems (FAS) with environment sensing FE 82.0546/2012 (Alexander Weitzel, Herrmann Winner, Cao Peng, Sebastian Geyer, Felix Lotz, Mohsen Sefati). Project report currently being printed, will be issued as BASt report in the F-series.

4.2. Currently ongoing / approved

- IP AdaptIVe SP2 and SP7, 2014-2017, European level (no Daimler involvement in SP7)
- ISO TC22 SC3 WG16 Functional safety
- ISO 26262 further development VDA AK 26
- Examination of the assistance function will take place from 2017 as part of the general inspection by the expert organisation
  (test drive, inspection of condition and function using the Adapter+ general inspection)
- Ko-HAF, national level, BMWi
- AdaptIVe
- Horizon 2020, European level
- Functional safety is focal area in aFAS
- Partial aspects in aFAS and Ko-HAF
- UR:BAN (BMWi) up to 2016
- Ko-FAS (BMWi) up to 2013

- MotorBrain (BMBF) up to 2014: Approaches of functional safety of electric powertrains
- TU9 / CN (BMBF) up to 2015 - secures C2X communication
- Cooperatively interacting automobiles (DFG) from 2015
- FE 82.0570/2012 research project (safe state)
- PEGASUS – Project to establish generally accepted quality criteria, tools and methods as well as scenarios and situations for the approval of highly automated driving functions

Annex 3:

Road Infrastructure and Traffic

- Long version -

by

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Road infrastructure and traffic cluster

16.01.2015

1. Road infrastructure and traffic

Automated driving takes place on the public road infrastructure within a fixed legal framework, and will have implications for the safety and efficiency of road traffic. Amongst other things, the introduction of automated driving is linked to the expectation that road safety and traffic efficiency will be improved compared to the status quo, and that ultimately it will also be possible to further reduce the emissions caused by traffic. Until now there has been no sound evidence regarding the degree to which these expectations will be met.

In particular, highly automated driving with the temporary retreat of the driver from the control of his vehicle is contingent on the fault-free functioning of all sensor and control systems on the vehicle. An effective method in this respect involves redundant systems for detecting and interpreting the environment together with fall-back levels for the failure of subsystems. The functioning of vehicle systems could, in turn, require the presence of a structural and transport-related infrastructure with adequate availability and quality. However, until now there has been a lack of knowledge needed to prepare for (highly) automated driving, addressing road environment and infrastructure requirements according to the degree of automation. In addition to the visual detection of traffic signs, light signals and markings, the question arises as to whether, and to what degree, a second non-visual information channel to communicate traffic-regulating information must be provided by the infrastructure in order to guarantee safe and efficient driving at all times. Of particular interest here are the expected costs of any additional infrastructure equipment, the possible expansion stages and conceivable operator models.

Highly and fully automated driving requires an adequate time buffer to hand the driving task to the driver when there are indications that the automatic vehicle operation is overstretched. During this time, vehicles may cover several hundred metres, so that it will no longer be possible for the vehicle sensor technology to identify the relevant situations. The networking of several vehicles for information transfer would also appear to be too unsafe, in particular when there is a low equipment rate of intelligent vehicles in the traffic area. In this respect it is necessary to clarify which information must be provided with which quality on the infrastructure side, and who is responsible for this.

Finally, it must be assumed that even with full equipment in future, there will still be road users who do not drive automatically and who can consequently evade a joint cooperative strategy for highly automated driving.

The need for research into the road infrastructure and traffic cluster will be set out below. The research questions derived from the discussions are listed in tabular form, and the **key points** and **key questions** are highlighted. Interfaces with other clusters will be mentioned here with reference to the cluster concerned, but will not be dealt with in depth.

Firstly, the functional requirements of highly automated driving on the road infrastructure are to be determined. These arise from existing and future functions of automated driving and the information required on the vehicle side for safe operation on the roads. In turn, road infrastructure and traffic management requirements can be concluded from this.

Since the introduction of highly automated driving can only take place gradually, the consideration of mixed traffic during the various expansion stages is essential. It is not merely the guarantee of road safety and of traffic efficiency that are important here, but also the acceptance on the part of users. This is fundamental to a rapid increase in the equipment rate and thus also for system expansion.

Expansion stages and road infrastructure requirements are directly linked, which is why they are examined together here. The impact on traffic efficiency and road safety to be established in the following section will for its part have an influence on the planning of the expansion stages. For this reason, Sections 2 and 3 are intertwined.

The requirements ascertained flow into the information technology: not only suitable system architectures and data structures must be developed, but system security - in particular at the organisational-institutional level - must also be guaranteed. New test methods must be developed for this. As there are not yet any references, a need for research is present here too.

Finally, the new systems will place previously unknown requirements on road traffic law. Only the technical aspects of these will be investigated here and others referred to the Legal WG.

Handling system failures and emergencies is also important. In view of the lack of existing reference systems, a need for research also exists here.

In order to enable the infrastructure side of automated driving to be developed in a structured manner and operated safely, strategic aspects must be discussed from the outset: previous roles must be redefined in the light of changed requirements, new cooperative ventures may be useful and new stakeholders required.

1.1. The term road environment

The term “road environment” in this context should be consciously defined in a broad manner and contain all elements required for automated driving that are not present on the vehicle. In addition to the structural, traffic-related and information-based infrastructure, external influences such as the weather will also be examined below.

The structural infrastructure comprises the road as a structure. Traffic infrastructure includes all mechanisms that impact on the traffic situation by means of prohibitions, requirements and information, and which have the necessary prerequisites, for example with respect to data processing. The information-based infrastructure contains the data provided for automated driving and all mechanisms for generating and updating these data, for data transmission and direct (bi-directional) communication.

1.2. Functions of automated driving

In order to determine the requirements of highly automated driving on the road and IT infrastructure, it is necessary to define the necessary functions performed by the vehicle and road and which services must be additionally provided (use cases). It must be established how the vehicle behaves in various traffic conditions, in free-flowing and congested traffic (at sub-levels to be defined), and how they react to specific traffic situations.
The functions of the vehicle that need information from the infrastructure side must be specified here, and the input and output data must be defined. Furthermore, the infrastructure may offer own functions such as traffic control and traffic management measures and provide data about the traffic situation and danger situations.
The degree of requirements is influenced by the various expansion levels and equipment rates. The incremental need for each level must also be established.
The following research areas arise from the requirements:

- *I2C and C2I functions:* Firstly, the functions required to guarantee a safe traffic flow must be established. Amongst other things these include transmitting the own status (at least speed and position) with sufficient accuracy. The results of various research projects that have been and are being conducted on cooperative traffic systems can be drawn on here. Particularly worthy of mention here are the SIM^{TD} (www.simtd.de), Ko-FAS (www.kofas.de), DRIVE-C2X (http://www.drive-c2x.eu) and CONVERGE (www.converge-online.de) projects, which unite several technologies used for the communication between vehicles and infrastructure and test their interaction. These cooperative services do not represent any key technologies of automated driving, however they are necessary to complete the data base representing the traffic environment.
- *Information services:* Information services provided by the road infrastructure or the infrastructure manager are drawn on to complete the information obtained from C2C communication. These also include data about changes to the traffic flow and course of the roads, for example regarding accidents, lane closures or changes to traffic routing, e.g. in the case of major incidents. The SIM^{TD} and LENA4ITS projects should be taken into consideration here. On the one hand they address the logging of the traffic situation by the traffic headquarters in combination with detection by vehicles, and on the other hand deal with the subsequent measures to control traffic by passing information on to navigation systems or directly to the motorist.
- *Additional services:* As well as the services required for the safe flow of traffic, optional services can also be offered.

