Challenges in forensic reconstruction of traffic accidents involving Advanced Driver Assistance Systems (ADAS)

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Abstract
The rapid technological advancements towards automated and connected vehicles are not only changing mobility to a considerable extent. But also, the reconstruction of traffic accidents will noticeably change in its complexity due to the pre-collisional influence of Advanced Driver Assistance Systems (ADAS). A variety of different functions warn and inform the driver, intervene autonomously and temporarily in the vehicle’s driving dynamics or take over entire long-term dynamic driving tasks. With the help of a survey, in which 173 international experts in accident analysis participated, the challenges for traffic accident reconstruction associated with the technological changes were identified. The results of the survey demonstrate that a significant number of traffic accidents involving ADAS cannot be reconstructed doubtless. One of the main reasons is a lack of available technical information that can be gathered independently from the manufacturer. Especially technical information of the pre-collisional influence of ADAS on the behavior of the vehicle’s driving dynamics and on the behavior of the driver are often missing. In order to meet these facts, it is necessary to store the ADAS related crash data in an Event Data Recorder (EDR) that is accessible for traffic accident analysts independently from the vehicle manufacturer. The ultimate goal would be an EDR that meets all the needs from an accident analyst’s point of view – a Forensic Event Data Recorder (FEDR).

Zusammenfassung

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Introduction

Since September 2012, NHTSA CFR 49 Part 563 specifies uniform requirements for light-duty vehicles equipped with Event Data Recorders (EDRs) concerning the collection, storage, and retrievability of onboard light-duty vehicle crash event data in the USA [1]. The EDR is intended to record, in a readily usable manner, valuable traffic accident vehicle data for effective crash investigations and analysis of safety equipment performance (e.g., advanced restraint systems) in the event of a collision [1]. The required event-based storage of punctual data elements in a narrow time window can be found in table 1 and table 2 of the regulation CFR 49 Part 563. This EDR is meanwhile also installed in several European vehicles, which is partially unlocked and is based on the regulation CFR 49 Part 563. Actually, UNECE is working on a worldwide EDR regulation. In Europe, the EDR will become mandatory from 2022 for new types of motor vehicles of the categories M1 and N1 [2]. Today (July 2020), it seems that the UNECE regulation will be very similar to the US regulation CFR 49 Part 563. This means that in the EDR hardly any data on the pre-collisional influence of ADAS on driver behavior and vehicle behavior will be stored in the event of a collision. Furthermore, in general data storage is only activated if any non-reversible occupant restraint system is activated, a VRU secondary safety protection system is activated, or a change in longitudinal or lateral vehicle velocity that equals or exceeds 8 km/h within a 150 ms or less interval is met or exceeded. Consequently, for many kind of collisions (e.g. side-swipes, collisions with VRUs and wild animals), there are often no data available in the EDR due to insufficient trigger criteria for data storage [3]. The need to improve the EDR, especially with regard to ADAS, has already been discussed in numerous publications [4–7]. Consequently, accident analysts face the problem that resilient digital traces of ADAS are generally only available with the support of the respective vehicle manufacturer. This means that accident analysts are usually dependent on the manufacturer’s willingness to cooperate, despite the fact that the manufacturer is in most cases also a party with a vested interest.

Next to a worldwide EDR regulation, UNECE is also working on a worldwide Data Storage System for Automated Driving (DSSAD) regulation. Each vehicle equipped with an automated driving function (SAE Level >= 3) shall be fitted with a DSSAD. The DSSAD is essentially a “driving mode storage” that continuously records with time and location stamps whether an automated driving function or the driver is performing the driving task in order to clarify the responsibility of the vehicle control and consequently liability issues. In addition, there are time and location stamps when the driver is requested to take over the vehicle control, when the system is deactivated respectively overruled by the driver, when minimum risk or emergency maneuvers are initiated or in case of system errors [7]. Further driving data as well as data from ADAS required for the accident investigation are not part of DSSAD.

