

Evaluation of Future Advanced Driver Assistance Systems Using Property Damage Insurance Claims

Julian Schatz

Philip Feig

Markus Lienkamp

Technical University of Munich

Germany

Johann Gwehenberger

Marcel Borrack

Allianz Center for Technology

Germany

Rolf Behling

Allianz Global Automotive

Germany

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ABSTRACT

Real world traffic accident databases allow an accurate determination of the effectiveness of Advanced Driver Assistance Systems (ADAS). Research shows that accidents with property damage have been increasing while accidents with bodily injury have fortunately decreased in the last decades. This development requires a shifted focus, from databases targeting bodily injury e.g. GIDAS, towards a new database setup that complies with requirements which occur when investigating property damage. The accurate evaluation of ADAS that mitigate or avoid property damage will help car manufactures developing future systems and insurers calculating future premiums. This paper describes a new method to analyze real world property damages and an approach to monetarily evaluate ADAS in terms of benefits for customers and insurances. An in-depth accident database containing 5,000 property damage accident cases is created by Allianz Center for Technology (AZT) and Allianz Automotive Innovation Center (AIC) using insurance claim files. Evaluating insurance data enables the analysis of a holistic image of traffic accidents retrospectively and the determination of the monetary benefit of a certain ADAS. The proposed method to assess property damage applying a new setup of a retrospective in-depth database and utilizing the data to develop test scenarios that create the foundation of further prospective evaluation analysis of future ADAS is discussed. This paper presents an application of the proposed method for the field of parking and maneuvering, which accounts for up to 50 % percent of insurance reported collision claims depending on the vehicle model.

INTRODUCTION

Advanced Driver Assistance Systems (ADAS) have been gaining in importance over the last years. As ADAS are becoming more diverse and efficient, motor insurers have to increasingly consider the influence of ADAS in accident situations [1]. Appropriate reductions due to innovative insurance premiums can lead to an increase in attractiveness to the customer and therefore improve the overall competitiveness for the insurer. Advantages to both an insurer and Original Equipment Manufacturer (OEM) can arise due to an increase in the number of sold vehicles equipped with ADAS and the sale of corresponding insurance policies [2].

In order to develop insurance products for vehicles equipped with ADAS, the respective monetary benefit and therefore the effectiveness of a specific ADAS has to be determined. Due to a rising number of different types of ADAS and various ways of software and hardware system-application by OEMs, it becomes necessary to develop a methodology to evaluate the effectiveness of a specific ADAS specifically for its vehicle class.

Retrospective and Prospective ADAS Evaluation

Literature proposes retrospective and prospective approaches using real world accident databases to determine ADAS effectiveness [3, 4]. Retrospective analyses are conducted when evaluating ADAS that have already been allocated on the market, as sufficient accident data for analysis needs to be available. This analysis is particularly advantageous to proof certain effectiveness rates of existing ADAS [4] and is currently performed by [5–11]. A representative sample of real world accident data is divided into two groups (Figure 1).

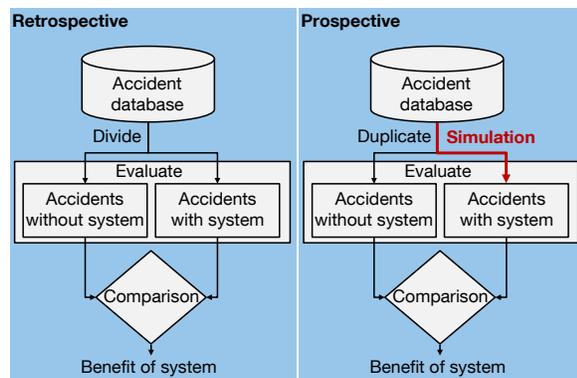


Figure 1: Retrospective and prospective ADAS evaluation according to [4].

One group contains the amount of accidents that happened to vehicles equipped with the investigated ADAS and the other group contains accidents of vehicles without the corresponding ADAS equipment. Prospective analyses are performed to evaluate future systems that have not been established on the market [12–14]. The main advantage to OEMs and insurances is the possibility to assess the monetary benefit of a certain system before it enters the market. Since accidents with future ADAS-equipped vehicles are not available, the corresponding accident database is duplicated. One option suggested by Busch [3] to determine the second dataset is the use of simulation of reconstructed corresponding accidents and a virtual image of the investigated ADAS. To determine the benefit of ADAS, the two groups are compared.

Accident Database

The main source to perform retrospective or prospective ADAS effectiveness analyses is an accident database. In order to derive useful information from a conducted analysis, it is important, that the database is representative of all of the accidents within a certain investigation period. Further, it is necessary that the database contains information about the scenario that caused the accident and the amount of damage that occurred both physically and monetarily. To calculate retrospective ADAS effectiveness, it is furthermore required to have knowledge about the ADAS equipment of the corresponding vehicles.

Different institutions e.g. research labs, car manufacturers and governments collect accident data worldwide. In many cases, the data originates from the local police that collects the data as the accident is recorded. Accidents that were not reported to the police, possibly due to only small property damages, are not included within these kinds of databases and lead to an overrepresentation of bodily injuries. Distortions due to different designs of database layouts or data sources enhance the effect. Furthermore, there is usually no documentation regarding the monetary effect the accident caused, which is essential in order to determine the benefit an ADAS could have had. In addition, police records usually do not specify the ADAS equipment of the affected vehicles. In Germany, officially registered accidents are documented by the Federal Statistical Office (DESTATIS). In-depth accident databases, such as the German In-Depth Accident Study (GIDAS) or the Audi Accident Research Unit (AARU) investigate accident cases in a high data

depth of about 3000 parameters for each accident. To do so, each accident is technically reconstructed and interviews by psychologists and physicians are conducted to gain information regarding the cause of the accident. Precondition to include an accident in these databases is that there is one or more bodily injury, which means, that the data is not representative of all or most of the accidents within a certain investigation period. Therefore, it is generally not possible to gain information regarding monetarily impacts.

