Needs and Requirements of EDR for Automated Vehicles - Analysis Based on Insurance Claims Reported to Allianz Germany

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Summary

UNECE WP.29 faces significant challenges in formulating UN regulations for the registration, homologation and operation of automated and autonomous vehicles. Out of 13 important safety issues that need to be regulated in detail, one main topic is the recording of accident and event data to clarify accidents involving automated vehicles in mixed traffic. In addition, the basis for the clarification of traffic offences is to be created.

An informal working group IWG EDR/DSSAD[1] is currently working intensively on the definition of an EDR for conventional vehicles (mandatory in the EU from 2022) [Reg (EU), 2019] and an EDR for automated vehicles. As a member of the informal working group, the Allianz Center for Technology contributes the position of Allianz and the perspective of the insurance industry. These contributions are essentially based on the work of the AHEAD[2] working group.

In this paper, on the one hand, the relevance and the need for EDR and DSSAD data based on real-world insurance claims on German motorways are given. On the other hand, this paper examines which data the EDR and the DSSAD should record in the future in order to guarantee an impartial accident investigation within a reasonable time. The findings are based on the evaluation of an accident database including motorway accidents. The database contains insurance claims reported in Germany to Allianz Versicherungs-AG in 2018. The research work was supported by the (Technical) University of Applied Sciences Ingolstadt (THI), the European Association for Accident Research and Analysis (EVU) and the TÜV SÜD.

1. Introduction

The World Forum for Harmonization of Vehicle Regulations, established in 1952, is a working group (WP.29) of the Inland Transport Committee (ITC) of the United Nations Economic Commission for Europe [UNECE, 2020]. Its task is to develop a unique framework concerning motor vehicles. The aim is to initiate and pursue measures for the global harmonization or further development of technical regulations for vehicles. Regulations on vehicle safety, environmental protection and energy consumption are the main focus. The multilateral

[1] Event Data Recorder (EDR); Data Storage System for Automated Driving (DSSAD), for an explanation see Chapter 3

[2] The working group AHEAD (Aggregated Homologation-Proposal for Event-Recorder-Data for Automated Driving) has the goal to design a data collection standard for automated driving.

agreements of 1958, 1997 and 1998 provide the legal framework for the activities of WP.29 and have been signed by numerous states [UNECE, 2020].

Due to the high urgency for globally harmonized regulations on automated and autonomous driving, representatives of WP.29 from China, the EU, Japan and the USA prepared a framework document entitled "Framework document on automated/autonomous vehicles" [ECE/TRANS/WP.29/2019/34 and ECE/TRANS/WP.29/2019/34/Rev.1] in 2019. The following original wording is used in the document to highlight the "safety aspect":

> *"… that for automated vehicles to fulfill their potential to improve road transport, then they must be placed on the market in a way that reassures road users of their safety. If automated vehicles confuse users, disrupt road traffic, or otherwise perform poorly then they will fail. …".*
>
> "*Safety vision: The level of safety to be ensured by automated vehicles is defined as "automated vehicles shall not cause any non-tolerable risk", meaning that automated vehicle systems, under their operational domain (ODD/OD), shall not cause any traffic accidents resulting in injury or death that are reasonably foreseeable and preventable."*

In total, the framework document addresses 13 vehicle safety topics, which form the basis for the development of future UNECE regulations concerning automated and autonomous vehicles:

a. System Safety

b. Failsafe Response

c. Human Machine Interface (HMI)/Operator Information

d. Object Event Detection and Response (OEDR)

e. Operational Design Domain (ODD/OD)

f. Validation for System Safety

g. Cybersecurity

h. Software Updates

i. Event Data Recorder (EDR) and Data Storage System for Automated Driving Vehicles (DSSAD)

j. Vehicle Maintenance and Inspection

k. Consumer Education and Training

l. Crashworthiness and Compatibility

m. Post-crash AV Behaviour

Comparable to these WP.29 safety topics, there are further approaches worldwide and in some cases already detailed publications containing "Guidelines for the development of automated driving functions". Examples include reports from NHTSA and the U.S. Department of Transport [DOT, NHTSA, 2017, 2018, 2020], a report from representatives of the automotive industry [OEMs, Suppliers, 2019] and a publication from the British insurance industry with requirements for a SAE [SAE J3016] Level 3[3] Highway Pilot [Thatcham Research, ABI, 2019].

[3] SAE Level 3: Automated driving function in which the driver must be ready to take over control of the vehicle at all times with notice.

Various national and international research projects such as the BMWI research project Pegasus[4] (2019) or the EU research project L3Pilot[5] (ongoing until 2021) are also dealing with requirements for "automated driving functions". Finally, numerous associations, in Germany including the German Insurance Association [GDV, 2018] or the German Road Safety Council [DVR, 2017] are considering the topic and have formulated recommendations and requirements for a safe design of automated vehicles.

After more than ten years of active participation of Allianz Center for Technology in relevant projects and working groups dealing with "Automated Driving", one thing in particular has become clear: The dimension and complexity of "Automated Driving Functions" has so far been underestimated by the vast majority of those involved in research and literature and especially in the public perception. For example, even a "congestion pilot without lane change" - with comparatively manageable functionality and complexity - is not yet available on the market, although this automated function in accordance with SAE Level 3 was supposed to have been introduced in 2018 [Audi, 2017]. The challenges and hurdles, particularly with regard to test scenarios, protection by tests and simulation, IT security and the definition of the necessary technical regulations that enable approval, homologation and operation, have not yet been overcome.

In order to enable car manufacturers, especially in the regions of China, the EU, Japan and the USA, to bring the first L3/L4 functions "safely" to the market from 2021, WP.29 initiated four informal working groups (IWGs). They are working at full speed on the topics of "functional safety", "new test methods", "cyber security" and "Data Storage System for Automated Driving (DSSAD) and Event Data Recorder (EDR)". Table 1 summarises tasks, activities and timetable in the original English text.