The main functionality of the DSSAD is therefore the clarification of the driver’s responsibility at a certain point in time in standard cases, such as speeding or simple traffic accidents. However, the data elements defined therein are not sufficient to clarify the causes of many accidents and the corresponding liability issues. For example, if the system requests the driver to take over the driving task, taking into account defined handover times, in the event of a dangerous driving scenario, the DSSAD only records the request and possibly a system-defined take-over of the driving task by the driver. Consequently, the decisive factor is whether the driver has really taken over the driving control in a controlled manner and was even capable of doing so. Such complex take-over scenarios and resulting accidents can only be solved with the support of an EDR, since the DSSAD is not specified for the detection of accidents.

According to SAE J3016, ADAS are SAE level 0, 1, and 2 features and the driver must constantly supervise these features to maintain safety [8]. As a result, the driver is always responsible for the vehicle control, even when a feature is activated. ADAS consists of a wide range of comfort systems like Adaptive Cruise Control (ACC) and Traffic Jam Assist (TJA) as well as active safety systems such as Autonomous Emergency Braking (AEB), Lane Keeping Assistance (LKA) and Automatic Evasive Steering (AES). All these features sense and monitor conditions inside and outside the vehicle for the purpose of identifying for example weather conditions, road conditions or present and potential dangers to the vehicle, occupants, and/or other road users. Based on the environmental perception, ADAS take over entire long-term dynamic driving tasks or automatically intervene to
help avoid or mitigate potential collisions via various methods, including alerts to the driver, vehicle system adjustments, and/or temporary active control of the vehicle motion [9]. Several ADAS like AEB and LKA become mandatory for light-duty and heavy-duty vehicles in European vehicles by 2022 [10].

The automation of vehicles is regarded to be an essential part for increasing road safety thus the final failure in the causal chain of events in 90% of crashes in Europe is driver error [10]. However, a study published in June 2020 by the Insurance Institute for Highway Safety (IIHS) assumes that an automated vehicle could have prevented at most only every third traffic accident [11]. The main challenges for such vehicles for example are misjudgments, incorrect evasive maneuvers, or mistakes made by other automated cars. Assuming that automated vehicles participate in mixed traffic, it is likely that even fewer traffic accidents can be avoided. The reason is an individual and highly divergent behavior of especially of pedestrians, cyclists, and e-scooter drivers as well as of driver of conventional vehicles [12]. Furthermore, according to a report by the German Federal Highway Research Institute (BASf), it can be assumed that new traffic accidents will be caused by automatization risks [13]. The reasons for this can be mistakes or gaps in the implementation of requirements for safety of the intended functionality (ISO 21448), functional safety (ISO 26262), and cyber security (ISO 21434 or SAE J3061). Exemplary situations are an emergency stop performed autonomously by the vehicle because a person on a poster next to the roadway was interpreted as an intersecting pedestrian or there is no braking at all because objects in the trajectory of the vehicle were not detected.

Looking at the stated facts, there will be numerous traffic accidents in the future, despite and because of vehicle automatization. Once it is suspected that an ADAS has had a pre-collisional influence on the driver's behavior and the behavior of the vehicle's driving dynamics, these traffic accidents must be clarified completely and beyond doubt. For this purpose, a technical basis for assessment is required. This information shall enable the investigation of the reasons why an ADAS did not prevent the traffic accident, as well as whether an ADAS was the cause of the accident, in that the dynamic behavior of the vehicle was no longer sufficiently controllable by the driver to avert the collision.

All in all, the question arises to what extent traffic accident analysts have the possibility of clarifying pre-collisional influences of ADAS beyond doubt despite the challenges described? To answer this question, a quantitative online survey was conducted among accident analysts of the European Association for Accident Research and Accident Analysis (EVU). As the vehicle manufacturer is generally a party with a vested interest, the restriction that the vehicle manufacturer cannot be involved in the reconstruction of a traffic accident was made in the introductory part of the questionnaire.

Study

The EVU is an association of experts in traffic accident reconstruction and accident research that operates beyond European borders [14]. The survey of the EVU members was based on the existing diverse knowledge of the individual members in the field of traffic accident reconstruction. According to Figure 1, in total 173 traffic accident analysts from 30 countries took part in the study.