No.	Research question / need for research
1	How are adverse conditions (visibility of markings, signs, missing hard shoulders) dealt with?
2	To what extent are requirements and prohibitions such as speed restrictions provided solely as signs adequate as an instruction for highly automated driving? Are corrections to the digital map or different or supplementary information needed here? Is an additional communication basis needed for the vehicles?
3	Do signs, signals and markings and their effective range (in particular their lifting) need to be identifiable redundantly on site or centrally in the form of a digital map?
4	What should be done about inconsistent information on signs or the traffic and road situation obtained from on-board sensor technology (such as camera, wheel sensors), from the digital map and from the traffic data and from the environmental data supplied on the infrastructure side?
5	To what extent should correcting information be directly reported to the infrastructure or other vehicles?
6	How can traffic regulation, for example by the police, be taken into consideration?
7	How can vehicles with special signals be prioritised in a cooperative manner?
8	In the case of a cooperative highly automated convoy: how is a failure within the convoy dealt with? How does a vehicle leave the convoy?
9	How does the transfer to a low-risk state work in the absence of hard shoulders?

1.3. Requirements arising from the interaction between the road environment and vehicles

After defining the functions and expansion stages, the current state of equipment of the road infrastructure and information-based infrastructure must be determined.
The equipment needs for highly automated driving will then be specified, whereby initially the cases of the greatest possible expansion and of the **minimum expansion** will be considered. The **need for gradual expansion** - where present – can be directly derived from this.
In this context it is necessary to answer questions as to whether and, where applicable by what factor, it is necessary to improve quality, integrity and availability as the prerequisite for automated driving; the same applies to the question of the stage from which further high-quality traffic-related equipment (road equipment and telematics) is needed.
The requirements placed on highly automated vehicles arising from the quality and the state of the road environment (from the time that the environment and infrastructure are used by highly automated vehicles) must furthermore be examined with respect to safeguarding an efficient and safe traffic flow.

In terms of the organisation and technical aspects, the expense of possible expansion should be estimated. The expansion stages should also be considered individually, and a time frame set. On the basis of the expense determined, the feasibility should be assessed, taking existing and future operator models into account.

The interaction between the infrastructure and vehicle systems should be considered from a conceptual point of view. For example, it is necessary to investigate whether and how the infrastructure can intervene to provide support during **emergencies**, such as the driver taking back the driving role. These could, for example, be functions covered by the area of telematics or properties of the road equipment.
It is necessary to analyse how currently used technologies such as DORA[1] or ASDA/FOTO[2] can continue to be used in the road infrastructure, or whether and how these should be gradually substituted by new elements. Research projects looking into and testing cooperative technologies, such as UR:BAN (http://urban-online.org/), DRIVE-C2X or Testfeld Telematik (http://www.testfeld-telematik.at/) can deliver information on this.
They also make it easier to determine the architectural demands placed on the road infrastructure, and in particular facilitate the identification and the features of suitable and unsuitable elements and topologies for highly automated driving.

The need for action on the part of road authorities or new stakeholders (see Section 2.4.8) can be concluded from the identified requirements. A concept for system operation and the embedding in future systems should be prepared.

[1] Dynamic location of roadworks

[2] ASDA/Automatic procedures for tracking traffic congestion

FOTO – Process to track the state of “synchronised traffic” on the roads

No.	Research question / need for research
1	**As from what functional scope will there be a need for additional traffic-related and structural infrastructure compared to the status quo?** **Are there any infrastructure elements that are particularly suitable or unsuitable for a high level of automation and which would have to be taken into special consideration during a roll-out?** **What characterises infrastructure elements and topologies that are particularly suitable for a high level of automation?** **Is the quality of existing signs and markings adequate? What action do road authorities need to take?**
2	**Are there requirements concerning the state of repair?** **What are the minimum requirements for the infrastructure?**
3	By what amount must the quality, integrity and availability of the data supplied on the infrastructure side be improved compared to the status quo? What expense does this entail? What adjustments are needed regarding the measurement and assessment of the condition and the maintenance of objects of road equipment (traffic signs, markings etc.)? Do new data need to be collected and made available?
4	Which type of marking will be assigned what priority for automated driving (lane restriction, road marking etc.)? White and yellow markings that run parallel to each other: can vehicle systems differentiate these immediately?
5	Is there a need for adjustment regarding existing requirements in accordance with ZTV M 13 for the markings required for highly automated driving?
6	Comparison of the requirements for traffic signs and markings derived with respect to “man” or “automated vehicle” users.
7	How can or must reference architecture look like? Are there differences compared to the current ITS (intelligent transport system) architecture? How can the ITS architecture be further developed?
8	How can a clearly "passive" infrastructure be guaranteed? (clear signalling classification, signposting for roadworks (in particular also the lifting of roadworks))
9	What is the functional and technical compatibility with conventional and future cooperative ITS like?

1.4. Road safety and traffic efficiency

The previously used models for calculating and forecasting the traffic flow assume the individual motivation of drivers. Autonomous vehicles behave differently to privately driven vehicles. If there is also information about the traffic situation in the direct environment or further afield, the behaviour of the autonomous vehicles will continue to change. As a result, new traffic models are needed that include this factor and also take quantitative information about various equipment rates into consideration.
The reports "Effects of Cooperative Adaptive Cruise Control on Traffic Flow: Testing Drivers' Choices of Following Distances " by S.E. Shladover et al. and " The impact of cooperative adaptive cruise control on traffic-flow characteristics" by B. van Arem et al. ([1] and [2]) may be considered here, for example.
In addition to equipment rates, there is a need to examine different levels of automation through to highly automated, self-steering vehicles.

Cases in which vehicles show an uncooperative or even destructive manner of driving when there are no assistance systems or where these have been turned off must also be looked at. A special case here lies in the consideration of “overlooked” signs or situations that lift the speed limits (such as the end of the indicated danger).

The question also arises here as to whether and in what way traffic is affected when automated vehicles communicate their status externally. Other road users can then see whether or not the vehicle is in automatic mode.

Adapting the traffic models permits investigations that enable conclusions to be drawn about the economic savings potential of autonomous driving. The effect on road capacity and thus on the traffic performance must be quantified by corresponding studies. These should also include future demographic development. Greater traffic efficiency increases environmental benefits, primarily by avoiding bottlenecks, because overall emissions are lower. This expected benefit must be quantified.
Autonomous driving should not only improve efficiency, but also road safety above all. Appropriate studies should be conducted to establish the progress that can be achieved here. In combination with research into the causes of accidents, risky traffic situations can be specifically identified and avoided, such as the endangering of operating staff on motorways, lanes through roadworks or braking at the tail end of a traffic jam. Dealing with these situations will vary according to the expansion stage, which is why they need to be looked at individually and quantitatively assessed.