Insurance Claims

Insurances generally do not only settle accidents reported to the police, but also minor property damages. A combined analysis of all damage claims that are reported to the insurer therefore represents the actual damage situation in the most precise way (Figure 2).

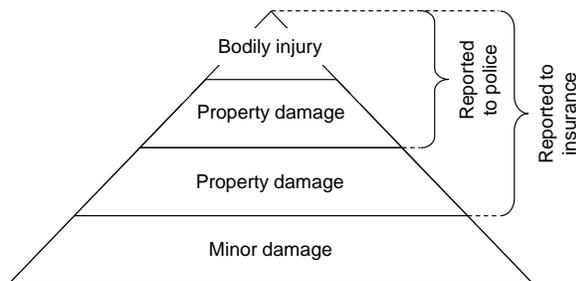


Figure 2: Bodily injury and property damage reported to police and insurer according to [15].

For every damage claim, certain damage files are available to the insurance in order to relate to the cause of the accident and other vehicle-specific parameters. The insurance further has knowledge regarding the cost that occurred due to the accident. For insurances, it is additionally advantageous to use insurance data to evaluate ADAS, as it directly represents the target group that is to be reached.

Impact of Property Damage and Bodily Injury

According to the Federal Statistical Office in Germany [16], accidents with property damage reported to the police happened almost six times more often than accidents also involving bodily injury within the last two decades (1995 – 2016). Gschwendtner [17] follows up research and reveals that 75 % of accidents with only property damage, that are known to insurances, are not reported to the police. Furthermore Gwehenberger [15] estimates, that an additional number of about 4.8 million accidents per year are not reported to either

insurances or the police. Concluding, Gschwendtner summarizes [14], that “... accidents involving property damage occur 42 times more frequently than accidents involving personal damage in Germany”. This research indicates that besides its importance to save lives, ADAS has the highest monetary impact on accidents in the operational field of property damage and is therefore further discussed in this paper.

To determine the corresponding effectiveness of ADAS, Gschwendtner proposed new accident types, that provide a detailed description regarding the accident cause for property damage [17]. He further developed variables that influence the monetary benefit of ADAS in the field of property damage and conducted a potential estimation using so called property damage risk functions [18, 19].

AIMS AND OBJECTIVES

To determine the effectiveness of ADAS addressing property damage accidents using an insurance in-depth accident database by applying the presented current state of science and technology, the following problems arise:

Previous accident evaluations using in-depth databases are focused on bodily injury. Especially property damage documentation is generally not as detailed, compared to bodily injury, since mostly no police reports or medical reports are available. Hence, especially when investigating property damage, it is necessary to understand the kinematics of the accident in order to determine ADAS effectiveness. Consequently, new methods have to be developed, to derive accident kinematics focused on property damage. To perform a retrospective ADAS evaluation, it is necessary to have information concerning corresponding ADAS equipment. To perform prospective ADAS evaluations, accident cases have to be reconstructed. Due to high case numbers and low documentation quality, reconstructions are mostly not feasible.

The aim of this paper is to propose a database layout with parameters that comply with the requirements and information quality of property damage claims that allow an accurate evaluation of accident kinematics. Furthermore, the accident kinematics are evaluated monetarily and combined with ADAS equipment rates. In addition, monetarily relevant accident kinematics will be determined and clustered. Corresponding test scenarios that

match the identified accident clusters can be derived and build the foundation of further prospective evaluation analysis of future ADAS addressing property damage.

METHODS AND DATA SOURCES

The proposed ADAS evaluation method (Figure 3) addressing property damage based on insurance claims is divided into three parts: Data Source, Database and Analysis.

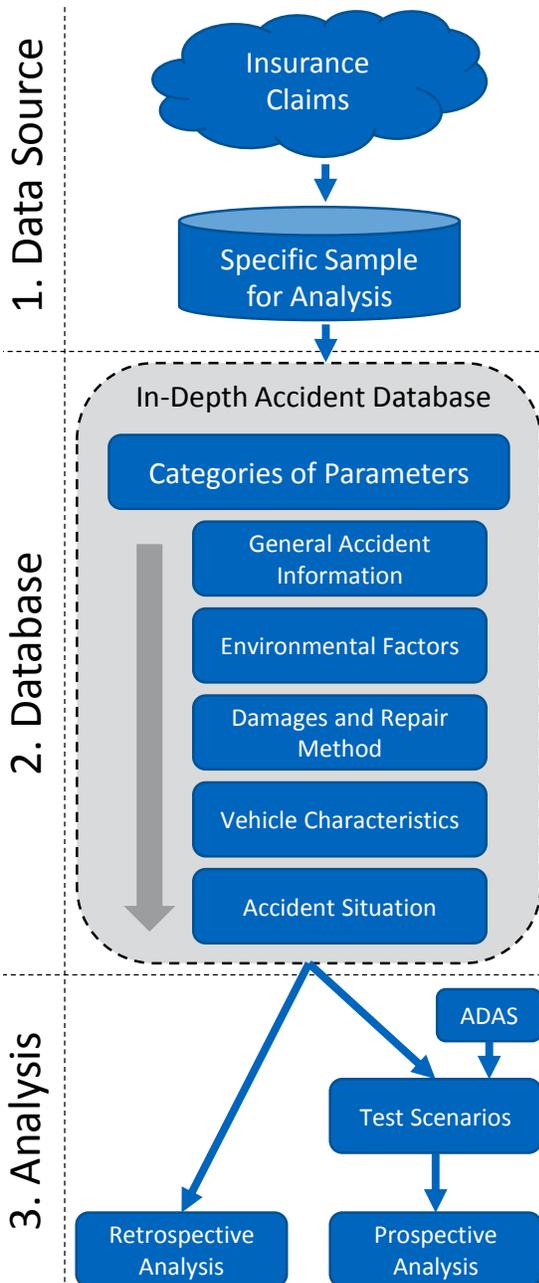


Figure 3: Method to evaluate ADAS addressing property damage based on insurance claims.