SAE Level 4: Automated driving function is capable to perform all driving functions under certain conditions.

[4] Project for the establishment of generally accepted quality criteria, tools and methods as well as scenarios and situations for the release of highly-automated driving functions [Pegasus].

[5] Piloting of vehicles with conditionally automated (L3) or highly automated driving functions (L4) [L3Pilot]

Table 1: Tasks and activities of the five GRVA working groups [Extract from ECE/TRANS/WP.29/2019/34/Rev.1] - status Jan. 2020

Title and Allocation	Description of work / ECE/TRANS/WP.29/2019/2	Activities and Deliverable Deadlines for WP29
Functional Requirements for automated/ autonomous vehicles GRVA/ ACSF informal group	This work item should cover the functional requirements for the combination of the different functions for driving: longitudinal control (acceleration, braking and road speed), lateral control (lane discipline), environment monitoring (headway, side, rear), minimum risk manoeuvre, transition demand, HMI (internal and external) and driver monitoring. This work item should also cover the requirements for Functional Safety.	ACSF/ALKS Functional requirements for Lane Keeping systems of SAE levels 3/4 (New UN Regulation for contracting parties to the 1958 Agreement) March 2020 Common functional requirements on existing national/regional guidelines and other relevant reference documents (1958 and 1998 Agreements) March 2020
New assessment / Test method GRVA/ VMAD informal group	Multi-pillar concept: Audit, simulation, electronic system compliance, digital identity, test track, real world driving evaluation. This work item should also cover the assessment of Functional Safety.	The test and assessment method, (including CEL) for Lane Keeping systems of SAE levels 3/4 as New UN Regulation for contracting parties to the 1958 Agreement March 2020 Review of the existing and upcoming methods and a proposed way forward for the assessment of AD March 2020 New assessment /Test method of AD March 2021 CEL for AD March 2021
Cyber security and (Over-the-Air) Software updates GRVA Cyber/software update informal group	Work of Task Force on Cyber Security and (OTA) software updates (TF CS/OTA) ongoing. Draft recommendations on the approach (based on draft technical requirements).	Test phase on the draft requirements under 1958 Agreement November 2019 Review of draft set of technical requirements for 1998 CPs November 2019 Review of the report of the test phase on the draft requirements November 2019
Data Storage System for Automated Driving vehicles (DSSAD) GRVA /EDR/DSSAD informal group	DSSAD are for autonomous vehicles (e.g. accident recording). This work item should take into consideration of the discussion at GRVA and its Informal Working Group on Automatically Commended Steering Function (IWG on ACSF). Clear objectives, deadline and the identification of differences with EDR to be determined first before discussion on detailed data information.	Clear objectives, deadline and the identification of differences with EDR November 2019 DSSAD requirements for Lane Keeping systems of SAE levels 3/4 as New UN Regulation for contracting parties to the 1958 Agreement March 2020 Review of the existing national / regional activities and a proposed way forward for DSSAD March 2020
Event Data Recorder (EDR) GRVA/ EDR/DSSAD informal group	Existing systems - as road safety measure (e.g. accident recording).	Clear objectives, deadline and the identification of differences with DSSAD November 2019 Review of the existing national /regional activities and a proposed way forward for EDR March 2020 Technical requirements on EDR November 2020

In addition to the delegates of the parties to the agreement (so-called "Contracting Parties"), non-governmental organizations (NGOs) are also admitted to the informal working groups in order to enrich the working groups with particularly specific expertise.

2. Research questions and approach

This paper describes the contribution to the IWG EDR/DSSAD, which addresses the following three research questions on EDR and DSSAD:

1. What is the need for EDR data for conventional vehicles in case of accidents on motorways (mandatory in EU from 2022)?
2. What is the need for automated vehicles (L3/L4) regarding EDR and DSSAD data in case of accidents on motorways (planned obligation for all AV)?
3. Which EDR and DSSAD system specifications are required to be able to clarify accidents involving automated vehicles as doubtlessly as possible?

In order to answer the three research questions, Chapter 3 first presents the DSSAD and EDR systems.

This is followed by a description of the underlying accident database (Chapter 4), which can be used to answer the research questions in Chapter 5. Finally, the results are discussed, including limitations and recommendations for further action.

3. DSSAD and EDR

The clarification of traffic accidents involving vehicles with SAE Level 3/4 functions requires the recording of certain data immediately before, during and after an accident or event. Experts differentiate between a Data Storage System for Automated Driving (DSSAD) and an Event Data Recorder (EDR, see schematic diagram in Figure 1).

The DSSAD is essentially a "driving mode storage" that records data to clarify responsibility and liability. In addition, the data obtained from the DSSAD after an incident should in future support accident research concerning automated driving in general. The content of the storage includes data used to establish who was actually performing the driving task at a certain time. This does not include further driving data required for the accident investigation. For example, the DSSAD uses flags to record quasi-continuously with time and location stamps whether the automated driving function or the driver is in charge of the driving task. In addition, time and location stamps are added when the driver is requested to take over, when the system is deactivated or taken over by the driver, when minimum risk or emergency manoeuvres are initiated or in the event of system errors. If an accident or traffic violation occurs during the transition sequence or when the system is deactivated, the assessment of the liability issue may depend on various factors. The mandatory storage of the reasons for a transition demand or deactivation, such as bad weather conditions (so-called "unplanned event"), lack of driver attention or overriding of the system, therefore contributes to clarifying who or what was in control of the vehicle at a certain time. In addition, not all questions concerning the storage device will be covered by the UN-ECE technical regulation. European and national legislators will have to regulate, among other things, the precise design of the storage location and detailed questions of access authorization through their own regulations. In Germany, the amendment of the Road Traffic Act (§ 63a StVG) has for the first time in the EU incorporated data processing and data recording in the sense of a Driving Mode Storage (DSSAD) for highly and fully automated vehicles into the legislation. In the future, the German legislator should exercise the enabling provision of Section 63b of the StVG and enact regulations in which the additional requirements for the DSSAD are laid down.