1. The study by the Dresden University of Technology on behalf of UDV about accidents in the area of roadworks on motorways and the article "Sensitivity analysis of CORSIM with respect to the process of freeway flow breakdown at bottleneck locations" by A. Kondyli could be included here ([3] and [4]).

No.	Research question / need for research
1	**What (quantitative) effects does highly automated driving have on road safety? Can infrastructure measures support the safety effect of automated driving functions?**
2	To what extent can high automation reduce the typical causes of accidents on country roads?
3	What problems may be encountered in mixed traffic?
4	Do safety risks arise for road users with vehicles that are not highly automated?
5	How does the cooperation between road users work at the functional and technical level? What can functionally and/or technically disrupt the cooperation?
6	Do highly automated vehicles contribute to instabilities in the traffic flow during heavy traffic? To what degree can (partially) failed highly automated vehicles contribute to instability? Does the driver taking back the control of the vehicle contribute to instability?
7	How can the infrastructure increase the time buffer for any necessary demand for the driver to take back control and what safety gain can be anticipated by this?
8	What happens when highly automated driving that complies with rules meets irregular driving behaviour?
9	What (quantitative) effect does autonomous driving have on traffic efficiency in the various expansion stages?
10	How is the traffic flow changed by automated driving (also according to the equipment rate)? As from what permeation rate does highly automated driving impact on traffic and in what way?
11	Should steering strategies follow the system optimum or user optimum?
12	To what extent can highly automated vehicles increase capacity, for example through safe use of the overtaking lane in the area of roadworks or through fast acceleration out of the bottleneck?
13	Today traffic flow models are the basis of much planning (e.g. investments, regulations). These models are based on the behaviour of people in road traffic. What models will apply in future?
14	Can/should there be different rules about distances for highly automated vehicles?
15	How do highly automated vehicles become embedded in cooperative traffic systems? What scenarios are conceivable?
16	What necessity for cooperative behaviour arises, for example when pulling into traffic or changing lane? Will this lead to reductions in capacity?
17	What are the effects on the modal split? What happens to (road) public transport?

1.5. Requirements placed on information technology

Information technology in all of its forms (the provision, security, updating and accuracy of data) will play a crucial role on the infrastructure needed in future for highly automated vehicles. Extremely accurate digital maps have been an indispensable basis for all previous highly automated showcase projects. For this reason, the content and standards of digital maps that are suitable for high automation and which go far beyond the accuracy of the navigation maps available today must be defined. This also includes a **standardised data representation** of relevant objects and elements that are presented in such maps. Without standardised data representation, vehicle data exchange is unnecessarily complicated both between vehicles and with the infrastructure, which in turn has negative effects on the creation of cooperative solutions. The central questions that (still) remain here are the generation of such highly accurate, standardised digital maps, the possibilities of keeping them up to date and guaranteeing that these maps are permanently correct and have a high level of availability. The question of who is responsible for this part of the infrastructure in the ultimate solutions has also not yet been clarified.

Furthermore, a global, very accurate vehicle self-localisation will be essential for cooperative applications. For safety-related applications a highly automated vehicle must have very accurate knowledge of where on the earth it is located. Only then can the exchange of information (e.g. by means of infrastructure objects) between vehicles and with the infrastructure achieve the requisite accuracy (keyword: cooperative learning, cloud solutions). The prerequisite for a sufficiently accurate automotive localisation (way beyond GPS accuracy) is also the existence of the necessary (digital) infrastructure, e.g. in the form of field markers in highly accurate digital maps or in the form of position encoding infrastructure elements.

In general, the entire approach (also for high automation) is still very vehicle-oriented and related to the individual vehicle. However, the transition from individual solutions for highly automated driving to mixed traffic requires moving away from a merely vehicle-centric perception of the environment towards a cooperative joint detection of the environment and situation.

Only in this way can cooperative solutions for assessing the situation, making a decision, planning trajectories and obtaining information by means of shared learning be realised. A standardised digital infrastructure is essential here, beginning with highly accurate digital maps. Parts of these subjects have already been identified in EU-sponsored projects as the next necessary steps, but have not yet been put into practice. In the communication area there are approaches towards standardisation (Converge, SIM^{TD}), but on the other hand the approaches for the underlying data is missing. In the planned Ko-HAF project, some aspects of cooperative learning of infrastructure components are being dealt with as prototypes, but this can by no means take place in a comprehensive manner. To conclude, the following points must be addressed:

- Highly accurate digital maps
    - Generation
    - Ensuring maps are up to date and accurate
    - High availability

In addition to automotive localisation and information about the surroundings, the requirements placed on data and data transmission in terms of standards, quality and information and communication technology must be defined. These also include the identification of essential basic information as well as other necessary data from the infrastructure.

Moreover, data security must be guaranteed; concepts for redundancies or fall-back levels must be developed to achieve reliability; an integrated safety concept must be developed.

Here too there is a need to overhaul the present role model so as to establish the **responsibility for digital infrastructure**.

No.	Research question / need for research
1	**Standardisation of data formats and transmission protocols**
2	**What standards are already present for communication infrastructure, and which others are still needed?**
3	**What data, information and functions must be provided externally and in which quality?**
4	What information must under all circumstances be provided for highly automated vehicles to ensure safe operation on the roads, taking account of the degree of automation and with a view to the necessary information-based redundancies and fall-back levels? What other information would be helpful?
5	What degree of updating, integrity and availability must the requisite data and information have, for example concerning the (micro) traffic situation, the road conditions and the digital map? (Keyword LOS: Level of Service)
6	How high must the availability of the required data be in the highly automated vehicle, what are the consequences of failures, and how are these dealt with?
7	**Definition of the content and standards for digital maps that are suitable for high automation, including standardised (data) representation of objects in these maps.**
8	What quality of digital map is needed and is expected to be available?
9	What possibilities and procedures are there for keeping the digital maps that are suitable for high automation up to date and correct?
10	What can the back end / a safety server guarantee in terms of ensuring that environmental data are secure / up to date?
11	How high must the data monitoring density be for external servers? To what degree must the reliability of the function chain be guaranteed? Who is responsible here?
12	What requirements for communication technologies arise from the function and architecture of highly automated driving?
13	To what extent - using existing cameras or other high automation sensor system in the vehicle to detect the micro traffic situation in the vehicle environment and that of oncoming traffic, and also passing this information on to other vehicles using C2C and C2I - can the perception horizon be expanded such that hidden situations can be recognised for example? How big is the resultant gain in terms of availability, redundancy and reaction time?
14	How can the concerns of data protection be regulated?
15	How good is compatibility with conventional ITS (traffic control systems, traffic managements systems etc.)? Are there any strategic conflicts during traffic routing?

1.6. Test methods

In the long-term, the vehicles will completely take the task of driving away from the driver. As this is predicated on the interaction of several complex methods and the consequences of a mistake can be fatal, comprehensive system tests must be conducted.