1. Data Source

A relevant selection of insurance data (third party liability and motor own damage collisions) is generated. At this point parameters, e.g. the time period and the analyzed vehicle type have to be specified. Additionally, it is necessary to generate a representative sample of data. In case it is required to downsize a sample due to time expense, it is proposed to do so regarding the claim expenditure.

2. Database

An in-depth accident database is created. In order to monetarily evaluate ADAS effectiveness in the field of property damage, it is essential to understand the cause and the kinematics of each individual accident. Furthermore, the monetary influence of an accident has to be known. To reflect an accident within a database as precisely as possible, correlating parameters have to be chosen and coded according to the real-world accident. In the past, this approach was mostly used for evaluating the effectiveness of ADAS addressing bodily injury. Medical, technical and police reports contribute to understanding the accident, as most of these cases are technically reconstructed and therefore pre-processed. When assessing property damage accident cases, most of the mentioned reports are not available, as due to usually small damage extents, no report was made by police and for instance no technical expert was consulted to settle the damage claim. To compensate for this possible information loss and to evaluate ADAS addressing property damage using an in-depth accident database, five categories of parameters are proposed:

General Accident Information

This category captures general information regarding the accident, as the date, the time and the location of the damage. Further, the expenditure and the repair cost of all involved vehicles are specified here separately.

Environmental Factors

Environmental factors can affect the effectiveness of ADAS and are therefore specified within the database. Specially focused parameters are the lighting conditions when the accident happened, e.g. daylight, night, dawn / dusk, the roadway surface and the condition of the roadway surface. Low friction values, due to unpaved or slippery road surfaces, or slippery surfaces caused by rain, snow or ice are documented.

Damages and Repair Method

A detailed analysis of vehicle damages and corresponding repair methods help to classify property damage accidents in order to evaluate ADAS. A method was developed to determine the accident cause and kinematics using a detailed analysis of damaged vehicle components and locations.

Damaged components:

In the first step, three different layers of potentially damaged vehicle components were defined (Figure 4).

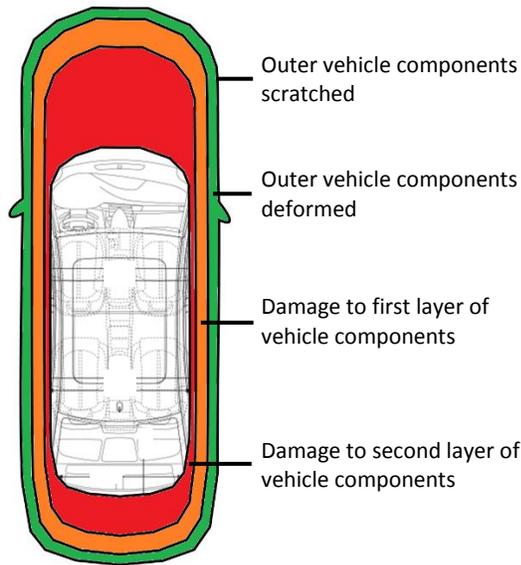


Figure 4: Classification of different layers regarding potentially damaged vehicle components, picture source [20].

The classification of vehicle components relating to their position within the vehicle structure gives reliable information concerning the severity of the accident.

Table I: Exemplary selection of vehicle components in each layer.

Outer vehicle components	
e.g.:	Head- / taillight, bumper covering, door, fender, side panel, sill, ADAS sensor, exterior mirror, tire, rim
First layer of vehicle components	
e.g.:	Cross member, radiator, air-condition condenser, intercooler
Second layer of vehicle components	
e.g.:	Longitudinal member, pillar

As damaged vehicle components have a major influence on the claim expenditure, the level of damage to the vehicle components can distinguish between a direct impact to the vehicle and a damage due to grazing, only damaging outer vehicle components. Table I shows an exemplary selection of vehicle components in each layer.

Repair Method:

The repair method of damaged vehicle components is determined and documented within the database, as the accident data is surveyed secondarily. Depending on the extent of damage, the repair complexity or cost of labor work of a certain component, some components are usually repaired and some are usually replaced. Statistical analysis aims to get a better understanding regarding the general damage occurrence and contributes essential information to repair research. Furthermore, repair approaches of different auto repair shops can be compared and analyzed. Figure 5 shows an example of replacement and repair rates for 188 damages to bumper coverings (front and rear) and side panels (left and right) based on 255 analyzed Audi A8 motor own damage (MoD) collisions. It can be derived, that side panels are generally repaired and bumper coverings are usually replaced. As side panels are complex and expensive components, in most cases, only certain cutouts are repaired, or dent repair is performed if possible. Due to comparably low bumper covering spare part prices, generally only small damage, e.g. paintwork is conducted in terms of repairing.

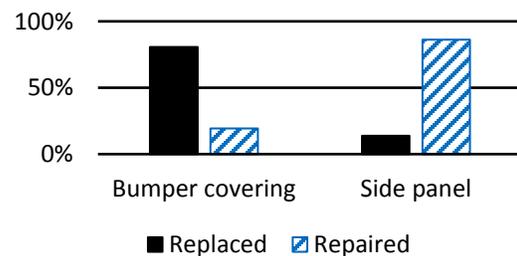


Figure 5: Repair method of bumper covering and side panel based on Audi A8 MoD collisions.

Horizontal damage:

The horizontal location of a damage to a vehicle specifies its exact position independently from the corresponding component. A fictitious vehicle seen from top view is divided into fourteen segments. Figure 6 shows horizontal damage segments A – N similar to [21].

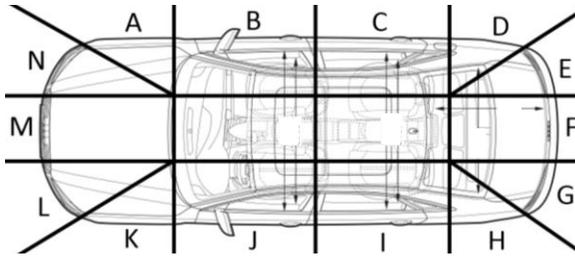


Figure 6: Horizontal damage, picture source [20].

Vertical damage:

The fictitious vehicle is divided into three segments I to III to specify the corresponding damage vertically as shown in Figure 7 (similar to [21]).