The EDR is an event data memory for accident data from the vehicle, which contains, among other things, information on driving dynamics and occupant safety systems shortly before and after the detected impact or rollover, and on crash intensity. A distinction must be made between **EDR for conventional vehicles (EDR-CV)** and **EDR for automated vehicles (EDR-AV)**. The latter must significantly exceed the performance of common EDR's according to US standard NHTSA 49 CFR 563. Only this will ensure the clarification of traffic accidents involving modern vehicles and provide important data for research. In the EU, the EDR will become mandatory for all new conventional passenger cars from 2022, followed by the obligation for trucks with a gross vehicle weight of more than 3.5 tons in 2026. The EDR in combination with the DSSAD is also mandatory for all vehicles with SAE L3/L4 functions. The automotive industry is aiming for the first AV functions from 2021, probably initially as a traffic jam pilot with ALKS (Automated Lane Keeping System).

The IWG EDR/DSSAD deals with the definition of the technical requirements as a prerequisite for the corresponding UN regulations for both EDR systems (conventional/automated).

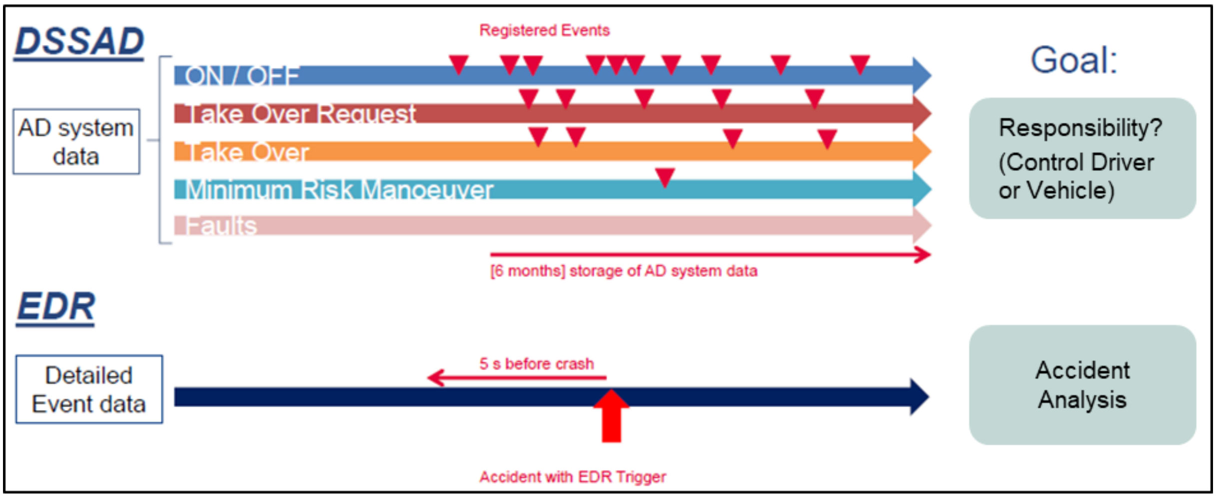


Figure 1: DSSAD versus EDR - schematic [see Kreutner et al., 2019].

In addition, account must be taken of the increasing use of vehicle connectivity. This applies in particular to the support of EDR and DSSAD with an external data memory and for manipulation-proof Over-the-Air (OTA) data transfer. In this way, accident research and periodic technical inspection can be guaranteed. This can be seen in detail in a position paper of the German inspection organizations and the Association of German Technical Inspection Services (VdTÜV) on data storage on neutral servers [VdTÜV].

4. Data basis

The data basis for the analyses to answer the research questions is a comprehensive accident database of the Allianz Center for Technology, which was created as part of a scientific project and contains a total of approximately 15,000 motor insurance claims from the year 2018 (random sample). From this database, a representative sample of a total of 297 accidents on motorways and motorway-like roads was analysed in detail. The database (DB) is subdivided into the three insurance claims lines of third party liability (TPL) claims with personal injury, third party liability claims with only property damage and motor own damage (MoD) collision claims. The development of this database was supported by the Technische Hochschule Ingolstadt (THI) and Audi AG.

5. Results

5.1 Relevant scientific literature

In the current literature there are some studies on the estimation of effectiveness and safety potential of L3/L4 vehicles. A work by [Ostermaier et al., 2019] should be mentioned here. On the basis of Allianz insurance claims and the ADAC accident database, it was determined that automated driving functions could prevent between 5.0% and 6.8% of all passenger car MoD collision claims in 20 years after their market launch, as well as 1.9% of serious accidents for which ADAC Rescue was called. Furthermore, [Liers et al., 2019] in a research work by [VUFO] have determined[6] similar prognosis results on the basis of the [GIDAS] data[7] and, among other things, that the results are strongly dependent on the introduction scenarios of the L3/L4 functions and the actual use of the functions.

In a further research project, based on data from the "Naturalistic Driving Study" in the US, [Schatz et al., 2019] have estimated the availability and applicability of a generic motorway chauffeur. In six selected federal states of the US, this is over 80% of the total distance travelled on the motorway in km. The additional results derived in the same study on the safety potential of the so-called traffic-jam chauffeur on the basis of insurance claims with injuries are just as promising in terms of loss prevention (28% reduction in motorway accidents with personal injury).