At the time of the survey (June 2020), 69% (n = 119) of the survey participants stated that they had professional experience of more than 15 years as an accident analyst. 14% (n = 25) of the interviewed persons stated to have between 11 and 15 years of professional experience. 13% (n = 22) of the survey participants have between 6 and 10 years of professional experience and 4% (n = 7) of the accident analysts stated that they have between 0 and 5 years of professional experience. Most respondents (38%) stated that they create on average more than 50 forensic traffic accident reports annually. According to their own statements, 29% of the survey participants produce on average 31 - 50 forensic traffic accident reports per year. 24% of the accident analysts stated that they create between 11 - 30 forensic traffic accident reports on average per year. The remaining 9% stated to create 0 - 10 forensic traffic accident reports per year.

These numbers illustrate that it can be assumed that the results of the survey are representative due to the very high level of expertise of the
survey participants in the field of traffic accident analysis.

![Figure 1: Number of survey participants by nations](image1)

**Figure 1: Number of survey participants by nations**

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<tr>
<th>Country</th>
<th>Participants</th>
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<td>Germany</td>
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<td>Poland</td>
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<td>Bosnia and Herzegovina</td>
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<td>China</td>
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**Cause of the collision**

One of the focal points of the survey is to answer the question whether the existing technical assessment bases allow to clarify beyond doubt whether a pre-collisional intervention by an ADAS led to a vehicle behavior that the driver was unable to control and in consequence the corresponding ADAS was the cause of the accident. The basis for answering this question is the knowledge of whether a corresponding ADAS was activated at the time of the collision. Consequently, the survey participants were asked to state whether the currently available technical bases of assessment enable a doubtless clarification of this issue.

More than three quarters of the respondents (76%) stated that the currently available technical assessment basis does not or only partially enable them to clarify whether an ADAS was activated at the time of the collision beyond doubt. The remaining survey participants indicated that they are able to clarify whether an ADAS was activated at the time of the collision beyond doubt. In summary Figure 2 illustrates that the majority of the survey participants is currently unable to clarify whether an ADAS was activated at the time of the collision beyond doubt.

Technical deficiencies of the vehicle are the cause of 6 percent of traffic accidents [15]. In the context of accident analysis, in particular brakes, steering, chassis/axle suspensions and tires are currently being investigated [16]. Within the scope of the survey, the participants were asked to state whether they are able to clarify doubtless with the currently available technical assessment bases that a technical deficiency of an ADAS could have caused the accident.
Figure 3: Number of survey participants for whom it is not applicable at all, rather not applicable, partly applicable, tends to be more applicable, or is fully applicable that they can clarify beyond doubt whether an ADAS had an accident causal technical deficiency at the time of the collision.

The analysis of the answers indicates in Figure 3 a clear trend that with the currently available technical assessment bases accident causal technical deficiencies of ADAS can only be identified to a very limited extent. These results also allow the assumption that a higher number of undetected accidental technical deficiencies of ADAS can be assumed compared to the official statistics. From the road safety point of view, it is thus indispensable that accident analysts must be enabled in the near future to verify accident-causing technical deficiencies of ADAS. In this way a solid data basis can be created. This offers the opportunity to develop a scientific potential estimation for the reduction of traffic accidents by ADAS.

Figure 4: Number of survey participants who totally agree, rather agree, partly agree, don’t agree rather, or don’t agree at all that accident prevention measures must be defined by checking the correct functionality of ADAS within the framework of the PTI.

That the evidence of ADAS malfunctions will increasingly lead to product liability or producer liability cases against vehicle manufacturers was totally agreed by 34% (n = 35) of the respondents. 41% (n = 42) of the survey participants agree rather with this statement and 18% (n = 19) agree in part. Only 7% (n = 7) do not agree rather or do not agree at all.

According to Figure 4, the majority of the survey participants agree that accident prevention measures must be defined by checking the correct functionality of ADAS within the framework of the PTI.

Figure 5: Number of survey participants for whom it is not applicable at all, rather not applicable, partly applicable, tends to be more applicable, or is fully applicable that they can clarify beyond doubt whether an ADAS has shown an environmental disturbance due to external influences at the time of the collision.