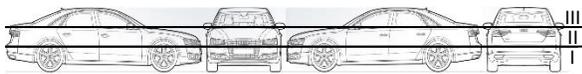


Figure 7: Vertical damage, picture source [20].

Besides the exact specification of a damage within the database, the horizontal and vertical analysis can help to understand the cause of the accident in terms of the opponent's object size and height.

Combination of horizontal and vertical damage

The combination of horizontal and vertical damage locations allows a damage raster view of the front, rear, left and right side of the vehicle (Figure 8).

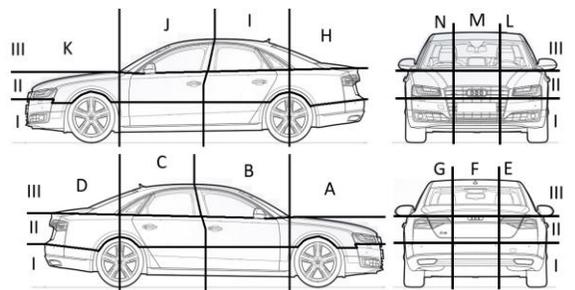


Figure 8: Damage locations in raster view front, rear, left and right side, picture source [20].

Direction of Impact:

The direction of the impact that caused the damage is specified according to [21] using twelve intervals of 30 degrees (Figure 9). The combination of damaged components, damage locations, repair method and the direction of impact helps to derive the accident situation.

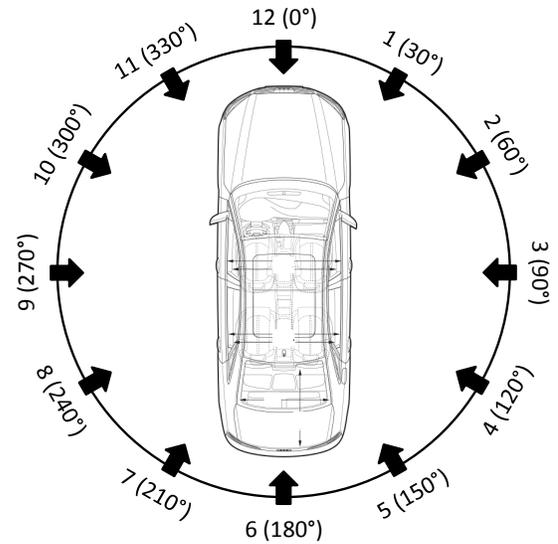


Figure 9: Direction of impact according to [21], picture source [20].

Vehicle Characteristics

In order to retrospectively determine the effectiveness of ADAS, vehicle characteristics may be specified using the corresponding Vehicle Identification Number (VIN) of the damaged vehicle. Information regarding vehicle brand, model and ADAS equipment can be derived. Additionally, special equipment as costly headlights or sensors are specified within the database, as damages to components with high repair or replacement costs indirectly lower the monetary effectiveness of an ADAS.

Accident Situation

The accident situation sums up all information regarding the accident kinematics and cause and specifies the corresponding accident type and accident kind within the database. The horizontal damage location is analyzed in relation to the direction of impact. Figure 10 shows an exemplary property-damage accident evaluation with accident type 801 between the policy holder vehicle (MoD collision claim) and a third party vehicle (corresponding TPL claim). Accident type 801 describes an accident of one vehicle parking hitting another already parked vehicle [17]. As the accident type 801 does not specify the driving direction (forward / backward) and the driving behavior (no steering, steering left, steering right) of the moving vehicle, detailed analysis is necessary. The comparison of horizontal damage location frequencies of both vehicles in combination with the corresponding directions of impact reveal the kinematics of the accident.

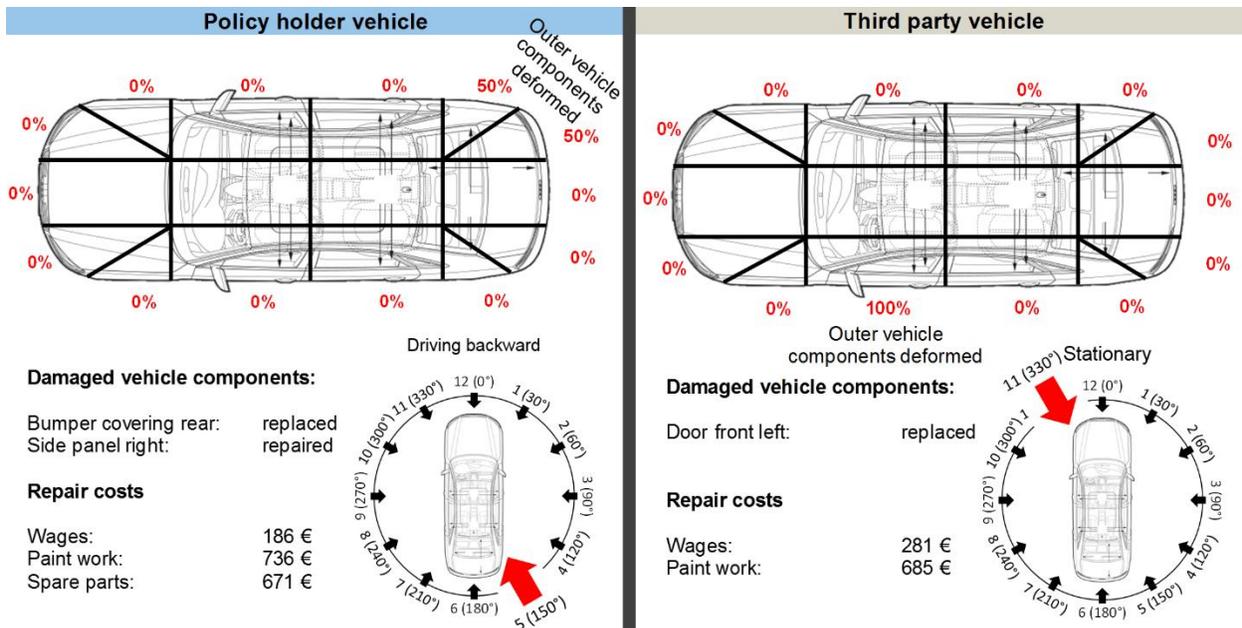


Figure 10: Exemplary evaluation of property damage accident according to [21], picture source [20].

