Interdisciplinary Accident Research and Research Projects of AARU Audi Accident Research Unit

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Abstract - AARU (Audi Accident Research Unit) is an interdisciplinary research project of the University Hospital Regensburg in cooperation with AUDI AG. Specific objective is to comprehend the respective accident scenario and retrieve generally applicable findings as to technical, medical and psychological processes. In order to prevent traffic accidents and to alleviate vehicle accident consequences, postulates of general traffic safety, human-machine interaction, technical design and function of new vehicles and occupant as well as third party protection shall be inferred from these findings. Specifically, each accident with new Audi, Lamborghini and Ducati vehicles involved is analyzed interdisciplinary, discussed in a case meeting and anonymously documented with more than 2,000 parameters. The database is continually used for solving safety relevant issues. Parallel to accident analysis, research projects are performed in the fields medicine, psychology and engineering in order to gain comprehensive insight and identify potential additional areas of activity of accident research.

INTRODUCTION

Accident research units mainly analyze accidents involving personal injury. Derived findings run in the development of infrastructural arrangements or the vehicle safety. This has been mainly reflected in the decreasing number of traffic fatalities during the last decades. In the last two decades the number of traffic fatalities on German roads decreased from 9,949 in the year 1993 to 3,377 in the year 2014 (-66.05 %). The number of accidents with personal injury decreased in the same time from 385,384 to 302,435 accidents (-21.52 %). But the number of accidents with property damage raise from 1,960,012 to 2,104,250 (+7.36 %) [1].
These are just the official reported numbers. An investigation of [2] shows that just every fourth of insurance cases of the property damage accident is reported officially. According to [3] the number of minor damage cases which do not appear in statistics amounts to 4,8 mio cases per year.
The main objective of accident research is to make „blank spots“ on the accident scenario map disappear. Therefore accident research has to focus on every kind of accident to attain an improvement of road safety. Detailed information and knowledge about the emergence of accidents and the underlying conflict scenario are very helpful for developing and designing advanced driver assistance systems. In the field of driver assistance more and more active driving functions will find their way to the customer. Now, if the frequency of the different conflict scenarios is known, where an assistance system can support the driver the potential of the system to minimize or to avoid certain injury or damage in this situation can be derived. An increase of the take-rates of assistance-systems may contribute to improve road safety and in the long term to reduce the number of accidents.

WHAT IS AARU?

AARU (Audi Accident Research Unit) is an interdisciplinary research project of the University Hospital Regensburg in cooperation with AUDI AG. Specific objective is to comprehend the respective accident scenario and retrieve generally applicable findings as to technical, medical and psychological processes.
Accident causes are often open to speculation. In most cases the focus is on accident consequences. An important question is: What are the causes of these accidents?

A look into the federal statistics reveals that the primary cause of death or injury of a person in more than 90 % of all traffic accidents is human failure [4]. As a rule, the police is not able to determine what eventually led to this human failure, and is therefore not listed in official statistics.
This means that each and every single accident leaves many questions unanswered: What occurred immediately prior to the accident ? What exactly led to the collision? Was the driver distracted? Was stress a contributing factor, and if yes, what triggered it? Was the situation perceived unsafe at all? Or was the risk maybe even knowingly accepted?
The classification of the accidents into various accident types as performed by official statistics allows an insight into the basic accident sequence, however, it provides only few specific accident details. Therefore, efforts to derive measures for accident prevention from accident types will remain a shallow attempt. In order to develop sensible counter-measures, facts surrounding the accident, driver behavior as well as driver reactions and accident mechanism are required. The development of driver assistance systems is a significant opportunity to support the driver in the driving task and warn of hazards or take immediately remedial actions. At best, this will prevent accidents. However, if an accident is unavoidable, such systems will often minimize the consequences of the accident.
Since its establishment in 1998, AARU has set itself the task to collect accidents at such a high level of detail, thus achieving the required understanding for developing sensible remedial actions. Bavaria is the major statistical territory of AARU.

Accident data collection

It is AARU's objective to analyze approximately 90 traffic accidents involving Audi, Lamborghini or Ducati models not older than two years at the time of the accident interdisciplinary per year. Other selection criteria for inclusion in the AARU database are: persons injured in the course of the accident and / or at least one airbag deployment and /or severe deformation of the involved vehicles. For the inclusion in the AARU database it is irrelevant in which of the involved vehicles the airbag deployed or the injured person was sitting in or if for instance a cyclist or pedestrian suffered injuries. Only recently, the scope of accident investigation has been supplemented by the analysis of material damage.
AARU is comprised of three disciplines working in parallel and considering and analyzing the original accident from various perspectives.