System here refers to all of the components involved in highly automated driving: drivers, vehicles, road infrastructure and the information technology infrastructure. Not included here are legal authorities.

Until now no comparable system has been implemented in terms of function and scope, so that no test concepts can be used as references and a new, complete concept needs to be developed.

The functions must be tested individually, in their respective environment and also in their overall context. This means, for example, that the position location must be checked to ensure it is correct; it is furthermore necessary to check whether the central data are correctly processed and also whether they are correctly transmitted to the overall system. Test methods must be developed for all functions involved on the infrastructure side, i.e. structural, road traffic and information technology infrastructure. A risk analysis prioritises tests and the interception of errors.

Some research projects, e.g. City Mobil (www.citymobil-project.eu) and SIM^{TD} (http://www.simtd.de) already implement sub-functions. Tests for sub-functions can be derived from these projects.

The complexity of the system and also of the system tests increases depending on the expansion stage. The test concept should initially therefore look at the stages individually, but should at the same time include the developments of the next stage to the extent that the requirements for the coming expansion step are present.

1.7. Handling emergencies and system failures

Strategies must be prepared for how to deal with any system failures that occur despite tests and safety measures. One example might be the failure of information channels. In this case a component of positioning equipment of vehicles or the information about the traffic situation might fail. A distinction must be made here between failures affecting an individual road user and failures that affect a collective group, as well as between partial failures which, for example, affect one of several redundant channels and total failures where an entire function is no longer available.

Management strategies must be prepared for emergencies such as accidents or natural phenomena. The types and causes of these emergencies may be diverse: a vehicle has an accident, a person in a vehicle suffers a medical emergency, or the road is damaged or is not passable etc.

An emergency can also result from a system failure or a malfunction. A risk analysis permits an assessment of potential emergencies and their consequences.
Two studies by the UDV on driver assistance and infrastructure-based driver assistance can be drawn on here ([5] and [6]).

No.	Research question / need for research
1	Which infrastructure requirements arise in terms of emergencies and system failures?
2	How does the transfer to a low risk state function without hard shoulders?

1.8. Strategic aspects and role models

New technology produces changes in the road infrastructure and traffic. The requirements for the road infrastructure will increasingly shift towards information technology, which is why the previous **role models** need to be revised. The differences in requirements must be analysed and classified; new **cooperation models** must be found. New stakeholders may have to be involved.

Above all, a **strategy** must be developed that describes the approach for the **introduction of highly automated driving** to the traffic environment (deployment strategy). After an analysis of the status quo and the research described in the above sections, it is possible to estimate how and in which order new functions can be introduced and to what extent the integration into existing systems is possible. What is more, the expense involved can then be estimated.

Since the introduction is expected to take place gradually, the definition of the expansion stages should be part of the strategy.
At the start of introduction, vehicles with advanced assistance systems will represent an obstacle in free-flowing traffic. This can already be observed today with Automatic Cruise Control. As a result of complying with the regulation distance to the vehicle in front, other vehicles continuously cut in ahead of the vehicle equipped with the system, causing the cruise control to reduce speed etc. For this reason one option can be to specially dedicate certain roads or sections of roads so that these may only be used by vehicles with a minimum level of assistance system equipment. In order to estimate the impact on traffic flow, measures of this kind must be appraised in advance according to aspects of traffic management.
By contrast, when a sufficiently large rate of equipment has been achieved, then vehicles without assistance systems will represent an obstacle. This is also something that an introduction strategy needs to consider. Finally, it is possible that some drivers do not want to give up the control of their vehicle in particular situations or at all. These cases must likewise be incorporated into the strategy.

No.	Research question / need for research
1	**What strategies can there be for the deployment of traffic-related infrastructures for high automation?**
2	What types of traffic and classes of roads should primarily be placed in autonomous mode? Passenger transport, goods traffic, commercial transport, public transport?
3	Is it at all necessary to link high automation and infrastructure? How will the implementation of the interaction between the systems be realised?
4	**What does the development path for the infrastructural retrofitting look like, and will this result in new role models?**
5	**Who is responsible for the digital infrastructure? How does the previous role allocation need to be further developed? Is there a need for new stakeholders?**
6	Taking account of a suitable role allocation, what organisational cooperation models and/or structures might there be?
7	How great is the interest or user acceptance? Is it essential for high automation to be free of charge? How great is the readiness of drivers to pay for the genuine increase in comfort? What price sensitivity exists here?
8	What infrastructure potential arises from future generations of automated systems?

1.9. Further action

The research areas set out above build on each other in some cases. This should be taken into consideration during their processing by following a structured procedure (Fig. 1).

Firstly, the requirements for the system must be analysed, which is why functions and use cases are defined as a first step.

This produces the **requirements for the road environment** – and in particular for the structural, traffic-related and information technology infrastructure. It is also necessary to clarify the need for expansion compared to the status quo and the estimated organisational, financial, technical and temporal expense and need for action on the part of road authorities (or other stakeholders).
The individual expansion stages must be defined and the needs aligned to these.

Furthermore the traffic models must be adapted in keeping with highly automated driving, taking into consideration the rates of equipment in the expansion stages. This should permit conclusions to be drawn about traffic efficiency and road safety and about the macroeconomic potential.

Requirements for the **information-based infrastructure** must be formulated, which also involves content such as the digital map material, formats, data transmission as well as the global system architecture. Added to this are data security and reliability.

Test methods must be developed after the system properties have been defined.

Institutional aspects such as the impact on road traffic law or road safety law can be derived from the system functions and the results of numerical modelling.

Knowledge of the functions, system architecture and test methods is the prerequisite for a discussion about emergencies and system failures.

All aspects specified have an influence on the **strategy** for the introduction of highly automated driving and on a possible **new role allocation**.