In this case, the rear right edge of the moving vehicle hit the front right door of the stationary vehicle. As the components of both vehicles are deformed and both areas of damage are relatively small, it can be assumed, that a direct impact rather than a damage due to grazing occurred. Further, it can be assumed, that the driver of the moving vehicle was driving in a straight direction, as otherwise, the damaged location would have been bigger at least on one of the vehicles and more components would have been exposed to grazing rather than denting. In addition to the pictures, repair costs broken down into wages based on working hours, paintwork and spare parts for every individual accident case provide an impression of where the focus of expenses lay.

3. Analysis

The data within the proposed in-depth accident database can be used for both retrospective and prospective analysis. The retrospective analysis can be conducted using the numerous parameters regarding accident kinematics and cause in combination with the corresponding ADAS equipment. To determine ADAS effectiveness prospectively, accident occurrence is clustered using corresponding accident types and vehicle damage information. Test scenarios addressing relevant accident kinematics were derived and monetarily weighted according to accident data [22]. Feig [23] describes in his research a method to monetarily evaluate ADAS

effectiveness prospectively using the in-depth accident database. ADAS performance within real tests return speeds until collisions can be avoided for each test scenario. Feig developed a method to link avoidance speeds within test scenarios to accident cases in the in-depth accident database using speed distributions [23]. Consequently, accident cases within the database that would have been avoided due to the ADAS can be determined, and a monetary benefit can be calculated.

RESULTS

An in-depth accident database containing 5,000 property damage accident cases is currently being created by Allianz Center for Technology (AZT) and Allianz Automotive Innovation Center (AIC) using insurance claim files.

Monetarily representative selection of relevant claims

In order to create an in-depth accident database, comprehensive accident data has to be utilized. However, as not all insurance claims regarding motor own damage (MoD) are relevant for ADAS evaluation, only certain kinds of claims - collisions with other motor vehicles and collisions without contact to other motor vehicles - are selected. Accidents due to fire, explosion, lighting, theft, etc., were not considered, as ADAS would not have an effect on it. Third party liability (TPL) claims can either emerge in the field of

property damage or bodily injury. In this paper bodily injury claims will not be taken into further consideration, as shown above, property damage has the highest monetary impact on accident data. 10,918 MoD and 16,098 TPL property damage claims of the vehicle models Audi A1, A3, A4, A6, A8, Q3, Q5, Q7 were requested for the years 2013 and 2014 from the Allianz actuary, each damage case with the following specifications:

- Date of the damage
- Claim expenditure
- Vehicle identification number
- Internal claim number

Table II shows the total number of claims vehicle specifically received from the actuary.

Table II: Claim samples from actuary.

Vehicle type	Number of claims	
	MoD	TPL property
A1	679	2,097
A3	558	1,168
A4	5,048	5,436
A6	1,596	2,834
A8	255	294
Q3	589	1,069
Q5	1,671	2,248
Q7	522	952

Monetarily representative claim samples were selected vehicle type specifically due to a time-consuming process of data analysis. Figure 11 shows the process and the number of claims to be analyzed.

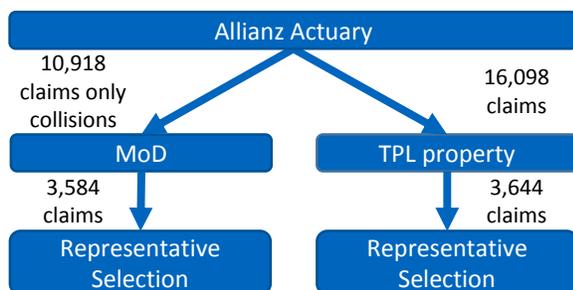


Figure 11: Distribution of claims.

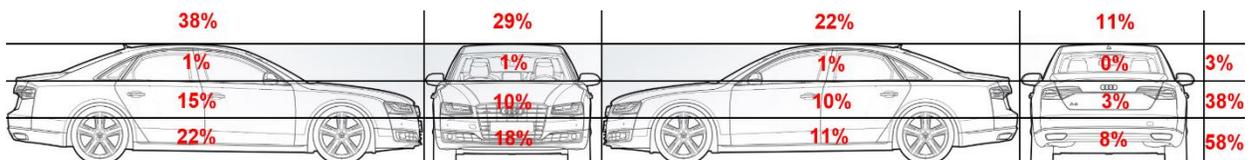


Figure 12: Vertical Damages (Audi A8 MoD collisions), picture source [20].

Table III shows the monetarily representative selection of the vehicle types for MoD collisions and TPL property claims. For Audi A8 a full sample was used for analysis, as only 255 MoD collisions and 294 TPL property claims were available.

Table III: Representative claim samples for analysis.

Vehicle type	Number of claims	
	MoD	TPL property
A1	480	479
A3	479	484
A4	478	479
A6	479	479
A8	255	294
Q3	471	475
Q5	478	478
Q7	464	476

Analysis

The accident occurrence of 255 motor own damage collision damage cases of Audi A8 in the year 2013 and 2014 with a total claim expenditure of approximately 882,700 € were analyzed.

Figure 12 shows the accumulated vertical distribution of damages to the Audi A8 based on frequencies of every severity of damage (scratch to second layer damage). Approximately 58 % of the considered damages happened in the lower part of the vehicle from the bottom to the edge of the front headlight. Whereas only 38 % damages occurred in the middle part (headlight to bonnet) and 3 % in the upper part (windshield). Further research shows that in 72 % of self-inflicted MoD collisions no other vehicle was involved in the accident. These damages account for 62 % of the corresponding claim expenditure. This analysis shows that most of the collisions of the assessed MoD property damage cases did not happen with other vehicles but objects of low height, which are especially difficult for ADAS to detect. However, the monetary benefit an ADAS can provide increases in case a third party vehicle is damaged within the same accident, thus the avoidable claim expenditure rises. According to the considered MoD damage cases, an additional monetary average of 20 %

of avoidable claim expenditure due to TPL occurred. In the next step, horizontal damage frequencies were analyzed (Figure 13).