Medicine

Among other things, the medical team collects information on biometric variables of persons involved, possible pre-existing conditions as well as information regarding first aid measures. Information sources for the medical team are standardized interviews performed by specially trained staff either on the phone or face-to-face. Medical records of the persons involved (medical reports, x-rays etc.) which are requested provided prior consent allow conclusions as to kind, extent and treatment of the respective injury. In addition, biomechanical sequence in the accident scenario is reconstructed and medical parameters are assigned for classification of the injury.

Psychology

Psychologist perform interview with drivers or pedestrians involved in the accident in order to determine the subjective view concerning the accident scenario. This allows the analysis of the surrounding factors of the accident and provides an opportunity to retrieve reliable significant insight concerning the behavior, subjective sensations and impressions of the involved persons in the pre-crash phase immediately prior to the accident by means of real-world traffic accidents. Standardized telephone interviews include questions regarding fatigue, stress, time pressure or distraction. The classification of accident causes is performed according to the 5-step method [5],[6] and [7], which are based on [8].

Technical aspects

Engineers analyze the accident site and the involved vehicles and based on this perform a physical reconstruction of the accident. These data range from debris areas as well as skid and impact marks on the road, road surface and routing, temperature, light and precipitation at the time of the accident, acquisition of nature and severity of vehicle damage up to seating position of the occupants and load. All these data are collected at the inspection of the accident site as well as the individual accident vehicles.

Case review

After conclusion of their respective analysis of the three independently cooperating expert teams, each individual case is discussed in an interdisciplinary case conference. A specialist of each team presents the respective results. The collected data are then synchronized and objectified.

For instance, the subjectively experienced accident sequence as reported in the psychological analysis is compared with the accident sequence objectified by technology. In addition, all injuries are allocated to an injury causing factor (e. g. component, body movement etc.) and the point in time at which the injury occurred. All participants discuss the accident until all details are understood and the three teams agree on sequence, accident cause and accident consequences.

The interdisciplinary discussion results in a significantly improved understanding of the accident scenario und allows an evaluation of accident causes and potential estimation of driver assistance systems.

Finally every case is anonymously documented with more than 2,000 parameters in the AARU database [5], [6], [7], [9]. The database is continually used for solving safety relevant issues.

Databases and data analysis

In order to prevent traffic accidents and to alleviate vehicle accident consequences, postulates of general traffic safety, human-machine interaction, technical design and function of new vehicles and occupant as well as third party protection shall be inferred from these findings.

For database analyzes two main sources of data are used: Data out of collected accidents of AARU and the GIDAS (German In-depth Accident Study) database. According to the application to certain areas of research different data sets are used. For getting more general overview of a certain topic the GIDAS database is used and in some use cases combined with a projection to federal level. For analyzes concerning a particular vehicle (esp. Audi models) the AARU database is used.

The required data analysis are used for questions out of engineering departments and also for displaying relevant fields of action or potential. There is a broad spectrum concerning vehicle safety and occupant protection up to driver assistance systems.

Parallel to accident analysis, research projects are performed in the fields medicine, psychology and engineering in order to gain comprehensive insight and identify potential additional areas of activity of accident research.

CURRENT RESEARCH PROJEKTS OF AARU

Medicine

In the medical field a reduction of injury severity in Germany was proven by 24,405 accidents in the GIDAS database, using accidents from 1991 to 2011. A further objective of the study was to identify main influencing factors for this decline. By means of a multivariate logistical regression model developed for this use case it could be demonstrated that the reduction of injury severity is a multifactorial event [10]. This study was published as original work in Injury, 2015 Oct; 46 Suppl 4: pp. 135-143.

Psychology

More than 90 % of accidents involving personal injury are due to human failure [4], proving that individuals require support in the driving task. However, official statistics reveal no details allowing the determination of an accident cause according to the 5-step method or information on reaction behavior of accident participants. Respective technical counter-measures may only be defined and evaluated if the accident mechanism is obvious in connection with driver behavior and reaction [11]. Analyses performed by the AARU reveal that in situations in which their right of way is taken from the right side, drivers tend to react by swerving to the left, mainly in combination with braking. Other accident analyses showed the same result [12], [13]. In order to investigate reaction behavior of drivers in critical intersection situations, two studies using the Vehicle in the Loop (a combination of a driving simulator with a real vehicle) were carried out [14]. In the studies the reaction behavior of drivers was tested who had the right of way when they encountered a critical crossing situation on a rural road. The participants were driving with 70 km/h when they experienced situations in which their right of way was taken from the right side. Each critical situation had been designed in a way that there would have been a collision, if the driver would react either with an emergency braking and no steering or with a combination of braking and steering to the left. All situations would have been manageable without a collision by braking and swerving to the right.