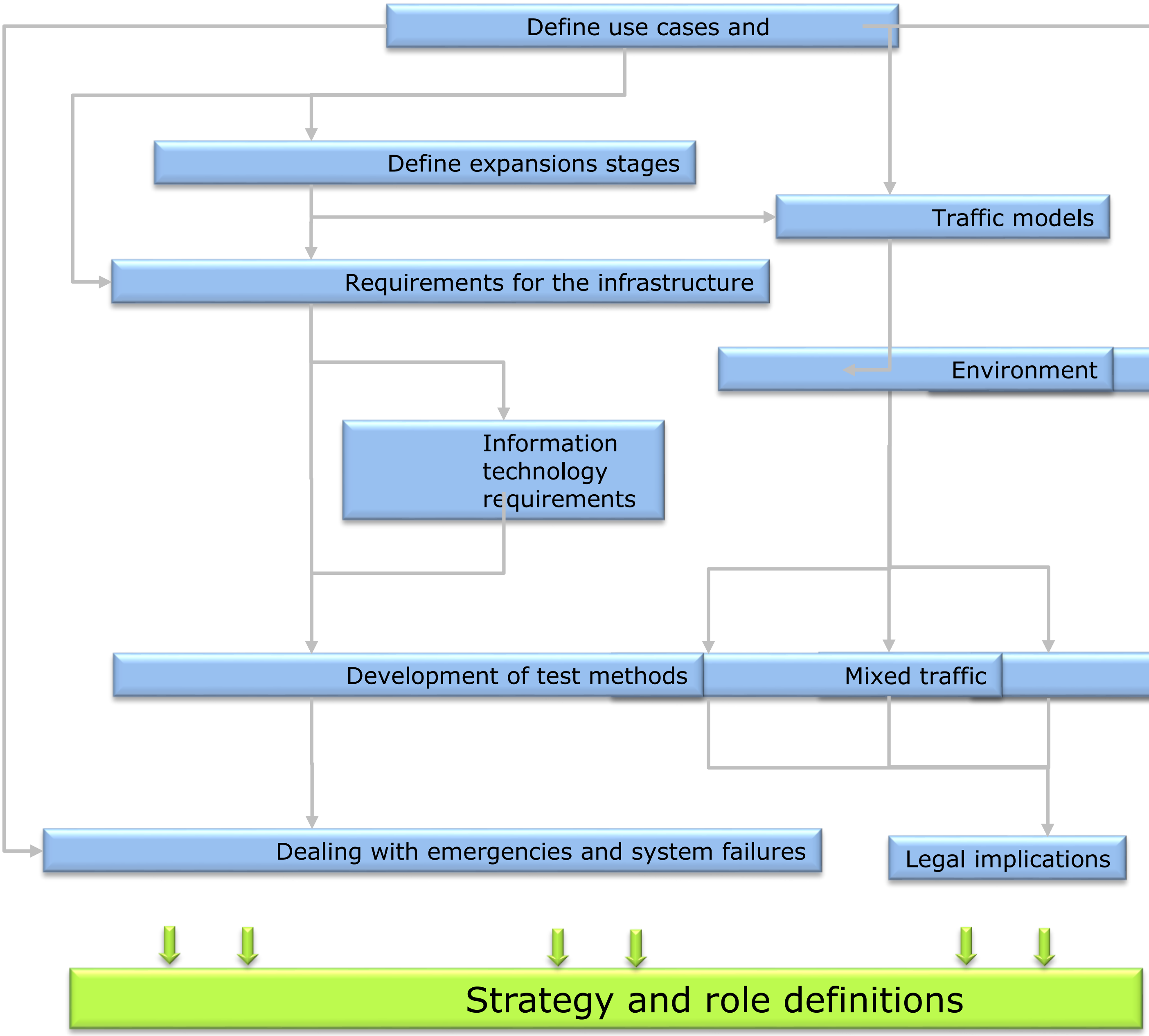

Figure 1: Course of action (draft): this diagram refers exclusively to research into road infrastructure and traffic. Interfaces with other research clusters have not been shown.

2. Overview: urgent need for research

The subjects indicating an urgent need for research are shown below, divided into four areas with equal status:

Traffic: Quantitative measurement of the potential of highly automated vehicles in the various equipment and penetration stages using predefined scenarios with the following target criteria:

- Improving traffic efficiency
- Increasing road safety
- Reducing pollution

Road infrastructure: Examination of the reciprocal requirements arising from high automation for both the infrastructure and for the vehicles, and also from their interaction.

- Establishing the minimum requirements
    - Depending on the degree of automation of vehicles and rate of equipment in traffic
    - With respect to the different classes of roads
    - Resulting from obligations regarding traffic management measures under road traffic law
- On this basis, infrastructure managers and vehicle manufacturers should extrapolate the concrete need for action with respect to the creation of a possible framework for the operation of high automation in terms of the degree of automation and equipment rate. Different versions of use of the road infrastructure that go beyond common practice should also be considered here.

Digital infrastructure: Description and design of the digital cooperative network between infrastructure and vehicle

- Definition of the content and scope of necessary data communication between vehicles and infrastructure
- Necessity of the requisite standardisation of interfaces, protocols, data models, digital map etc.
- Determination of responsibilities for the role models derived from the scenarios.
- Uniform description of the technical features of the digital cooperative network

Strategic aspects of introduction and operation

- Assessment of introduction scenarios for highly automated vehicles, particularly regarding the aspect of traffic organisation and also regarding existing traffic management solutions
- Development of scenarios for new cooperation models, role models and new operator models
- Reflection of all aspects in the European context and highlighting a possible need for action

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Annex 4:

Social Aspects

- Long version -

by

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Christian Reitter
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BMVI Round Table on “Automated Driving”

Research Working Group

Report by the “Social Aspects” Topic Cluster

Barbara Lenz, Welf Stankowitz, Eva Fraedrich

Date 18 January 2015

Contents

Introduction:

Motives and arguments in favour of addressing fully automated driving from a social perspective

The expected transition to “autonomous” or “fully automated” vehicles on the roads (“fully automated” according to the definition of BASt in 2012) is not only an enormous technical challenge, but rather simultaneously implies a possibly profound change to the entire traffic system. This system is embedded in social values and norms, political and economic objectives, legal stipulations and agreements as well as in the everyday practices of road users. Whereas the previous development of driver assistance represented merely an incremental advance in vehicle innovation although it involved the automation of functions, the introduction of fully automated road vehicles has the potential to produce a fundamental change both in traffic and in driving. In this context there is a real need to discuss social aspects. In detail we would like to raise the following motives and arguments:

The introduction of autonomous vehicles in the traffic system affects all road users.

As partners in the immediate traffic environment, other road users in addition to the users of automated vehicles will be influenced by the driving behaviour of autonomous vehicles. A high degree of acceptance at a societal level which goes beyond pure user acceptance is therefore the prerequisite for a successful and prompt implementation of the new vehicles. It is assumed that autonomous vehicles will offer great potential with respect to reconfiguring the traffic system towards greater sustainability and efficiency and also towards significantly greater road safety. This will substantially depend on a high degree of acceptance by society.

The draft of scenarios is the prerequisite for reliable estimates.

Long before the introduction of an autonomous vehicle in the traffic system, it is necessary to draft concepts and scenarios (application cases) for the possible and expected functions and modes of operation of the vehicles, so that potential impact can be estimated better and more reliably. This is necessary both from the point of view of the individual user, and with a view to the entire traffic system. Fundamental decisions about the algorithms with which the vehicles are controlled, the legal aspects that need to be regulated to operate the vehicles and about possible requirements for the traffic system as a whole are based on it. Questions include those concerning the necessary configuration of traffic infrastructure, the communication technologies required to transmit data or the form of interfaces with other modes of transport. Many of these decisions must be made in advance of the implementation of autonomous vehicles on public roads.

The public, media response currently pays little attention to systemic aspects.

It can also be seen that the societal discussion (via media representation and its reception) is already taking place today – albeit gradually – and therefore long before the introduction of the first fully automated vehicles. In any event it is to be expected that the subject will be increasingly addressed by the media in future, particularly when, for example, software manufacturers such as Google announce a project such as the 100 vehicle AMoD project, Daimler carries out the Berta-Benz trip or Volvo plans to test a motorway pilot on the Gothenburg motorway ring road. At the moment it is only possible to see the first indications of how the (German) public debate will ultimately be conducted. So far, in addition to an examination of the subject that currently focuses on individual features that are becoming possible by virtue of the new technology (such as safety, alternative use of time etc.), there have hardly been any contributions that take a more holistic view of impact at the level of the traffic system and on society as a whole.