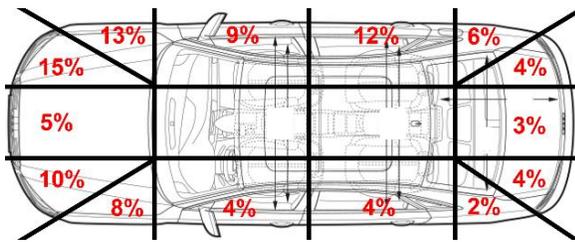


Figure 13: Horizontal damages (Audi A8 MoD collisions), picture source [20].

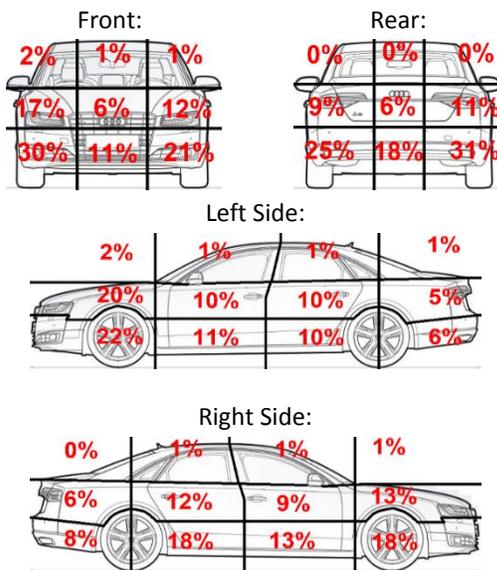


Figure 14: Combination of horizontal and vertical damage (Audi A8 MoD collisions), picture source [20].

It can be derived, that the damages are more likely to happen to the front and the right side of the vehicle than to the rear and the left side.

Figure 14 shows damage frequencies of the front, rear, left side and right side independently. Analysis reveals, that especially the vehicle's edges and the lower area of the vehicle's sides are exposed to damages.

In order to determine ADAS effectiveness, accident types were used, to classify accident kinematics. Analysis was conducted, depending on the frequency a certain accident type occurred, the average claim expenditure and the monetary relevance. The monetary relevance describes the product of both frequency and average cost and therefore represents the overall monetary risk of a corresponding accident type. It can

be observed, that accident type 8 - parking and maneuvering - has by far the highest frequency while the average claim expenditure is relatively low (Figure 15). However, monetarily seen, accident type 8 accounts for 45 % of the total claim expenditure of the considered MoD collision cases and is therefore the most important accident type for ADAS evaluation and development within property damage. Hence, accident type 8 has the highest monetary potential for ADAS and is therefore further discussed.

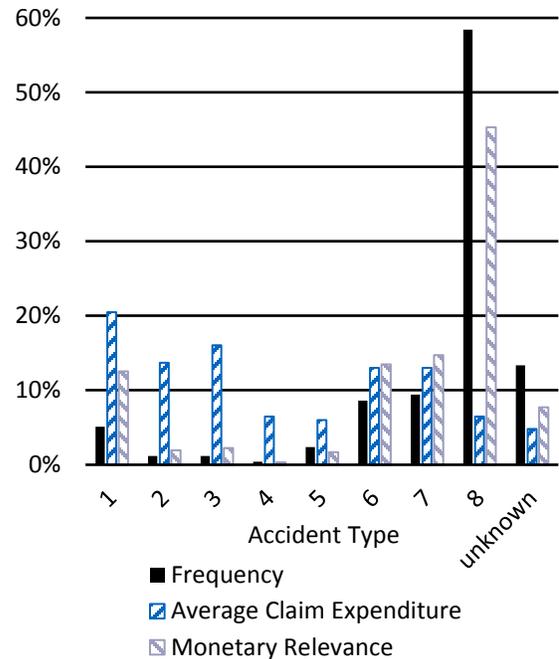


Figure 15: Frequency, average claim expenditure and monetary relevance of accident types (Audi A8 MoD collisions).

An analysis regarding generic ADAS configurations was conducted using the in-depth accident database, showing a high potential concerning claim frequency and claim expenditure as to ADAS addressing parking and maneuvering (Figure 16). Although equipment rates within the analyzed samples are high, (100 % availability of parking assist (park distance control front and rear) and 78 % availability of rear cameras) ADAS addressing parking and maneuvering still seem to have certain limitations.

As the analyzed parking and maneuvering systems (e.g. park distance control) are not automatically intervening functions, the discussed limitations can be due to uncertainty factors as for example the individual driver reaction.

In order to increase the effectiveness of ADAS in the field of parking and maneuvering, autonomous intervening parking systems have to be developed.

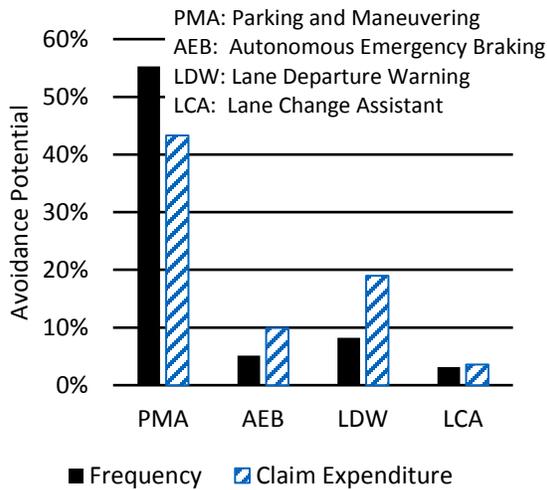


Figure 16: Potential of generic ADAS (Audi A8 MoD collisions).

The corresponding ADAS effectiveness can be determined prospectively, which on the one hand enables

system developers to adjust and optimize system parameters at an early stage and on the other hand allows a monetary system evaluation at market launch of the vehicle.