There is considerably less published scientific work on the question which technical requirements have to be set for the design of the EDR and the DSSAD. The publications of [Kreutner et al., 2018, 2019], in which an EDR data model for highly automated vehicles is described and accident detection is discussed, should be mentioned. A group of experts defined data elements for crash behavior, driving data, driver activity and the vehicle environment with recording interval, frequency and accuracy as required for accident investigation on highly automated vehicles. In the case of highly automated vehicles, the question will increasingly arise as to whether the system or the driver controlled the vehicle. Here, the stored data from the DSSAD can make a significant contribution to clarifying the question of responsibility.

The work further exemplifies the need for storage and further processing of DSSAD data by an independent third party (the so-called "Data Trust Center Concept") for a transparent and manipulation-proof determination of responsibility in the context of accident events or traffic violations.

As of January 2020, no further published study has been found that deals with the relevance of EDR or with the quantitative evaluation of the technical requirements with regard to sensor technology and the necessary data to be recorded for EDR and DSSAD.

5.2 Relevance of EDR

EDR-relevant accidents within the scope of this article are claims in which the origin and cause of the damage cannot be clearly determined without consulting suitable vehicle data of one or more parties involved. These claims contain incomprehensible and/or missing reliable information on the progression of the accident, especially in the case of accidents with conflicting statements by the parties involved.

[6] The Traffic Accident Research at the TU Dresden GmbH (VUFO) functions as a research institute and development service provider. It records and analyses traffic accidents with personal injuries in the Dresden area and offers software solutions for recording and processing accidents.

[7] German In-Depth Accident Study (GIDAS) is an interdisciplinary project in the field of traffic accident research in which real-world traffic accidents are documented and reconstructed. The data collected serve as a knowledge and data basis for various interest groups.

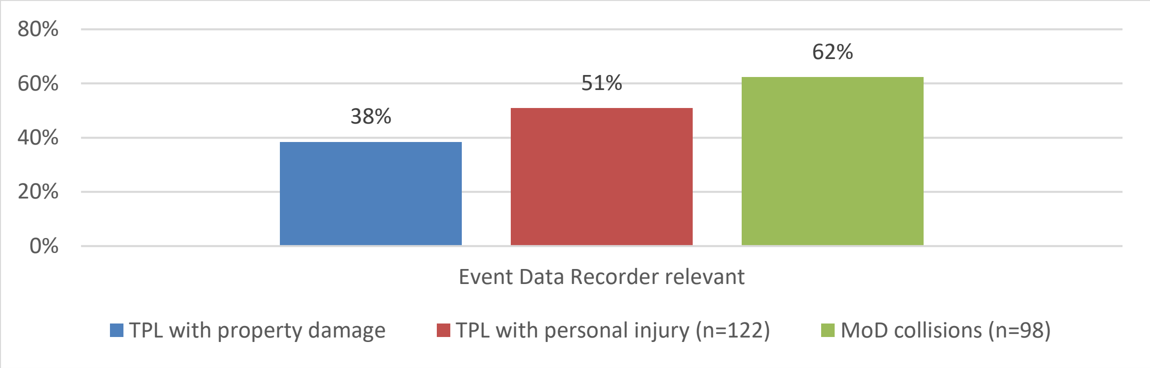


Figure 2: Distribution of EDR-relevant cases [Braxmeier, 2019].

While TPL claims with only property damage, at 38%, have the lowest proportion of EDR-relevant cases, the proportion of EDR-relevant cases in TPL claims with personal injury is 51% and in MoD collisions as high as 62%. With reference to research question number one, on the basis of insurance claims for the ODD "Motorway", there is a considerable need for EDR data for conventional vehicles. For example, accidents in which the vehicle left the carriageway to the right or to the left for reasons that were not obvious occurred particularly frequently in the case of MoD collisions (14% of EDR-relevant claims). In the case of TPL claims with property damage, five claims were registered which were caused by a lateral collision between two vehicles. According to the interviews with witnesses, no cause of the accident could be determined due to different statements. In the case of TPL claims involving personal injury, twelve traffic accidents were due to the inattention of the person causing the accident, but the reason for the inattention could not be determined in any case. The surprisingly high result on the need for EDR underlines the great importance of the introduction of EDR obligation from 2022 for conventional vehicles in the EU.

Research question number two “EDR and DSSAD needs for automated vehicles" cannot be derived directly from real-world accidents of conventional vehicles. Assuming that in each or at least some of these 297 accidents at least one driver had operated his vehicle in the automated driving mode and had legitimately turned away from the driving task, the driver's testimony might be missing in whole or in part. This would further complicate the proper clarification of the specific accident without EDR data. Overall, the proportions of EDR-relevant cases for conventional vehicles therefore form a lower limit for estimating the proportion of EDR-relevant cases for the automated driving function on the motorway. Legal questions of responsibility, liability, preventability, perceptibility or product failure remained unresolved to the detriment of the victims without further traces or evidence.

5.3 Technical requirements of EDR-AV regarding data to be recorded and sensor technology

In order to be able to assess the requirements for EDR-AV with regard to the sensor technology and the data to be recorded, it is necessary to first have a general idea of the future accident occurrence of AV vehicles in mixed traffic.

