ADAC accident research – accident analysis based simulation of the most dangerous scenarios

Thomas Unger*, Johannes Ludwig Haslbeck*, Prof Dr Stefan-Alexander Schneider**

*ADAC Technik Zentrum, Otto-Lilienthal-Strasse 2, 86899 Landsberg a. Lech, Germany
** Kempten University of Applied Sciences, Bahnhofstrasse 61, 87435 Kempten, Germany

Abstract

For more than a decade, ADAC accident researchers have analysed road accidents with severe injuries, recording some 20,000 accidents. An important task in accident research is to determine the causative factors of road accidents. Apart from vehicle engineering and human factors, accident research also focuses on infrastructural and environmental aspects.

To find out what accident scenarios are the most common in ADAC accident research and what driver assistance systems can prevent them, our first task was to conduct a detailed accident analysis.

Using CarMaker, we performed a realistic simulation of accident scenarios, including crashes, with varying parameters. To begin with, we made an initial selection of driver assistance systems in order to determine those with the greatest accident prevention potential.

One important finding of this study is that the safety potential of the individual driver assistance systems can actually be examined. It also turned out that active safety offers even much more potential for development and innovation than passive safety. At the same time, testing becomes more demanding, too, as new systems keep entering the market, many of them differing in functional details.

ADAC will continue to test all driver assistance systems as realistically as possible so as to be able to provide advice to car buyers. Therefore, it will be essential to develop and improve test conditions and criteria.

MOTIVATION

There is evidence that active and passive safety systems have contributed substantially to the positive trend in accident statistics over the past decades. Unlike passive safety systems, which are designed to mitigate the consequences of accidents, active safety systems can actually prevent accidents. Among the latter, ESC (electronic stability control) and ABS (anti-blocking systems) have proved to be particularly effective in the past few years.

Passive safety systems, such as belt tensioners, airbags, improved crumple zones and passenger compartments, also reduced the number of accident victims. Although there is still some potential for development here, too, it is considered much lower than that of active safety systems.

Current safety-oriented driver assistance systems can already contribute to active accident prevention. The aim of this paper is to determine the most promising of these systems. For this purpose, we will identify the most common accident scenarios, simulate them using special software (IPG CarMaker), conduct an efficiency analysis to determine the most important driver assistance systems for these scenarios and then apply them to the accident scenarios in another simulation.

ADAC ACCIDENT RESEARCH

Launched by the ADAC Technik Zentrum in Landsberg am Lech in 2005, the ADAC accident research project aims to contribute to improvements in active and passive vehicle safety and to increase road safety in general.

The key data source for ADAC accident research is air rescue. ADAC HEMS crews are tasked with documenting and keeping records of accidents allowing the subsequent assessment of accident parameters by accident researchers.

Further accident-related information is then culled from other data sources (police, public prosecutors) to complete the picture.

A total of 18,925 cases were documented in the ADAC accident research database from the beginning of the project until mid-August 2015. This means an average of 155 cases per month or approx. 1,860 cases per year since the start of the project. The current average is approx. 3,200 cases per year. It should be noted though that the database includes hardly any night-time accidents because – with few exceptions – HEMS helicopters are not on standby around the clock. This is a unique feature of ADAC accident research. The statistics comprise a total of 639 individual data per case, split up into various subcategories, such as vehicle, patient, etc.

Evaluations of these cases allow e.g. an efficiency analysis of individual components of differently equipped vehicles in similar accident scenarios. For instance, if ESC is installed in vehicle A but not in vehicle B (their equipment being the same otherwise), the efficiency of a system is easy to determine by evaluating the accident dynamics, such as lane deviation. This frequently involves accident reconstruction. In addition to improving vehicle safety, the ADAC accident research project also aims to further improve crash test procedures. It goes without saying that accident data are a particularly important criterion in this regard. ADAC accident research data can also be useful for first responders.