In addition to technical deficiencies, weather conditions (e.g. heavy rain, fog) or the condition of the road (e.g. missing road markings) can also have a decisive influence on the behavior of an ADAS. In the event of a collision, this allows the question to be asked whether an ADAS could have been the cause of an accident due to an environmental disturbance. However, according to Figure 5, the majority of accident analysts are not able to clarify beyond doubt with the existing technical bases of assessment whether an ADAS has shown an environmental disturbance due to external influences.

All in all, the results of the survey demonstrate that accident analysts are not able to clarify beyond doubt, with the existing technical bases for assessment and without the support of the vehicle manufacturer, whether a pre-collisional intervention by an ADAS led to a vehicle behavior that the driver was unable to control, and con-
sequently the ADAS in question was the cause of the accident.

Avoidability of the collision

A further focus of the survey is to answer the question whether the existing technical assessment bases can be used to determine beyond doubt whether the traffic accident could have been avoided by an ADAS itself as well as by the driver-ADAS interaction. As described in the introduction, there are two types of ADAS – the active safety systems and the comfort systems.

Active safety systems

Active safety systems permanently detect the vehicle environment and warn the driver acoustically, visually or haptically about the occurrence of a dangerous driving situation. Warning systems are for example Forward Collision Warning (FCW), Lane Departure Warning (LDW), and Blind Spot Detection (BSD) [9]. In the event of a collision, the question arises why the driver was unable to avoid the collision despite a warning. Was the warning delayed or was there no warning at all? Did the driver not notice the warning or possibly even ignore it?

In the survey, 81% (n = 83) of the participants stated that the existing technical assessment bases are not or only partially sufficient to clarify beyond doubt whether an ADAS had warned the driver about the occurrence of a dangerous driving situation. For 19% (n = 19) of the accident analysts it is possible, according to their statements, to clarify these facts beyond doubt with the currently available technical information.

As part of the avoidability assessment, it must also be clarified whether the driver may have been mistakenly not warned about an existing dangerous driving situation? In addition to these so-called false negatives, false positives must also be taken into consideration in the analysis of traffic accidents. In this case, the driver would have been wrongly warned about a non-existent dangerous driving situation. The basis for unambiguous clarification of these complex constellations is the knowledge of whether the respective ADAS has detected a hazard in the vehicle environment. However, 81% (n = 83) of the accident analysts stated that they could not or could only partially clarify with the currently available technical assessment bases whether an ADAS had detected the occurrence of a dangerous driving situation. For the remaining 19% (n = 20) of respondents, it is rather possible to prove this fact technically. Consequently, the majority of accident analysts are unable to clarify beyond doubt with the currently available technical assessment bases whether, why and when the driver was warned, nor how the driver perceived the warning and reacted to it.

In addition, the survey participants were asked if they agree that the warning of the driver by an ADAS about the occurrence of a dangerous driving situation significantly influences the estimated delay time of the driver. 86% (n = 89) of the accident analysts agree that the warning of the driver about the occurrence of a dangerous driving situation, which is issued by an ADAS, has an influence on the delay time of the driver to be taken into account in the traffic accident reconstruction. 14% (n = 17) of the survey participants do not share this view.

From the authors’ point of view, warning systems particularly shorten the time the driver needs to look at the hazard, since an acoustic, visual or haptic warning triggers the driver’s perception of a potentially dangerous driving situation.

In addition to the warning systems, there are other active safety systems, the so-called intervention systems. Examples are AEB, LKA, and AES. Depending on the respective dangerous driving situation, these systems also warn the driver first. In the absence of any braking or steering response from the driver, these systems intervene autonomously and temporarily in the longitudinal and/or lateral dynamics of the vehicle to avoid a potential collision or to minimize the severity of a collision [9]. The systems are also capable of amplifying a braking or steering torque generated by the driver.

If a collision nevertheless occurs, the question arises why ADAS did not avoid the collision either spatially or temporally. As described in the introduction, the driver is always responsible for the vehicle control. This means that the driver can override and consequently deactivate the system at any time. Thus, in principle, this is also possible when an ADAS has already initiated an intervention in the vehicle’s driving dynamics. In this case the driver would consequently compensate the system effect consciously or unconsciously. For witnesses outside the vehicle
involved in the collision, this ADAS driver interaction is usually not recognizable.