5.3.1 Accidents involving automated/autonomous vehicles in mixed traffic

The future accident occurrence of AV vehicles with L3/L4 functions on motorways in mixed traffic can be roughly derived by combining the following approaches:

1.) Analysis of current real-world traffic accidents of conventional vehicles as a baseline

2.) Analysis of conflict situations and near-accidents from field tests (FOTs) with L3/L4 vehicles

3.) Simulation of future traffic events and possible scenarios in mixed traffic

4.) Expert assessment, especially with regard to changes in mobility and risk

Within the framework of the current EU research project L3Pilot [L3-Pilot], the main, general and overarching scenarios with potentially positive and potentially negative effects shown in Figures 3 and 4 have so far emerged [Fahrenkrog, 2019]. This rough subdivision of the scenario categories shows how complex real-world accidents can be in reality. Taking the "cut-in conflict situation" in Figure 3 as an example, and allowing possible parameters such as speed, delta-v, acceleration, vehicle type, vehicle width or weather conditions and road characteristics to vary in mind, as well as temporary objects (e.g. mobile road works, speed monitoring, construction site vehicles) and infrastructure objects (e.g. traffic guidance systems, overhead sign gantries), it becomes clear how quickly an almost infinite number of scenario variations can be achieved. In this respect, the Pegasus research project has determined a number of 10^8 scenarios on German motorways in the speed range from 0 to 130 km/h. The simulation of scenarios with extensive parameter variation on the basis of FOTs and real-world accident analyses will therefore – besides test site tests - continuously have to be an essential support in the assessment of the safety of L3/L4 functions.

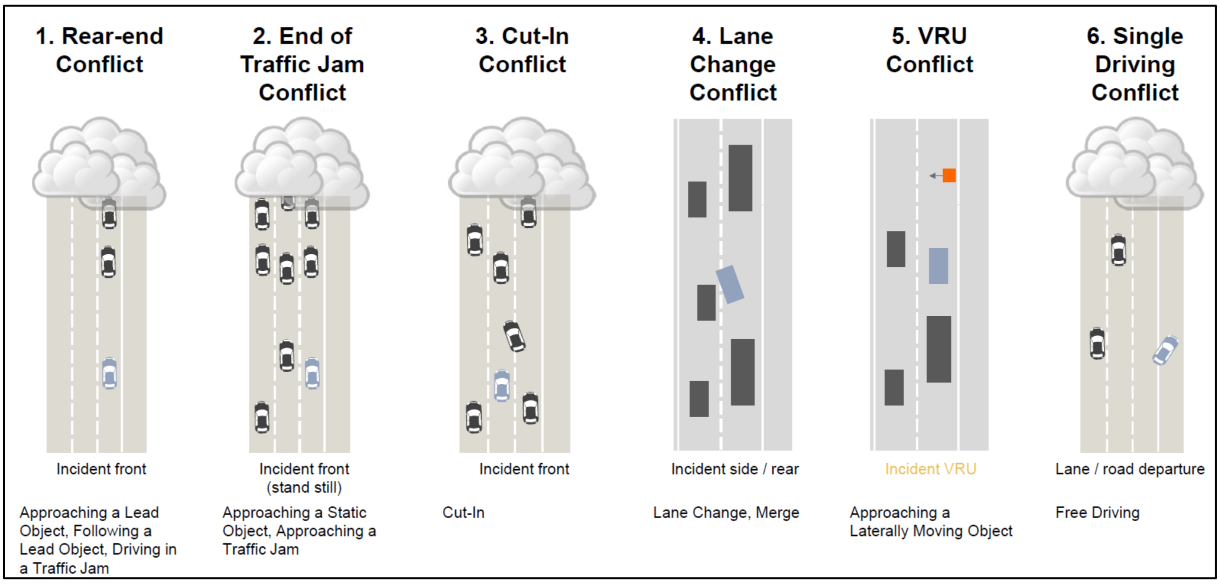


Figure 3: Scenarios with potential positive effects [Fahrenkrog, 2019].

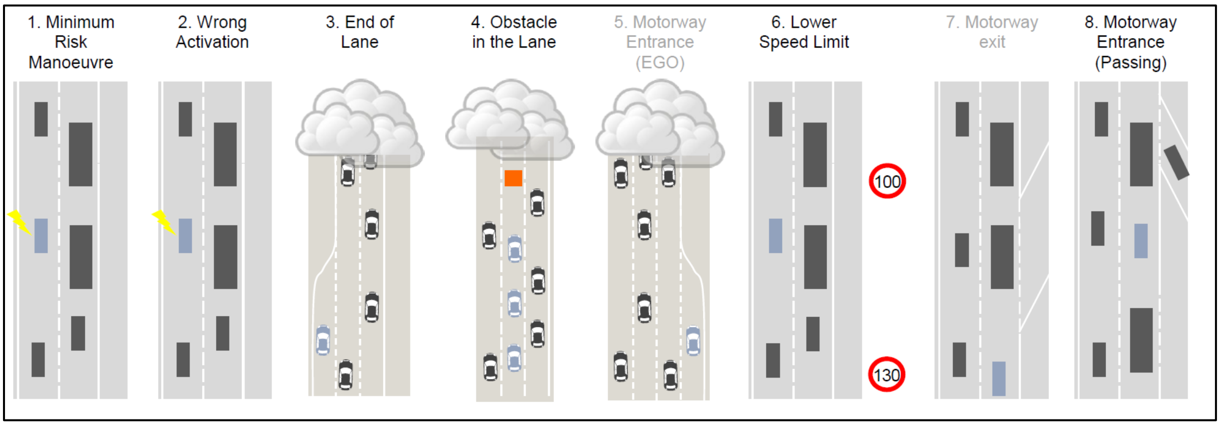


Figure 4: Scenarios with potential negative effects [Fahrenkrog, 2019].

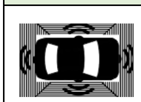
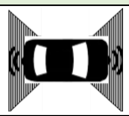
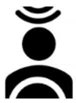
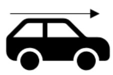
The scenario categories make obvious that only sufficient available EDR-AV data can identify the specific conflict situation in each case, so that the cause and consequences of the accident can be determined with as little doubt as possible. An example of this is an accident with lane change conflict in Figure 3. For clarification purposes, questions such as the directional stability of the conflict partners, turn signals on/off, speed or avoidability must be covered. For accidents of the "Obstacle in the Lane" scenario (Figure 4), on the other hand, questions would have to be answered regarding the detectability of the object by the built-in sensors and the avoidability by braking or steering.