DETERMINING THE MOST IMPORTANT ACCIDENT SCENARIOS

This section focuses on the most important types of road accidents, which will be determined by evaluating official statistics and the ADAC accident research database.

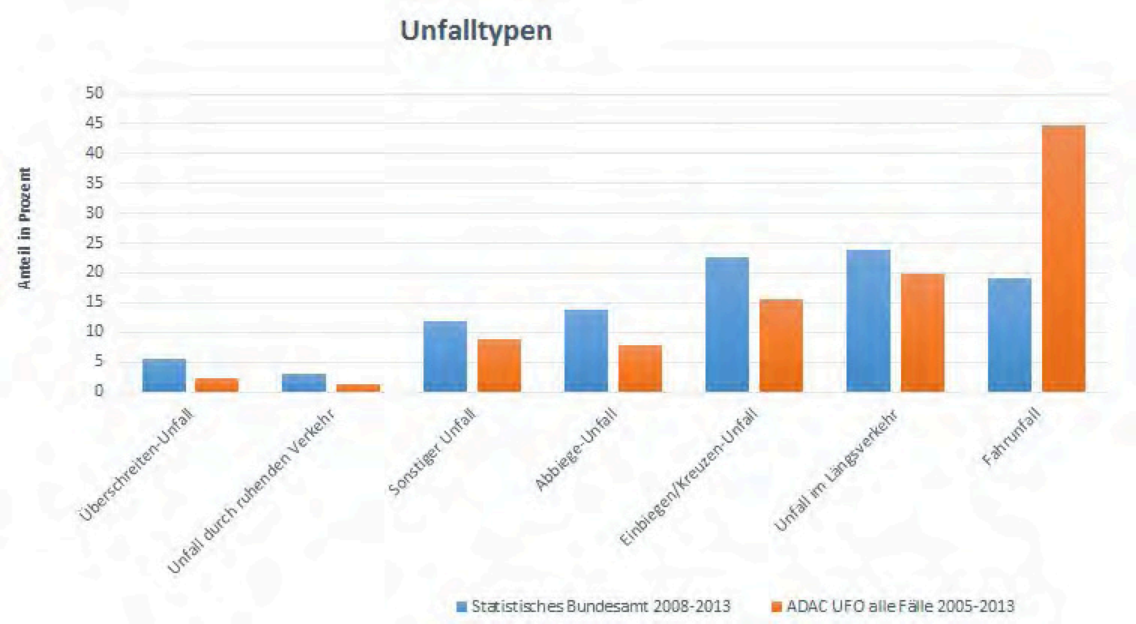

Figure 3.1: Accident types in percent according to official statistics and ADAC accident research *[3]*

Figure 3.1 shows considerable discrepancies in the percentage of each accident type in a direct comparison between official statistics and ADAC accident research data. This is also evident from the frequency ranking of accident types in Table 3.1.

Accident type	**Ranking (Federal Statistical Office of Germany[3])**	**Ranking (ADAC)**
Loss of control accident	3	1
Turning accident	4	5
Accident joining/crossing traffic	2	3
Road-crossing accident	6	6
Accident caused by parked/stopped vehicle	7	7
Head-on, rear-end, sideswipe	1	2
Other accidents	5	4

Table 3.1: Ranking of accident types by frequency

The filter criterion applied here is ADAC air rescue from whom the ADAC accident researchers receive their data, mostly involving severe accidents. This shift towards severe accidents explains the high percentage of loss of control accidents. Since this type of accident occurs more frequently on extra-urban roads where speeds are usually much higher than in urban traffic, the resulting injuries are severe in most cases. Focussing on severe accidents, most crashes occur on extra-urban roads (unlike the totality of accidents).