The automation of commercial vehicles must also be addressed.

Integration of autonomous road vehicles into the traffic system does not mean merely looking at cars; the automation of light commercial vehicles and trucks must also be taken into consideration as part of the change to a fully automated system. Since goods traffic will continue to be a substantial component of road traffic, a discussion focusing solely on cars is ill-advised.

The economic requirements of road haulage differ fundamentally to those of private transport.

In road haulage, there are very high demands for economically optimal manners of driving and driving times. The tasks and performance of the driving personnel are also considered in the light of optimisation. The possibility of automated driving resulting in more time that can be used for other duties could, for example, result in a real change to the job description of a lorry driver. For this reason it is essential to examine the connection between goods traffic and automation.

The autonomous vehicle produces data and needs data.

The regular checking of the most important driving functions and constant updates (e.g. relating to changes in conduct under road traffic law) is necessary just to guarantee the permanent technical safety of automated vehicles. Technical and legal stipulations for this are needed. Drivers can be obliged to facilitate permanent communication. It may also be necessary to make changes to the arrangement of the ownership structure of the vehicle or parts of it compared to previously.

Furthermore, increased networking creates possibilities for integrating autonomous vehicles in the transport system in a novel way, for example as part of the development of the “new mobility concepts” that are currently emerging, and which signify a link between diverse quasi-individual vehicles and public transport. Assuming that data security and privacy can be guaranteed, this could mean active use of the data for road users.

The networking between vehicles and to other modes of transport finally also offers an opportunity for optimisation processes in different respects. All traffic could be directed in an environmentally friendly way. Individual vehicles could be optimised by influencing traffic management. In the same way as the priority networks for data transmission in the internet that are currently being discussed, there could be priority models for certain vehicles or categories of vehicle.

Consideration of the alternative development paths of technological development.

The current discussion about autonomous driving is dominated by a linear understanding of the further course of development: according to this, advances in the development of driver assistance will result in the complete automation of road vehicles so that “one day” almost inevitably the moment of full automation will arrive. Alternative paths of development, for example in the form of the introduction of autonomous vehicles in specific public or semi-public “niches”, as would be the case in the grounds of a university, a company or on an island, are only infrequently discussed. At the same time there is a lack of scenarios addressing the interaction between automation of road traffic and those systems (traffic, politics, the law, economy, society) in which road traffic is embedded.

Car driving does not only entail the control of a mobile machine.

There is a lack of concrete ideas about the demands on the “drivers” of automatically driving vehicles. The question in the long-term regarding increasingly automated driving is whether drivers lose their ability for self-determined driving. This rather psychological questioning is followed by the question of which basic requirements (driving permit) must apply to drivers of automated vehicles. Associated with this is the possible development whereby the vehicle driving services hitherto provided by the individual drivers are transferred to others. The former contribution of individuals to shape the traffic process through their self-determined manner of driving, for example, is restricted. The question then arises as to which institutions will then assume the necessary shaping of the decisions previously taken by the driver.

Participating in road use involves a high degree of communication with other road users, and understanding and predicting their behaviour. In doing so, social rules of conduct must be applied in addition to formally learned rules (Highway Code). Social conduct during driving has diverse connections to social conduct in other areas of life and indirectly also shapes these. As a result of automated driving, an important social space may be lost in which young people in particular are able to learn and apply social rules of conduct.

Based on these observations, those areas of research are to be specified below that we believe to be significant to the possible introduction of autonomous vehicles in road traffic from a social perspective. Their significance lies less in direct support for whatever the type of implementation process, and rather in addressing and discussing the opportunities, possibilities and effects of automation in road traffic at an early stage both from the perspective of a large number of social groups and from the point of view of the individual road user. This also means that the main concern is less about estimating the market potential of autonomous vehicles, and primarily about the discourse on realising the mobility of tomorrow that meets the needs of large sections of society.

Reference should also be made at this juncture to issues outside the “social aspects” directly connected to autonomous driving and which have not therefore – at least at the present time – been elaborated on. These primarily concern the competences and framework conditions affecting the production of autonomous vehicles and their integration in a general traffic system.

In light of the dramatically growing importance of information technology in vehicles, it cannot be ruled out that location-related conditions and assessments will change. However so far there have not been any signs of specific consequences for the vehicle industry in Europe, even if ever more European manufacturers in the current development phase are clearly seeking proximity to leading software developers and the corresponding political-societal environment. Associations and policy-makers are gradually starting to take note of these issues; we strongly recommend the use of scientific expertise in further development.

Research status

The research into the "social aspects" of automated driving is currently only present to a limited extent. Various market-oriented surveys can be found, such as the 2013 Mobility Study by Continental, the studies by KPMG and CAR 2012 and 2013, Ernst & Young 2011 or Autoscout24 2012 and 2013. There have also been approaches such as those in the "Villa Ladenburg" project from the Daimler und Benz-Stiftung, which on the one hand tackle socially relevant aspects of automated driving, for example the possible impact of availability of autonomous vehicles on the choice of the means of transport or on urban structures, and on the other hand empirically extrapolate the expectations and hopes as well as the fears and concerns of road users.

The primary challenges currently facing surveys conducted on autonomous driving, which can essentially be assigned to market and opinion research and which directly examine perceptions concerning autonomous driving, are that it is impossible to assume either a broad level of knowledge or concrete experience of the technology. Above all it is unclear what those surveyed actually understand by the term "autonomous driving", the context in which their perceptions and judgements are embedded, and which challenges and hurdles as well as which benefits they recognise on the basis of a little specified presentation of autonomous driving. The attitudes and assessments recorded are therefore only valid to a qualified extent, because the subject of the survey is scarcely familiar and has not been clearly defined.

The few studies that have looked at the acceptance aspects of automated driving communicate a very heterogeneous picture in general. In their study on active and passive safety systems, Frost & Sullivan demonstrate that the majority of car users have so far shown a basic resistance to the idea of handing control of the vehicle control system over to a machine or a robot. By contrast, other surveys suggest that in particular young drivers aged between 19 and 31 often find driving itself to be a burden, because the IT-based communication with others is actually more important. A survey about what Europeans want in future cars has shown that around two-thirds of the people questioned are quite open to autonomous driving. The mobility study conducted by Continental designed to obtain an international comparison questioned drivers from Germany, China, the USA and Japan. On the one hand the study was able to confirm openness towards autonomous driving in principle, but on the other hand also demonstrated that a large number of those questioned across all countries currently (still) has doubts about the safe mode of operation of the technology or even finds this rather alarming.