Figure 17 shows the top ten most monetarily relevant accident types regarding parking and maneuvering using the in-depth accident database. Accident 898 - parking conflict without details - does not account for a high average claim expenditure, but due to its high frequency, it is the monetarily most relevant accident type. In this case, accidents could not be sorted into accident types with deeper details, as essential information e.g. left or right steering during the accident was unknown. Unfortunately, this accident type cannot be used for ADAS evaluation or development, as no further information besides parking and maneuvering is known. The second most monetarily relevant accident type within parking and maneuvering is 801. Besides the fact that one vehicle damaged a second parked vehicle, nothing else is known. Steering angle and driving direction are not further specified as per definition, even though it could have been derived from the claims. Another monetarily important accident type which is difficult to use regarding ADAS evaluation is 891.

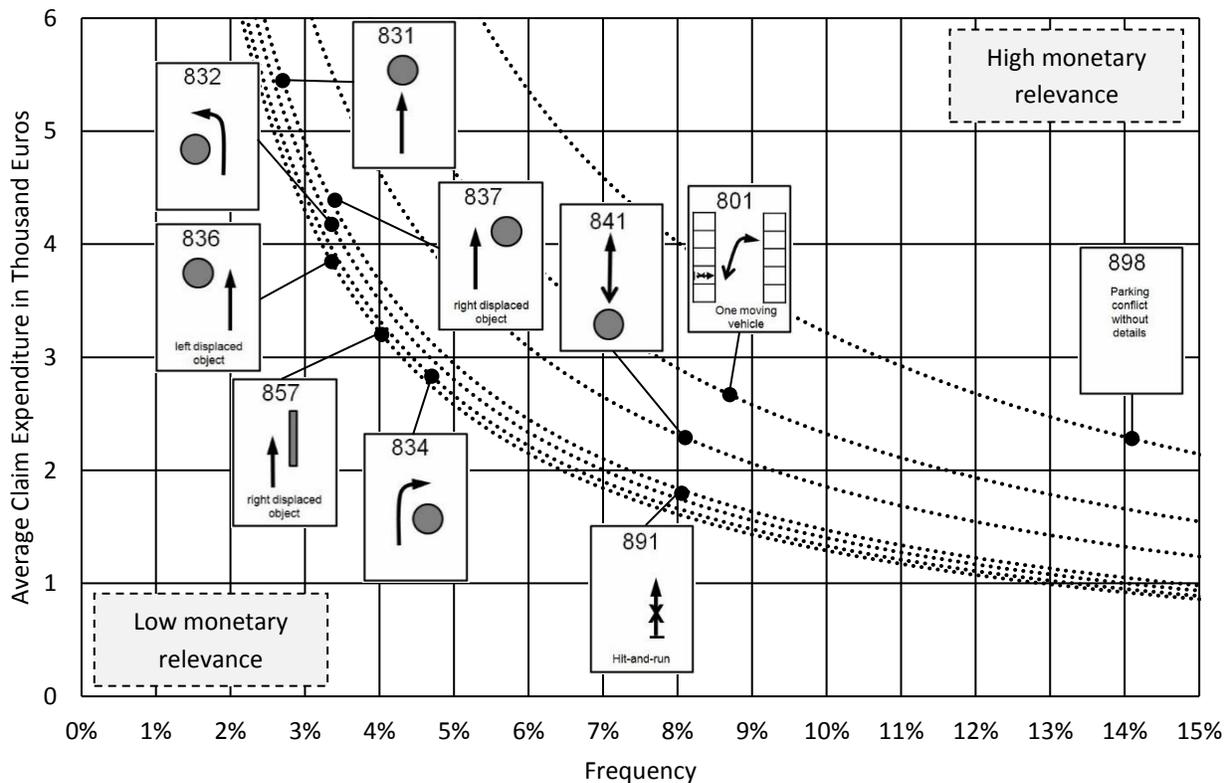


Figure 17: Frequency and average claim expenditure of accident type 8 (Audi A8 MoD collisions), picture source [17].

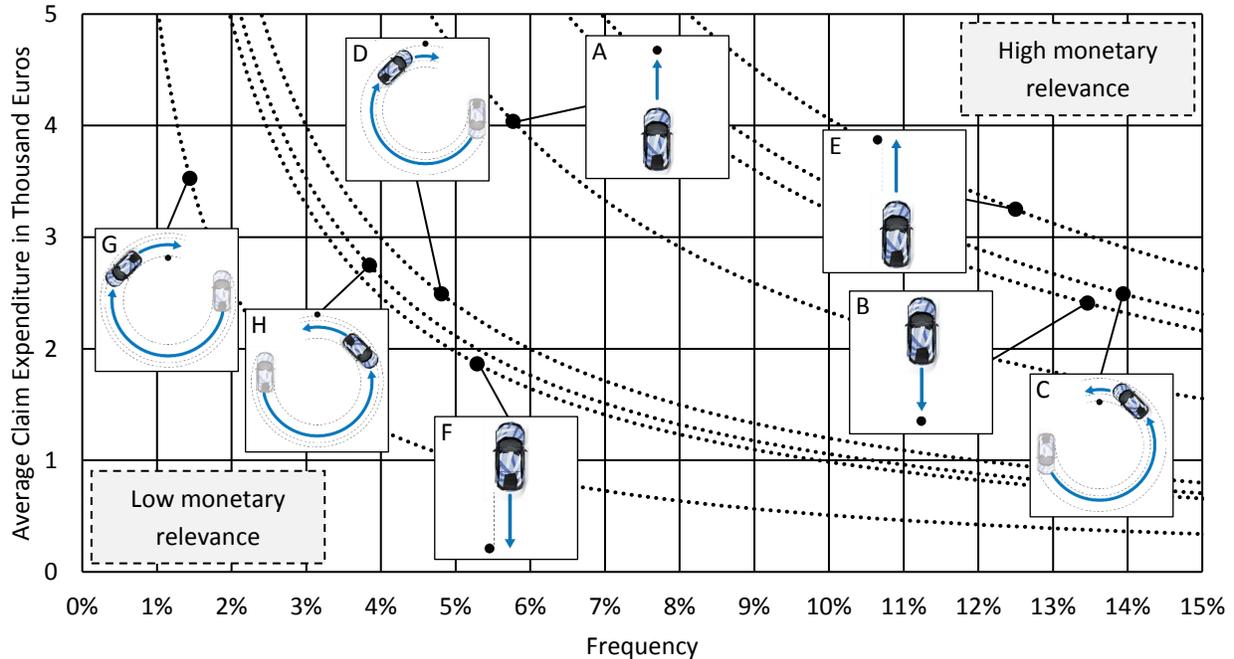


Figure 18: Frequency and average claim expenditure of test scenarios for prospective analysis (Audi A8 MoD collisions), picture source [22].