These examples point out that an EDR-AV must cover the detection of a large number of conflict situations, although in individual cases only a subset of the recorded data may be required. Simple rear-end collisions could, where appropriate, be sufficiently well clarified by recording vehicle and crash data such as location, time, speed, delta-v and accelerations, while more complex accident sequences require additional object data and, in particular, environment data and information on driver position and activity. The AHEAD initiative has designed a comprehensive data model at simultaneous data economy to ensure sufficient coverage of accident scenarios, cf. [Kreutner, 2019]

5.3.2 System specifications for EDR-AV

The generic technical requirements for the EDR-AV system specifications were derived from the individual EDR-relevant insurance claims [Braxmeier, 2019]. In order to clarify the extent to which real accidents can be recorded by a particular system specification, a number of generic system specifications were defined and applied in the following. The basic categories (see Table 2) vehicle environment, driver activity, driving data and crash data were considered first. In addition, various types of sensor data were defined for the vehicle environment and driver activity. Subsequently, it was examined which constellations would be able to clarify the different proportions of the analysed motorway accidents.

Table 2: List of icons for data recording [Braxmeier, 2019]

Acquisition of vehicle environment				Acquisition of driver activity		Acquisition of driving data	Acquisition of crash data
Camera 360°	Camera front/rear	Sensor 360°	Sensor front/rear	Camera	Sensor		
							

Based on the AHEAD DATA MODEL [Kreutner et al., 2019], the "top-down method" for an EDR-AV system results in the following specifications:

System specification I (maximum)

- Detection of the vehicle environment in 360° by cameras and other environment detection sensors (e.g. radar, LIDAR)
- Detection of driver activity by camera and other sensors inside the vehicle
- Detection of driving data and crash data

System specification II

- Detection of the vehicle environment by environment detection sensors (360°) and cameras (front/rear only)
- Detection of driver activity by camera and other sensors
- Detection of driving data and crash data

System specification III

- Detection of the vehicle environment by environment detection sensors (360°)
- Detection of driver activity by camera and other sensors
- Detection of driving data and crash data

System specification IV

- Detection of the vehicle environment by environment detection sensors (360°)
- Detection of driver activity by sensors without camera
- Detection of driving data and crash data

System specification V

- Detection of the vehicle environment by environment detection sensors (front/rear only)
- Detection of driver activity by sensors without camera
- Detection of driving data and crash data

System specification VI

- Detection of driver activity by sensors without camera
- Detection of driving data and crash data

System specification VII

- Detection of driving data and crash data

System specification VIII (minimum)

- Detection of driving data

5.3.3 EDR-AV recording time

For automated vehicles, AHEAD recommends data recording from 30 s before to 10 s after the collision. This time proves to be sufficient for the individual EDR-relevant claims of the present claims collective. For example, in some cases, the person causing the accident forced the policyholder to take evasive action by changing lanes, causing the policyholder to leave the road or collide with the vehicle driving in the adjacent lane. In these cases, a recording start of 10 s prior to the collision would have been sufficient in order to capture the cause of the accident visually. In another exemplary claim, the policyholder skidded due to a driving error and then came to a halt on the road without collision. In the temporal sequence of about 5-10 s two following vehicles collided with each other, which were about to avoid a collision by braking and evading. If multi-collisions occur within the 10 s or after that, a sufficient number of memory locations for the individual events needs to be defined. In addition, it should be mentioned that the recording time of 30 seconds before the collision is required in order to assure the record of the entire take-over/transfer process in the EDR-AV if necessary.

5.3.4 Needs analysis for the EDR-AV system specifications

The first objective of the needs analysis is to determine the required EDR-AV system specification for each individual accident in the overall claims collective. A further aim is to determine the proportion of accidents that can be evaluated appropriatly with the respective EDR-AV system specification. It is irrelevant whether the L3/L4 driving function is assumed to be switched on or not during the accident. Rather, it is important to be able to clarify this precisely, along with the cause, origin and consequences of the accident.

Accordingly, for each individual claim it was examined on the basis of the claim file which data an EDR-AV must record in an accident with activated or deactivated L3/L4 driving function in order to be able to guarantee a sufficiently accurate accident clarification of the respective claim. Following examples explain what kind of accidents can be clarified with the respective system specifications.

System specification VIII: in order to be able to completely clarify a sudden vehicle defect, it is necessary to record driving data. Data regarding driving speed and vehicle status can be used to reconstruct, for example, an accident caused by sudden tire damage or a defect in the braking system.

System specification VII: in the seventh system specification of an EDR-AV, crash data can be recorded in addition to the driving data. In this way, some of the accidents due to insufficient safe driving distance (rear/front collisions) or excessive speed can be reconstructed within a more narrow tolerance band with regard to the speed driven. In addition, these data make it possible to check the plausibility of medical diagnostic findings (e.g. cervical spine distortion) of the occupants.

System specification VI: in order to distinguish possible driver misbehaviour from errors of the automated vehicle, information on driver activity related to steering, acceleration, braking or operation of other vehicle equipment is required. This can be used to determine the driver's override of the automated system.

System specification V: in order to be able to clarify accidents of the collision type "rear-end collision" due to unclear cause, evasive manoeuvres due to animals, collision with lost load and sudden braking manoeuvre of the vehicle in front, an additional detection of the vehicle environment (front/rear) is required. This makes object detection by sensors for environment detection necessary. However, if no camera images are used, only the objects known to the software can be stored in object lists. On motorways, it should at least be possible to plausibilise a sudden emergency braking manoeuvre of the vehicle in front (due to traffic or situation).