By contrast, the work carried out as part of the "Villa Ladenburg" project primarily examines the connection between current everyday practices, above all with respect to car use, and their significance for attitudes towards autonomous driving and the expectations and fears shown towards this new technology. The corresponding studies (Fraedrich/Lenz a and b, Cyganski) firstly demonstrate that existing comments in the public (online) media (and in particular national daily and weekly newspapers) about autonomous driving seize on common arguments of users and especially the expected increase in safety, as well as an emphasis on the continued growth in flexibility for individual mobility. At the same time it is clear that simple "patterns" such as "young people" versus "older people" are only partially applicable when examining autonomous driving. More important would appear to be the role of the car as a "space" that satisfies both the emotional and social needs of users, such as the provision of a not merely passively used area of retreat during the transition between obligatory and non-obligatory activities: car driving permits an active changeover here. What is more, these studies illustrate the necessity of highlighting the assessment of concrete substitution scenarios by road users in addition to general acceptance. There are initial indications – and this follows on from the observations on transition situations reported above – that the direct situation in which a currently used means of transport could be replaced by an autonomous vehicle has a direct influence on acceptance.

Further studies that deal with the social discussion on autonomous driving and the tensions between the consideration of benefits and risks emphasise how important it is to use open and transparent communication to broach and throw light on the significant aspects of use (Grunwald).

Research questions

In view of the current, still very rudimentary status of research into the social aspects of autonomous driving, which also includes questions about (potential) use, we believe the research questions set out below to be particularly relevant, especially in terms of the transition to fully automated driving. The order of topics corresponds to their prioritising by the “Social Aspects” subgroup of the Research/Need for Research WG.

Subject 1: What are the possible drivers of social and individual acceptance of automated driving?

Currently it is only possible to describe the first indications of the expectations and fears that currently exist on the part of road users in relation to the individual vehicle as well as to the entire traffic system. At the moment there is insufficient knowledge about the expectations and fears themselves and also about the reasons behind these. However it can be assumed that knowledge about expectations and fears (frequently termed “acceptance”) as well as about the reasons behind them is a fundamental prerequisite for subsequent introduction of autonomous vehicles in the traffic system.

The following principal aspects can currently be identified as possible expectations – predominantly derived from expert scientific and specialist discourse - and which first and foremost have a societal benefit:

Greater road safety;

Faster traffic flow;

Options for individual mobility also for those with limited mobility or driving ability;

Fuel savings.

Possible fears currently dominating discussion – also among the interested public – concern the following:

The level of the costs that might ensue. The concern here is about justice, especially with respect to the question of whether and to what extent society will have to bear the costs of technological developments that will ultimately only benefit the few.

Conflicts between automated vehicles and those that are not automated;

Being disempowered by technology;

Pressure to change to an autonomous vehicle / autonomous driving because in time mixed traffic will hinder or at least substantially limit efficiency gains and thus the fundamentally possible, positive environmental effects;

Possibility of greater monitoring of the individual through increased data exchange.

In some cases the benefit at the individual level goes hand in hand with the societal benefit, for example with respect to the increased safety resulting from autonomous vehicles. One really important question here is the evaluation of journey times, especially regarding the evaluation of the time gained for non-driving activities. The question also arises about the way in which the feeling of belonging to a group of innovators (which essentially applies to early adopters and first followers) can influence the introduction of autonomous driving.

It will additionally be necessary to look at how social demographics / the social structure, gender, ethnicity and the social and cultural context impact on the acceptance or rejection of autonomous driving.

In general the question arises as to the extent to which these expectations and fears about socially relevant effects, but also on the individual benefits of autonomous driving, will act as a driver or an obstacle to the acceptance of these new technologies. Ideally these questions should be answered in the form of monitoring, possibly linked to the national MiD mobility study (Mobilität in Deutschland – Mobility in Germany) or to the “mobility panel” as well as by means of direct surveys. It is difficult to imagine that individual cross-sectional surveys will succeed in producing a consistent picture of this. Going beyond a quantitative approach, it would appear important to record the everyday context of conventional car use much better than has previously been the case, so that the approaches for the comparatively fast and visibly beneficial deployment of autonomous vehicles can be identified.

What special considerations apply when automatic buses and trucks are used?

In addition to the question about the acceptance of autonomous driving with cars is the issue of acceptance of automation in commercial transport. The basic differentiation according to individual and social acceptance also applies to commercial transport, i.e. to trips carrying passengers on the roads and to trips with small commercial vehicles and trucks. However different constellations apply here:

The ***individual acceptance*** on the part of the driver will be superseded by the interests of the hauliers and bus operators. Whilst in the case of a car, the period of time in which automated driving takes place might be regarded as “leisure time” for the motorist, there are indications of a different development in the commercial sector. It is already apparent today that the haulier or scheduler will give the driver duties to carry out during this period of time and that these will clearly not be leisure-oriented. Furthermore there are likely to be efforts by the hauliers and bus companies to obtain permission for a proportional extension of the driving time for the automated driving period. Significant adjustments to framework conditions would be needed here, however.

To the knowledge of the authors of this report, the ***social acceptance*** of road vehicles in commercial transport, i.e. their acceptance primarily by the various groups of road users, has not been addressed at all until now. Presumably nobody currently assumes that there is also an interest in automated driving with these vehicles in regional or urban traffic, as well as on through roads.

In view of this, there is an urgent need for research into the following issues:

What are the consequences of introducing automated commercial vehicles for the work to be carried out by the driver?

To what extent and in what way do framework conditions have to be adapted in order to implement automated commercial vehicles – with respect to aspects under labour law, insurance law and road traffic law?

What are the specific drivers for or against acceptance in the case of commercial transport?

What are the social benefits of autonomous vehicles in commercial transport?

Which requirements for the location and infrastructures of dispatchers and recipients (macro and micro perspective) result from the introduction of automated commercial vehicles? What does this also mean in terms of existing settlement structures and their integration in the road network?

Subject 2: How will the traffic system change as a result of automated road vehicles?

In principle the introduction of autonomous vehicles into road traffic offers the potential for a fundamental change to the traffic system. The following scenarios are conceivable:

Change to the choice of the means of transport due to the reassessment of journey times.

Change to the available transport through the redefinition of private and public transport.

The resulting questions will be described below.

2.1 - How will the automation of motorised private transport change the choice of the means of transport?

Currently traffic research assumes that the choice of a means of transport is chiefly dictated by the monetary costs and by the expenditure of time resulting from use. There are also further important factors, in particular the level of comfort perceived. If we assume that an autonomous vehicle is able to offer a changed interior concept that permits “new” activities in the car, such as reading, watching films, working or talking to people, then this is likely to alter the way travel time is evaluated. It is therefore necessary to investigate - in a much more differentiated manner than has previously been the case - how the assessment of travel times depends on factors such as travel comfort, the length of access and departure times, existing mobility patterns, the time spent in the vehicle, the subjective significance of driving itself as well as those activities that then become possible as an alternative to the driving task. This would also seem to us to be important in the light of the discussion that is still very open at the moment surrounding the importance to Generation Y of always being connected and the mutual effect on car use and possibly also on car ownership.

Possible changes to the evaluation of travel time are also extremely important in view of the close connection between the choice of the means of transport and residential location. A change in travel time from non-productive to productive time could have a substantial impact on settlement structure because of an acceptance of longer commutes. Here first and foremost it will be necessary to examine whether, and if so how, different degrees of productivity during commutes influence the choice of transport.

The questions raised in this topic block are closely connected in terms of context to the general issue concerning the subjective benefit of autonomous driving.