Technical Aspects

For a long time accident research survey focused on accidents involving personal damage. However, more than 87 % of officially reported accidents on German roads involved merely property damage [4]. A significantly higher number of property damage accidents are not recorded by the police, but are only reported to the insurers [15]. Furthermore, approximately 4,8 million minor loss accidents [3] occur annually. Prevalence of these accidents and nescience on conflict creating scenarios in property damage is a field of action for accident research [2]. For this purpose the existing accident types were extended and an evaluation method has been developed to demonstrate customer value of future assistance systems by preventing accidents. Thus, a monetary purchasing incentive may be derived [16], [17].

RESULTS

Medicine

In the conducted study a significant decrease regarding all types of severe injuries and killed passengers was found. The relative decrease in mortality was 68.8 % according to the German Federal Statistical Office. Fortunately, especially the percentage of severely injured traffic victims was less than half (50.3 % to 65.4 %) during the study period, in terms of both the whole body and all individual body regions like head, thorax, abdomen, pelvis, upper and lower extremities. The percentage of uninjured passengers increased by 8.5 %.

Furthermore, independent factors were found that are clearly associated with injury prevention. The use of seatbelts and airbags and a lower age of the passenger cars appeared to be factors on the positive side. Severe injury, however, was significantly associated with serious accidents like roll-over, skidding, collapse of passenger compartment, ejection or trapping, positive blood-alcohol, accidents on country roads compared to inner-city accidents, increased change in velocity and accidents at night for example. The implementation of protective factors increased over time, whereas factors constituting a high probability of serious injuries declined [10].

Psychology

The result of the first study revealed the importance of the so-called Time-To-Arrival (TTA) for the prediction of the reaction behavior. TTA is applied for objective estimation of the criticality in cross traffic. It describes the time up to a potential collision with a conflict partner at an intersection [18]. It is calculated by dividing the distance to the critical area by the speed of the vehicle that has the

right of way [19]. With longer TTA drivers were able to perform an evasive steering maneuver to the right in order to prevent the accident. With decreasing TTA there was a tendency towards swerving to the left side which lead to having an accident.
In the second study TTA was systematically varied in order to investigate its influence on evasive behavior. Overall it appeared that the percentage of mere braking actions basically dropped the lower the TTA was. However, it became evident that the smaller the TTA, the more rarely braking actions occurred at all. Besides, it became obvious that the drivers were not able to perform a sufficient emergency braking. Regarding the evasive behavior, the percentage of evading increased the smaller the TTA was. An analysis of the reaction of those drivers who performed a combination of braking and steering revealed that no driver started braking and steering simultaneously. The data indicated that all persons who steered first steered to the left side. If the drivers braked first there was a higher probability that there would be a steering to the right side, and therefore a higher chance to avoid the accident.

Technical Aspects

The developed evaluation method makes it possible to evaluate the claims cost of a future vehicle concept in combination with a certain driver assistance system. The material of all outer attachment parts and the technical configuration of every vehicle can be considered by means of damage points and damage units to derive a damage risk score [16], [17]. A damage risk function is used afterwards for evaluating modified accident parameters [20]. Therefore the vehicle is divided into damage segments: Front, fender, doors, side panel and rear.
If the distribution of damage frequency of a certain vehicle is known the damage risk score can be determined best. If it is not known the damage frequency can also be taken from a precursor or comparable model.
The used material of the outer attachment parts is one of the main influence factors like [17] shows. Based on a middle class vehicle equipped with steel an plastic bumpers an adjustment to aluminum parts shows only a little higher risk. Changing all attachment parts to CFRP (carbon reinforced plastic) would result in a higher damage risk. Plastic attachment parts lower the risk on the other hand.
In addition the influence of technical equipment like the light technology on the claims cost can be determined. With reference to halogen headlights LEDs lead to an increase of 38 %, laser-lights to an increase of 129% [16]. Furthermore the fitting position of ADAS sensors can be evaluated. Nearly every component brings a rise of the damage risk score. By means of ADAS functions this effect has to be compensated due to an active intervention for mitigating or avoiding a collision.