System specification IV: the extended detection of the vehicle environment (360°) makes it possible to detect multiple collisions with an untraceable course of events. In the case of multiple collisions, it is often difficult to make an exact statement about the main cause. In the accidents evaluated involving three or more participants, the policyholder was accused of causing the accident in five cases. In all claims, however, according to the policyholder’s statement, the policyholders did not run into the vehicle in front, but were pushed onto it by a third party. To enable an accurate reconstruction, in these claims, in addition to acceleration values, 360°-views can also contribute to the clarification of the accident. Furthermore, in the case of a side collision with an unclear cause, an abstract representation of the vehicle side can help to determine the cause of the accident. In each of the 10 relevant claims in the accident database, it was not clear who was responsible for the accident and what triggered the accident.

System specification III: if there is an accident with a vehicle leaving the road due to unclear reasons, a hit-and-run accident or the driver is suddenly physically incapacitated; an interior sensor system is required. When leaving the road without any external influence, microsleep or distraction of the driver by electronic communication devices (mobile phones) are frequent causes. However, a sudden physical limitation due to a medical emergency may also have been present. Especially from the point of view of the victims or their relatives, the reason for leaving the road in these cases is a highly emotional and important issue. Images from an interior camera and an abstract driver model created with it could – in compliance with data protection regulations and privacy rights - clarify these questions.

System specification II: in order to be able to determine the traffic participant responsible for an accident and absconding the visual detection of the license plate is required. This is possible with the second system specification with appropriately resolved camera images.

System specification I: in the first system specification, like in the second specification, all accidents of the present number of claims could be clarified. Thus, there is no additional potential in the present sample if the camera perspective is extended to 360°. An additional clarification potential can be expected in cases with conflicts between vehicles driving side-by-side.

The shares of accidents that can be addressed and analysed with the respective EDR-AV system specification are summarized in Figure 5. All motorway accidents classified as EDR-relevant in the AZT accident database form the basis of the analysis (see chapter 5.2). These are 25 TPL claims with property damage, 61 TPL claims with personal injury and 61 Mod collision claims.

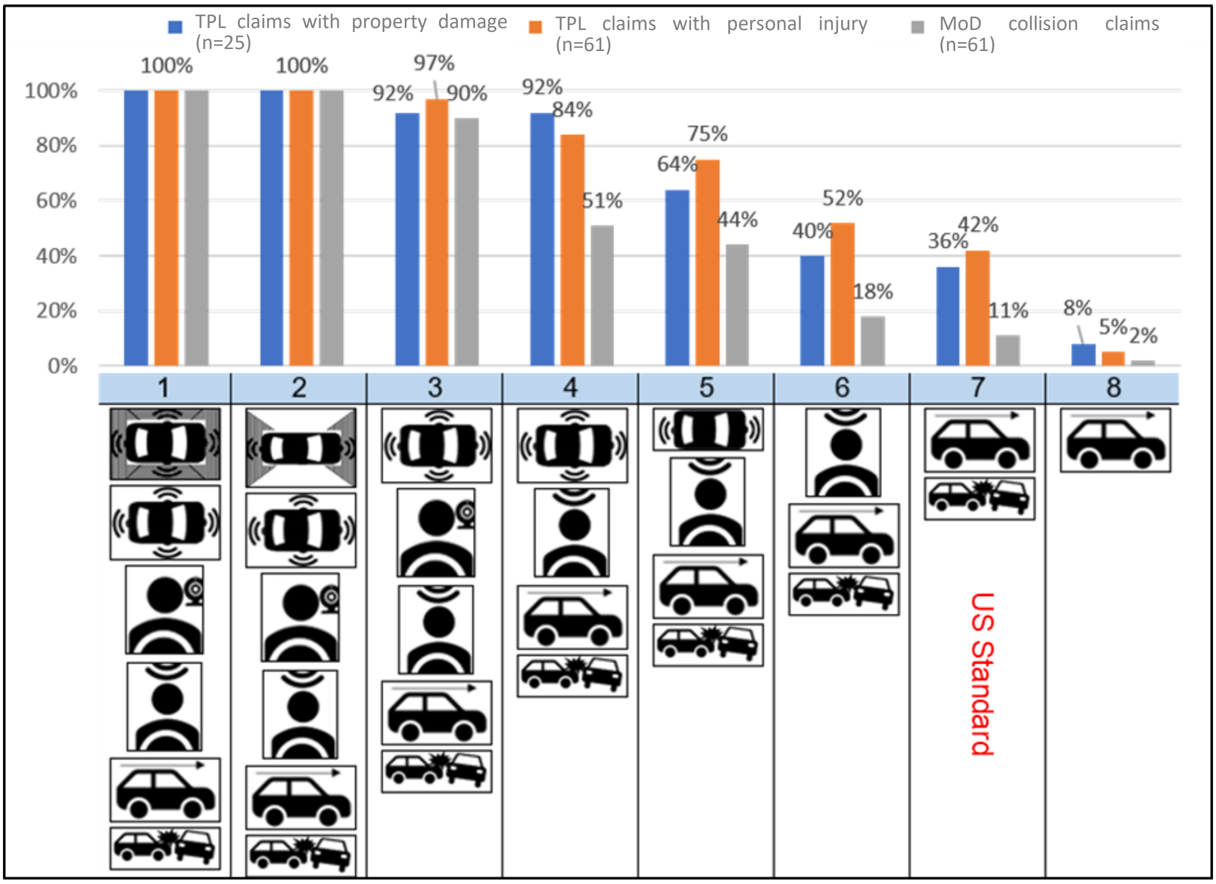


Figure 5: Need for EDR-AV system specifications for EDR-relevant cases, divided into insurance claims lines [%] [Braxmeier, 2019].