According to Figure 6, 74% (n = 74) of the accident analysts stated to have no possibility with the currently available technical assessment bases to identify whether an intervention system was activated or deactivated in the pre-crash phase and in-crash phase. 17% (n = 17) of the survey participants stated to be partially able to clarify this issue. Only 9% (n = 9) of the accident analysts feel able to clarify whether an ADAS was overridden by the driver and thus the system effect was compensated.

In order to prevent the driver from unconsciously overriding or deactivating the intervention system, he or she is usually kept continuously informed of ADAS activities. Whether the driver was actually informed by an ADAS about the impending and performed intervention in the longitudinal and/or lateral motion control of the vehicle, however, cannot be clarified beyond doubt for the majority of accident analysts according to Figure 7.

In addition, for the avoidability assessment in the context of traffic accident reconstruction, it is necessary to clarify whether a braking, acceleration or steering maneuver was initiated by the driver or an intervention system. As a rule, statements from witnesses outside the vehicle involved in the collision cannot be taken into account to clarify the described circumstances, as it is not possible for these witnesses to differentiate whether a system or the driver was responsible for the vehicle behavior. As part of the survey, the participants were asked whether they could use the existing technical assessment bases to clarify beyond doubt whether an intervention system has intervened in the longitudinal and/or lateral control of the vehicle. Here 64% (n = 66) of the survey participants stated that they were not able to clarify this issue beyond any doubt. 15% (n = 15) of the accident analysts can, according to their statements, partially clarify whether an ADAS has intervened in the longitudinal and/or lateral control of the vehicle. The remaining 21% (n = 22) of the participants stated that they were able to clarify this issue beyond any doubt.

**Comfort systems**

Comfort systems take over long-term entire dynamic driving tasks in order to relieve the driver of his driving task. Examples are ACC, LKA or the Tesla autopilot. Especially in the case of comfort systems, the driver must continuously confirm his presence. If the driver does not comply with this request, the vehicle requests the driver to take over the vehicle control and the respective activated feature usually shuts...
down completely after a pre-warning. For 79% (n = 77) of the accident analysts, it is not possible with the available technical assessment bases to clarify beyond doubt whether this driver-ADAS interaction took place in the pre-crash phase. 13% (n = 13) of the survey participants stated that they could partly clarify this issue. Only 8% (n = 8) of the accident analysts see a possibility to clarify with certainty whether a comfort system has requested the driver to confirm his presence or to take over the driving control of the vehicle before the collision.

Furthermore, comfort systems will have a significant impact on the estimated delay time of the driver within the framework of traffic accident reconstruction. Because according to Figure 8, 80% (n = 82) of the survey participants fully or rather agree that the increasing long-term takeover of complete dynamic driving tasks by comfort systems is associated with an increasing neglect to observe the vehicle environment by the driver, which leads to extended delay times of the driver when a dangerous driving situation occurs.

Similar to active safety systems, the driver is always responsible for driving his vehicle even if a comfort system is activated. Since the driver must be able to control the vehicle at all times, in particular the comfort systems are designed in such a way that they can be overridden and thus deactivated by the driver at any time [17]. With regard to the complete clarification of the temporal and spatial avoidability of a collision, this implies that, identical to the active safety systems, it must be considered in the future whether the driver or a comfort system has controlled the longitudinal or lateral motion of the vehicle in the pre-collisional phase.