DISCUSSION

Medicine

For the first time it was possible with an accident data analysis to prove that the frequency and severity of directly accidental serious injuries decreased significantly during the study period. This could not only be explained through medical improvement. It is rather a multifactorial process including legal amendments, enhanced road layouts and improvement in automotive safety above all. To account for the impact of multiple factors, a multivariate regression analysis was applied. After identifying independent variables associated with lower morbidity, changes over time were calculated for relevant variables.

Using seatbelts, age and avoidance of serious accidents for example are well known protecting factors. Interestingly, the year of construction and female gender had a moderate effect on morbidity in this study. The year of construction reflects the development of active and passive safety in passenger cars. Airbag and seat belt use were independent variables to avoid serious injuries. Next to seat belt use and airbag, the vehicle's body stiffness is one of the most important

passive safety factors for passenger cars. The stiffness is more and more advanced from model line to model line.
In the univariable analysis, the gender effect was observed for minor injuries like whiplash, but not for severe injuries. Osteoporosis in elderly women could have a tremendous influence, resulting, besides the factor age, in significance in the multivariable analysis. An effect of the seating position was examined and excluded. In the literature, a gender effect is mainly described for minor injuries. However, further studies could evaluate the influence of gender on severely injured vehicle occupants.
In summary, the implementation of protective factors increased over time while accident constellations with a high probability for severe injury decreased over time [10].

Psychology

The question of whether an accident is preventable may be approached from a number of points. The first option involves supporting the person responsible for the accident in order to prevent the error causing the accident. Therefore, the error underlying the accident has to be known in detail. This is possible by using the 5-step-method like AARU does. By knowing the error, suitable countermeasures can be applied, e.g. through driver assistance systems.
A further option is to support persons involved in an accident to react in the best possible way in critical situations caused by the person responsible for the accident. In order to provide the party involved in an accident with the best possible support, it is initially necessary to understand how persons behave in critical situations. Therefore, the behavior of drivers was examined whose right of way was taken from the right side at an intersection. It could be shown that the shorter the TTA and thus the more critical the situation was the percentage of steering in the direction of movement of the crossing vehicle increased and braking decreased. This resulted in a higher number of collisions. Furthermore, it became obvious that most drivers were not able to perform an appropriate emergency braking. However, since a higher deceleration extends the available time in order to evaluate the situation, it would be reasonable to support the driver by means of a driver assistance system in order to prevent the collision. A vehicle system that provides a rapid deceleration could support the driver beneficially. It would suit the driver's natural reaction to brake in a critical situation and would result in more time for the driver to comprehend the situation and to steer to the correct side to avoid the accident. Further studies should be conducted to examine the reaction behavior in other critical situations.

Technical Aspects

The developed evaluation method of damage points and damage units is validated by means of real world damage cases. Subsequently to the calculation of the damage extent the result of the damage points were compared to the estimated damage of authorized experts.
The averaged deviation between the two different approaches is 2.9 % in motor own damage cases. 64.1 % of the analyzed cases were calculated directly under the assumption only to change outer attachment parts. The amount of cases repaired by smart repair or repair varnish is 15.4 %. In 20.5 % of the cases slight structural damages occurred [17].
The determination of damage extent in property damage accidents on the basis of the systematic of damage points and damage units is suitable for model and manufacturer independent calculations. Although the methodology is based on one manufacturer and on a limited number of vehicle models. Regarding SUVs and high price models a larger deviation occurs which has to be analyzed in further work.
Superordinate objective of the evaluation method is to use it in an early stage of the product development process for evaluating vehicles according to their class, materials and equipment in combination with an ADAS function. Up to now the methodology works for minor deformation depths which are very common in property damage accidents but will be extended in the future.

CONCLUSION

Detailed analysis of traffic accidents by AARU generate data resulting in an improved understanding of accident mechanisms and accident consequences and their analysis of the pre-crash phase as well as the behavior and reactions of the driver. Based on this analysis, appropriate remedial actions may be developed which are able to positively influence the accident scenario. An opportunity for vehicle manufacturers is the development of driver assistance systems, which at best may help to avoid accidents or at least minimize the accident consequences. Traffic accident research provides a valuable contribution by improving general traffic and road safety with attention to medical, psychological and technical aspects.

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