With EDR-AV of system specification I or II, all investigated traffic accidents of the data sample could be clarified. The clarification potential in all DB segments is thus 100%.

The exclusion of the camera system for recording the vehicle environment (system specification III) results in a loss of 8 percentage points (n=2) in the TPL claims with property damage DB. In the case of TPL claims with personal injury, this loss is only 3 percentage points (n=2). Within the MoD collision claims, the highest loss of clarification potential can be observed. This amounts to approximately 10 percentage points (n = 6). In all cases, the policyholder was forced to take evasive action due to the lane change of a third party. The perpetrators of the accident left the accident place after the collision (one time crash barrier, one time opponent vehicle).

Due to a further reduction in the scope of the system (driver activity not recorded by camera, system specification IV), the recorded data is not sufficient to be able to clear up a leaving the road due to unclear reason, the hit-and-run of the policyholder or a sudden physical incapacity. A reduction of 8 cases (13 percentage points) was recorded for TPL claims with personal injury. In MoD collision claims, these clusters account for the largest number of traffic accidents, with 24 cases. Accordingly, this is clearly reflected in the loss of clarification potential for the fourth system specification (reduction by 39 percentage points).

In system specification V, the sensor-based detection of the vehicle environment is limited to the areas in front and behind the vehicle. This means that accident clarification is no longer possible in the case of a side collision with an unclear cause and in the case of a multiple collision with an untraceable course of events. In the case of TPL claims with property damage, the potential for clarification is reduced by 28 percentage points (n=7). In the case of TPL claims with personal injury, the loss is approximately 7 percentage points (n=5). Multiple collisions were present in the MoD collision claims and lead to a reduction of seven percentage points (n = 4).

As of system specification VI, the vehicle environment is not recorded. As a result, the clarification of a rear-end collision with unclear cause, an evasive manoeuvre due to animals, a collision with a load or a sudden braking manoeuvre by the person causing the accident is only possible to a limited extent. The potential for MoD collision claims drops sharply by 26 percentage points (n=16) to approx. 18%. In the TPL claims with personal injury (minus 23 percentage points; n=14) and property damage (minus 24 percentage points; n=6), the potential for clarification is also clearly falling.

If, as in the seventh system specification, only driving and crash data are available, the reason for the driver's inattention can no longer be determined. This results in a loss of four percentage points (n=1) in the case of TPL claims with property damage. In the case of TPL claims with personal injury, in six cases the policyholder stated inattention as the cause of the accident, but not the exact reason. This leads to a reduction of the potential for clarification by ten percentage points. In the case of MoD collision claims, the clarification potential of the seventh system specification is approximately 11% (reduction of seven percentage points).

The system specification VIII only records driving data. As a result, only vehicle defects can be validated as plausible. On this assumption, the potential for clarification in the TPL claims with property damage segment will be reduced by 28 percentage points to 8%. There is a significant loss of 37 percentage points (n=23) for TPL claims with personal injury. In the case of MoD collision claims, after a loss of nine percentage points, there is only one case that can be analyzed (approx. 2%).

6. Discussion and conclusions

For the investigated claims of conventional vehicles on motorways, a high need for EDR systems could be identified with regard to the determination of the causes and the course of the accident (EDR relevance 38% to 62%). The introduction of EDR in 2022, which is mandatory throughout the EU, can thus clearly lead to an improvement in accident clarification if the system is suitably designed. This is especially important for accidents with injuries and fatalities. According to the available data, 42% of the relevant motorway accidents involving personal injury could already be resolved with an EDR according to current US standards, and a further significant increase in the clarification rate can be expected with sensors that record the vehicle environment and driver activity.

The significant relevance of EDR for automated vehicles (L3/L4) on motorways underlines the high demand for such a system. EU legislation has appropriately provided for an obligation in this respect - something that nobody in professional circles doubts today. Furthermore, the accident data examined made it possible to approximately determine which EDR-AV system specifications are required to clarify accidents involving automated vehicles (AV on/off) as unambiguously as possible. In this context, legislation should pay particular attention to accidents involving personal injury and aim for the EDR-AV system specification with a correspondingly high clarifying potential. In this way, victim protection and transparency can be guaranteed. Only if accidents involving automated driving can be evaluated beyond doubt and manipulation-proof, the systems will be accepted by society. By using anonymized EDR data in accident research, the systems can be continuously improved and thus the highest possible safety potential - also in terms of Vision Zero - can be expected.

A Car Data Trust Center, to which data is automatically transferred over-the-air and which is operated by a neutral or authority body, also contributes to this. This neutral body supports the periodic technical vehicle inspection in the context of the digital verification of safety- and security-relevant functionalities in the vehicle ("PTI of the future") and also enables the determination of weakness in software and systems using anonymised data.

The results presented here regarding the EDR relevance and the required EDR system specifications for L3/L4 vehicles are naturally subject to certain restrictions with regard to general statements. These are in particular the limited number of 297 investigated claims on motorways and the restriction to German insurance claims. Furthermore, no modelling of changes in future traffic flow, mobility behaviour or a modal split on motorways by L3/L4 vehicles was considered.

In order to continuously evaluate the research results on EDR-AV obtained in this analysis as well as further accident research results concerning the safety potential of L3/L4 functions, and thus to improve road safety, an increase in the number of cases to be analysed, an increasing standardisation of databases and a continuous performance of Naturalistic Driving Studies, especially in Europe, is urgently required. Only then the safety aspects mentioned at the beginning of Chapter 1 can be achieved, which are written down in the "Framework document on automated/autonomous vehicles" [ECE/TRANS/WP.29/2019/34 and ECE/TRANS/WP.29/2019/34/Rev.1].

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