**Kind of collisions**

In Germany, the Federal Statistical Office publishes annually a traffic accident report [18]. It distinguishes 10 kind of collisions. The kind of accident describes of the entire course of events in an accident the direction into which the vehicles involved were heading when they first collided on the carriageway or, if there was no collision, the first mechanical impact on a vehicle. The following kind of accidents have been defined for the survey based on [18]:

1. Collision between vehicle and pedestrian
2. Collision between vehicle and cyclist
3. Collision between vehicle and e-scooter driver
4. Collision with another vehicle which turns into or crosses a road
5. Collision with another oncoming vehicle - with full overlap
6. Collision with another oncoming vehicle - with small overlap
7. Leaving the carriageway
8. Collision with another vehicle moving laterally in the same direction (accidents occurring when driving side by side (side-swipe)) or when changing lanes (cutting in)
9. Collision with another vehicle moving ahead or waiting
10. Collision between vehicle and wild animals
Within the scope of the survey, the participants were asked to select three kinds of collision which, in their view, can often only be clarified with a high degree of tolerance. The fact that no general statement can be made on whether a kind of collision can be clarified very precisely or only with a high degree of tolerance is illustrated in Figure 9. Because the statements of the accident analysts show that every collision is unique in its sequence and its reconstruction can become very complex even in supposedly simple constellations. The reasons for this are manifold. Often the challenges are a poor evidence (e.g. no skid marks) at the accident scene, non-existent witness statements, and minor damage to the vehicle. Furthermore, the experience of the authors shows that, especially the pre-collisional behavior of wild animals, pedestrians, cyclists and e-scooter drivers is often unknown and also highly divergent.

Considering the above-mentioned additional challenges in the investigation of pre-collisional influences of ADAS, it can be assumed that in the future, without the necessary technical basis for evaluation, not all traffic accidents can be fully and unequivocally investigated.

**Conclusion**

The results of the survey illustrate that in general pre-collisional influences of ADAS on the behavior of the driver and the behavior of the vehicle’s driving dynamics cannot be fully clarified beyond doubt with the existing classical investigation methods. For example, 86% (n = 81) of the accident analysts stated that they could not determine the intensity of the braking or steering behavior of an ADAS. Further 88% (n = 77) of the respondents stated that they are not able to determine whether the driver was in full control of the vehicle or whether an ADAS has controlled the longitudinal and/or lateral motion of the vehicle. It is also astonishing that 95% (n = 81) of the survey participants stated that they could not clarify beyond doubt whether an erroneous intervention by an ADAS has led to a dynamic behavior of the vehicle that the driver was unable to control. Moreover, the survey clearly demonstrates that the driver-ADAS-interaction is hardly possible to reconstruct with the available technical information.

According to the statement of 96% (n = 110) of the accident analysts, the main issue in the reconstruction of the pre-collisional traffic accident
sequence is the lack of access to vehicle data on the pre-collisional behavior of ADAS and the interaction of the driver with ADAS. Therefore, digital vehicle crash data are required in addition to the traditional acquisition of traffic accident data as well as traffic accident reconstruction. Consequently, a legally required EDR is needed which, in the event of a collision, stores all the data elements required to clarify ADAS’ pre-collisional influences. In addition to these data elements, the EDR also requires improved triggers for data storage in the event of a collision, so that crash data is available for all kind of collisions. Furthermore, 89% (n = 100) of the accident analysts stated that pictures/videos of the vehicle system cameras would simplify the reconstruction of the behavior of people involved in the accident significantly. The ultimate goal would be an EDR that meets all the needs from an accident analyst’s point of view—a Forensic Event Data Recorder (FEDR).

It should be noted that the correct interpretation of the EDR data together with an appropriate error estimation and plausibility check is not trivial and requires specially trained experts. Thus, there is an urgent need of advanced training, especially regarding the predicted explosion of EDR capable vehicles on the European market. Also, the embedding of the findings derived from the EDR data into the classical accident analysis as well as into common virtual simulation tools has not yet been fully developed from a scientific point of view. In this context, attention should also be paid to an improved, physically correct mapping of sensor systems (e.g. system cameras, lidar, radar).

In addition to accident analysis topics, the survey also revealed that the majority of survey participants see an urgent need to check the functionality of ADAS within the framework of the PTI. In this way, accident-causing technical deficiencies of ADAS can be reduced preventively and thus road safety can be increased.

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Conflicts of interest

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

References


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Appendix

Within this chapter the full instructions and questions that the survey participants got are shown. The online questionnaire was published in “SoSci Survey”. All relevant survey participants received the participation link via e-mail from the EVU board. Before the survey link was distributed, the duration, content, understanding and ethics of the survey was verified and validated in several loops by several different people.