The accident type 891 describes hit and run accidents in which, besides damages, nothing else is known regarding the accident kinematics. In order to decrease inaccuracies due to low information levels, different accident types that have no influence on the function of the ADAS (due to sensor layout) e.g. position of object (left / right) or object size (small diameter / large diameter) were accumulated and combined in eight test scenarios [22]. Accident types (regarding parking and maneuvering) involving two vehicles (e.g. 801) and accident type 898 were allocated manually using the high-detail damage data within the database. Within each test scenario, the most difficult situation for the ADAS to address is performed (e.g. collision test against small ISO-pole (diameter: 75 mm [24]) vs. large wall). Collisions with other vehicles (e.g. accident type 801) were treated as collisions with objects as there is no difference regarding the addressability for ADAS.

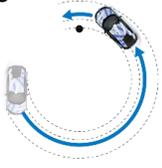
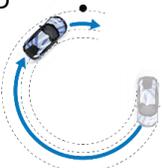
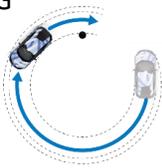
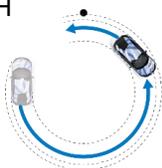
The following test scenarios were developed (Table IV). Figure 18 shows 127 accident cases out of the assessed accident occurrence of 255 Audi A8 damage claims in terms of frequency and claim expenditure analogue to Figure 17 and describes the monetarily most significant accident kinematics in terms of parking and maneuvering. It can be derived, that test scenarios E, C and B have the highest monetary avoid-

ance potential regarding ADAS. Using these test scenarios in simulation or real test, ADAS addressing parking and maneuvering accidents can be evaluated prospectively, addressing a total potential of almost 50 % of all MoD collision cases representing a total monetary potential of 40 %.

DISCUSSION AND LIMITATIONS

For the presented research, property damage insurance claims of Audi vehicles of the years 2013 and 2014 provided by Allianz Center of Technology (AZT) and Allianz Automotive Innovation Center (AIC) were analyzed. Therefore, this analysis is only valid for Audi vehicle respective Audi driver clientele. Due to high evaluation efforts per accident claim, representative data samples of approximately 450 - 480 damage claims were generated for different vehicle models dependent on the corresponding claim expenditure. Damage claim samples of MoD and TPL claims of Audi A1, A3, A4, A6, A8, Q3, Q5 and Q7 were analyzed. The conducted analysis in this paper was performed using 255 MoD Audi A8 damage collision claims, as this sample was holistic. The impact of third party liability claims was estimated, as the cost of TPL cannot be predicted using accident kinematics. Approximately 18 % of the available damage claims were not usable for ADAS evaluation due to non-accessible claims and hit and run accidents.

Table IV: Test scenarios for ADAS addressing parking and maneuvering.

Test Scenario [22]	Accident Kinematics
A 	Collision with ISO-pole driving forward straight.
B 	Collision with ISO-pole driving backward straight.
C 	Collision with ISO-pole cornering inside driving forward. Performed turning left or right.
D 	Collision with ISO-pole cornering outside driving forward. Performed turning left or right.
E 	Damage due to grazing on the left or right side driving forward.
F 	Damage due to grazing on the left or right side driving backward.
G 	Collision with ISO-pole cornering inside driving backward. Performed turning left or right.
H 	Collision with ISO-pole cornering outside driving backward. Performed turning left or right.

CONCLUSIONS AND OUTLOOK

In this paper, a methodology to retrospectively and prospectively evaluate ADAS for property damage is proposed. The method is divided into the sections data source, database and analysis. Regarding data source, different resources of data were investigated. Analysis showed that insurance data provides the most representative accident data, as also accidents that were not reported to the police are included. In the next step, a database layout for in-depth accident databases addressing property damage was proposed. As the information level within property damage accidents is generally low, this paper proposes to deeply research damaged vehicle components, locations and repair methods. Furthermore, damages to vehicles are connected to corresponding directions of the impacting force in order to reconstruct possible accident kinematics. Resulting accident kinematics can be directly connected to ADAS functionalities. Using equipment rates of ADAS, retrospective monetary effectiveness evaluations can be performed. Utilizing Audi A8 MoD collision damage claims, a high monetary potential of ADAS addressing parking and maneuvering was determined. Due to an already high installation rate of corresponding ADAS and high uncertainty factors e.g. unpredictable driver reaction, a necessity for automatically intervening ADAS was shown. Test scenarios to prospectively evaluate ADAS were developed by Feig and Schatz using the in-depth accident database. Research shows a monetary potential of 40 % regarding parking and maneuvering within the analyzed Audi A8 MoD collision cases. Using these test scenarios, prototype ADAS in the field of parking and maneuvering can be evaluated.

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Julian Schatz (corresponding author) initiated and implemented this paper. Philip Feig contributed to test scenario development and database layout of this paper, critically revised the manuscript and is working within the same research project. Dr. rer.nat. Johann Gwehenberger, Marcel Borrack and Rolf Behling supported database acquisition. Prof. Dr.-Ing. Markus Lienkamp made an essential contribution to the conception of the research project. He critically revised the paper for important intellectual content. Mr. Lienkamp gave final approval for this version to be published and agrees to all aspects of the work. As a guarantor, he accepts responsibility for the overall integrity of the paper.

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