2.2 How will the traffic system be changed by the introduction of automated vehicles?

Expectations repeatedly expressed in conjunction with autonomous driving centre on the fact that in the medium term the development will not stop at the simple replacement of conventional vehicles by fully automated vehicles. Rather they recognise the potential offered by autonomous vehicles to blur the still largely rigid boundary between private transport and public transport and to combine individual mobility demands with publicly available services. The present flexible car sharing schemes with pick up points can be seen as a first step towards the "individualisation of public transport". This is connected to the following research questions:

What influence do changes on the supply side have on the traffic system, in particular resulting from the integration of autonomous vehicles into "new mobility concepts" (especially car and trip sharing), and resulting from the (partial) individualisation of public transport?

Which adjustments and changes are needed regarding explicit (e.g. Highway Code, driving licence law) and implicit (general socially and culturally recognised) regulations or have an influence on the functioning of traffic, not least for the interaction between road users?

Which possible innovative products (optimisation of traffic flow, entertainment en route, information about traffic data etc.) will be offered by the market, and what influence will they have on the traffic system?

To what extent do traffic events represent an everyday shared, lived social space, and how would autonomous vehicles on the roads influence this social interaction? (social-philosophical question)

2.3 How can and should the use of autonomous vehicles be implemented in the traffic system?

Autonomous vehicles and autonomous driving have the potential to initiate a radical change, because this will not only be at the level of the individual vehicle, but at the level of the entire traffic system and its associated systems such as the law and liability, or urban and settlement structures. At the same time, experience of past discussions about new technologies and their implementation has shown that the question of the usefulness and usability in radically new technologies needs to be "mediated" to potential users. This mediation can occur virtually passively by allowing niches in which the technology is permitted in a public or quasi-public space, such as in the grounds of a public institution. Alternatively broad approval in certain areas, e.g. in particular designated zones in cities of different size, is also conceivable.

Initially considerations about possible experimental areas and implementation phases are paramount. The following questions then arise:

What type of “niche applications” and publicly accessible experimental areas are conceivable? Which requirements (relating to vehicle technology, the law, infrastructure-related, structural) exist for the implementation of such niches and experimental areas?

How can such niche applications and experimental areas facilitate an experience of fully automated vehicles and simultaneously offer an opportunity for making the interaction with fully automated vehicles come alive for road users outside of the vehicles?

How can niche applications and experimental areas be used to obtain important findings for possible implementation of fully automated vehicles in the system as a whole?

There is also a need to examine which costs will be associated with setting up a traffic system used by autonomous road vehicles, not least in view of current discussions about the cost of maintaining infrastructure. This in turn leads to the following research tasks:

Defining a possible (additional) need for infrastructure, including the possible costs;

Estimating the social benefits versus the social costs.

2.4 How will attitudes towards driving and the handling practices of car use change as a result of the introduction of automated vehicles?

It can be seen at present that various groups of the population are changing their car use: young adults use the car less frequently now than a few years ago, older people much more frequently, while city dwellers are likewise tending to reduce car use. The reasons for the changes observed are diverse and should not be further discussed here. Above all it is currently unclear whether the observed developments are just temporary or will have a longer term character. Repeatedly these observations of the actions of people are used to infer a concomitant change to attitudes to car use and to the car. De facto there are no established findings about this yet. Subjects permitting a much better understanding of everyday practice of car use and the possibly changing attitudes to the car are therefore important as a starting point but also as a possible breaking point in the transition to autonomous driving. The corresponding questions are as follows:

Which aspects of attitudes to car driving are subject to a change? How are emotional and status-related motives (the pleasure of driving) changing? How is the attitude towards the functional significance of the car changing?

It may be presumed that people driving automated vehicles move on the roads more safely than self-drivers. This socially desirable situation may turn into social pressure if organisations (e.g.

car manufacturers, insurance companies, public offices) increasingly argue in favour of automated driving. The question arises as to whether, and which attitudes and values the self-drivers and the drivers of automated vehicles develop with regard to their own and to the other group.

Subject 3: What "ethics" are expected from the "car" machine?

In recent discussions about fully automated driving, attention is increasingly paid to the question of whether or how ethical principles can be "implanted" in a machine. This firstly links software-based issues such as the resolution of dilemma situations or necessary infringements to guarantee the traffic flow; it also involves questions that analyse the conceptions held by different social groups regarding the ethics of machines and robots and interpreting these with a view to the expectations and fears resulting from the possible introduction of fully automated vehicles. We also believe the following questions to be particularly important:

Which attitudes exist towards machines/robots?

Which expectations and fears are mentioned regarding the functions and mode of operation of such machines/robots? How does this influence their acceptance?

When are machine errors accepted? Which errors are accepted? What machines may make mistakes, and which may not?

Where do dilemma (and polylemma) situations arise when handling machines? How are these dealt with in discussions on the deployment of machines/robots?

Work on these questions must take place from a cultural and social scientific point of view as well as from a legal perspective.

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Annex 5:

Overview of Terms used in the

Round Table of Automated Driving:

“Specification and Classification of Automated Driving Functions”

Specification and classification of continuous vehicle automation		
Nomenclature	**Description of degree of automation and expectation of the driver**	**Example of system feature**
Driver only	Driver has permanent control (throughout the entire journey) of forward guidance (accelerating/slowing down) and sideways guidance (steering)	No system intervention (driver assistance) in the forward or sideways guidance is active
Assisted	Driver has permanent control either of the sideways or the forward guidance. The other task will, within certain limits, be carried out by the system. • The driver must constantly monitor the system • The driver must constantly be ready to take over the driving completely	Adaptive Cruise Control: • Forward control with adaptive distance and speed control • Parking assistant: • Sideways control using parking assistant (automatic steering into parking spaces. The driver controls the forward guidance).
Partially automated	The system takes over sideways and forward guidance (for a specific period and/or in specific situations). • The driver must constantly monitor the system • The driver must be ready at all times to take over the driving completely	Motorway assistant: • Automatic forward and sideways guidance • Up to a certain maximum speed limit on motorways • Driver must monitor constantly and react immediately if prompted to take over control
Highly automated	The system takes over sideways and forward guidance for a specific period and/or in specific situations. • The driver does not need to monitor the system constantly • Where necessary, the driver is prompted to take over the driving and is given a sufficient time buffer for this • All system limits are detected by the system. The system is not able to bring about the lowest risk state from any situation	Motorway chauffeur: • Automatic forward and sideways guidance • Up to a certain maximum speed limit on motorways • The driver does not need to monitor the system constantly, but must react to a prompt to take over the driving with certain time buffer
Fully automated	The system takes over sideways and forward guidance completely in a defined application. • The driver does not need to monitor the system • Before leaving the application, the system prompts the driver to take over the driving and gives the driver a sufficient time buffer for this • If this does not occur, the system is moved to the minimum risk state • All system limits are detected by the system. The system is able to bring about the lowest risk state from any situation	Motorway pilot: • Automatic forward and sideways guidance • Up to a certain maximum speed limit on motorways • The driver does not need to monitor the system. • If the drives does not react to a prompt to take over the driving, the machine brings the vehicle to a halt on the hard shoulder
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