Dear colleagues,

the rapid technological advancements towards automated and connected vehicles are not only changing mobility to a considerable extent. But also the reconstruction of traffic accidents will noticeably change in its complexity due to the pre-collisional influence of Advanced Driver Assistance Systems (ADAS).

In cooperation with DEKRA Automobil GmbH and the University of Žilina, Technische Hochschule Ingolstadt is researching innovative methods to face these developments.

By participating in this expert survey, you help us to identify the challenges in our daily work as accident analysts so that we can develop appropriate solutions and keep pace with the technological changes.

The survey will take about 10 – 15 minutes of your time.

Please answer as many questions as possible and do not interrupt the survey prematurely. To answer the questions, you usually only have to select predefined answer categories.

If you have to interrupt your participation for a short time, you can save it and continue later at the appropriate point.

Your data will be collected anonymously, evaluated according to data protection guidelines and used exclusively for scientific purposes. Your data will not be passed on to third parties. No questions will be asked about personal details that would allow conclusions to be drawn about individual persons.

Thank you very much for your cooperation.

Sincerely,

M. Eng. Daniel Paula
Dipl.-Ing. (FH) Klaus Böhm

Research assistants in the field of accident analysis at the CARISSMA research centre of Technische Hochschule Ingolstadt.
In which country do you work as an accident analyst?
Please make your note in the text field.

How many years have you been working as an accident analyst?
Please select one option.
- 0 – 5 years
- 6 – 10 years
- 11 – 15 years
- > 15 years

How many forensic traffic accident reports do you prepare on average per year?
Please select one option.
- 0 – 10 reports
- 11 – 30 reports
- 31 – 50 reports
- > 50 reports

Please estimate the percentage of your forensic traffic accident reports, where you did extract data from an Event Data Recorder (EDR) in the last two years?
Please select one option.
- 0 %
- 1 – 5 %
- 6 – 10 %
- 11 – 15 %
- 16 – 20 %
- > 20 %

What is your current employment status as an accident analyst?
Please select one option.
- Self-employed
- Employed (e.g. in an engineering office)
- Officer / Civil servant
- Other

As an accident analyst, you have to reconstruct the course of a traffic accident. In this context, the vehicle involved in the accident is equipped with several modern Advanced Driver Assistance Systems (ADAS).

While creating the forensic accident report, you must clarify in a forensic manner which pre-collisional interactions took place between the driver and the ADAS. Furthermore, there is a suspicion that an ADAS was the cause of an accident due to an intervention in the longitudinal and/or lateral motion control of the vehicle.

Examples of ADAS are:
- Advanced Emergency Braking (AEB)
- Advanced Emergency Steering (AES)
- Adaptive Cruise Control (ACC)
- Lane Keeping Assist (LKA)

Note: The vehicle manufacturer should not be involved in the reconstruction of the traffic accident, as he is a party with a vested interest.
Challenges in forensic reconstruction of traffic accidents involving Advanced Driver Assistance Systems (ADAS)

With the methods and tools available to you and without the support of the vehicle manufacturer, can you clarify legally secure whether an Advanced Driver Assistance System...

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<thead>
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<th>... was activated at the time of the accident?</th>
<th>not applicable at all</th>
<th>rather not applicable</th>
<th>partly applicable</th>
<th>tends to be applicable</th>
<th>fully applicable</th>
<th>don't know / no statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>... had a technical defect at the time of the accident?</td>
<td></td>
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</tr>
<tr>
<td>... had an environment-related malfunction (e.g. due to heavy rain, fog) at the time of the accident?</td>
<td></td>
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</tr>
<tr>
<td>... has detected the occurrence of a dangerous driving situation?</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>... has warned the driver about the occurrence of a dangerous driving situation?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>... has intervened in the longitudinal and/or lateral motion control of the vehicle when a dangerous driving situation occurred?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>... has erroneously intervened in the longitudinal and/or lateral motion control of the vehicle?</td>
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</tr>
<tr>
<td>... has informed the driver about the intervention in the longitudinal and/or lateral motion control of the vehicle?</td>
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<tr>
<td>... was overruled by the driver and thus the system effect was compensated?</td>
<td></td>
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</tr>
<tr>
<td>... has requested the driver to confirm his presence or to take over the driving task?</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

During the reconstruction of the accident described above, the question of the braking and steering reaction of the driver arises.

In the following, please assess whether you can determine the described facts beyond doubt.

<table>
<thead>
<tr>
<th>The time of the driver’s braking or steering reaction resulting from a warning of the occurrence of a dangerous driving situation by an ADAS.</th>
<th>not applicable at all</th>
<th>rather not applicable</th>
<th>partly applicable</th>
<th>tends to be applicable</th>
<th>fully applicable</th>
<th>don’t know / no statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The intensity of the driver’s braking or steering reaction resulting from a warning of the occurrence of a dangerous driving situation by an ADAS.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The intensity of the braking or steering behavior of an ADAS.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An erroneous intervention by an ADAS which has led to a dynamic behavior of the vehicle that the driver was unable to control.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>How attentively the driver has observed the vehicle environment in case of an activated ADAS.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>At what time the driver was in full control of the vehicle.</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Do you agree with the statement, that the reconstruction of the pre-collisional traffic accident sequence is made more difficult by the lack of access to ...

<table>
<thead>
<tr>
<th>Statement</th>
<th>don't agree at all</th>
<th>don't agree rather</th>
<th>agree in part</th>
<th>agree rather</th>
<th>totally agree</th>
<th>don't know / no statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>... vehicle data on the pre-collisional behavior of ADAS?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>... vehicle data on the pre-collisional interaction of the driver with ADAS?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>... vehicle data on the pre-collisional behavior of Car2X communication systems?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>... images / videos of the system cameras on the behavior of the people involved in the accident?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>... vehicle data on remote accesses to the vehicle (e.g. for over-the-air software updates)?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

In your opinion, are there any other aspects that make the reconstruction of the pre-collisional traffic accident sequence more difficult?

Please make a note in the text field.

Now, we would like to ask you for your personal opinion on the changes in forensic traffic accident reconstruction due to the pre-collisional influence of ADAS.

Do you agree with the following statements?

<table>
<thead>
<tr>
<th>Statement</th>
<th>don't agree at all</th>
<th>don't agree rather</th>
<th>agree in part</th>
<th>agree rather</th>
<th>totally agree</th>
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</tr>
</thead>
<tbody>
<tr>
<td>The warning of the driver about the occurrence of a dangerous driving situation, which is issued by an ADAS, affects significantly the applicable reaction time of the driver in the context of the accident analysis.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The long-term take-over of complete driving tasks by ADAS is accompanied by an increasing neglect to observe the vehicle environment by the driver, which leads to extended reaction times of the driver when a dangerous driving situation occurs.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The evidence of malfunctioning of ADAS will increasingly lead to product liability or producer liability cases against vehicle manufacturers.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The evidence of malfunctioning of ADAS will lead to the fact that the correct functionality of the systems must be checked periodically as part of the technical inspection.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Challenges in forensic reconstruction of traffic accidents involving Advanced Driver Assistance Systems (ADAS)

Even without the pre-collisional influence of ADAS, some collisions can often hardly be reconstructed legally secure, due to a poor evidence (e.g. no skid marks) and non-existent witness statements. Finally, we would like to ask you to select three types of collision which are in your opinion most difficult to reconstruct legally secure.

- Collision between vehicle and pedestrian
- Collision between vehicle and cyclist
- Collision between vehicle and e-scooter driver
- Collision with another vehicle which turns into or crosses a road
- Collision with another oncoming vehicle – with full overlap
- Collision with another oncoming vehicle – with small overlap
- Leaving the carriageway
- Collision with another vehicle moving laterally in the same direction (accidents occurring when driving side by side (sideswipe) or when changing lanes (cutting in))
- Collision with another vehicle moving ahead or waiting
- Collision between vehicle and wild animals
- Other

In this field, we would like to ask you to briefly justify your choice of the three collision types.

What else would you like to tell us?
Here you find space for suggestions, wishes, comments or criticism.