Based on the accident type numbers [4], which amount to 296 in total, we conducted a specific database evaluation to establish which accident type numbers are documented most frequently in the ADAC accident research database. The official statistics do not indicate the frequency of each accident type number, preventing a comparison with all accidents recorded by the police.
We evaluated cases up to the end of 2013. There is a total of 2,167 datasets for the period from 2005 to 2013, providing sufficient data.
Since the present study requires a reasonable restriction of accident scenarios and, consequently, accident type numbers as well, we made a selection.
The study focuses on the third most frequent scenario (accidents joining/crossing traffic) as an example. This scenario is interesting in terms of safety and very frequent in the official statistics.

Accident type	**Accident type**	**Number of cases**
141	Loss of control accident	318
101	Loss of control accident	231
102	Loss of control accident	214
681	Head-on, rear-end,	120
211	Turning accident	115
302	Accident joining/crossing	99
301	Accident joining/crossing	75
321	Accident joining/crossing	65

Table 3.3: Most frequent accident type numbers *[20, end of May 2015]*

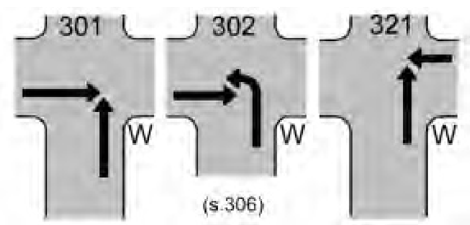

Figure 3.4: Selected accident type numbers [4]

The above Figure 3.4 shows the selected accident type numbers as they appear in the accident type catalogue. They represent the accident scenarios in the subsequent CarMaker simulation.

Key parameters of the accident scenario

The key parameters of the selected accident scenarios are analysed individually on the basis of a representative selection of samples.
The following parameters are considered to be most relevant (most frequent value) for accidents joining/crossing traffic:

Accident type number (302)

Figure 3.8: Typical accident joining/crossing traffic (accident type number 302) in CarMaker

Location: extra-urban

Number of vehicles involved: 2

Road condition: dry

Road intersecting angle (reference point: driver with right of way): 75°-90°

Visibility impaired: no

Downward / upward gradient of minor road vs. major road: 0 - plane

Irregular pavement: no

Degree of curvature / road 1 vs. major road: 0°-5°

Degree of curvature / road 2: 0°

Number of lanes (incl. turn lanes) / road 1: 2

Number of lanes (incl. turn lanes) / road 2: 2

Signs: Right of way

Behaviour of driver with right of way: braking

Braking force applied, if any: moderate – up to approx. 75%

Speed limit / road 1: 71-100kph

Speed limit / road 2: 30-50kph

Vehicle class: family

Time of day: 15-18 hours (summer)

Light conditions: daylight

SIMULATION OF MOST RELEVANT PARAMETERS OF THE ACCIDENT SCENARIO

The accident scenario is based on accident type number 302, i.e. the driver of the “ego” vehicle wants to turn left from the minor road onto the major road. However, another vehicle approaches from the left. After approx. 16.5 seconds, the driver on the minor road brakes upon recognising the Right of Way sign. Just before entering the intersection, the car reaches the minimum speed of 3.7kph and is in the other car’s lane at t=25.7s. However, the driver of the other car, having recognised the situation very late, brakes after 25 seconds. Too late: the crash occurs at approx. 25.9s. The car on the major road has a residual speed of approx. 70kph. However, the opponent’s change in velocity after the crash cannot be simulated realistically.

Figure 4.10: The most frequent accident joining/crossing traffic in the IPGControl data window and in IPGMovie

The decisive factor is that the driver on the major road had less than one second left for braking. This was barely sufficient to reduce the initial speed (96kph) by no more than approx. 25kph. Even full braking force (assuming a deceleration of 10 m/s2) allows the car’s speed to be reduced by no more than 32.4kph prior to the crash. In this case, the residual speed is still 63.6kph. However, this is a very idealistic assumption, which does not consider the average response time of approx. 0.5s to more than 1s. For a safe response to the “ego” car suddenly entering the intersection, emergency braking must be initiated before.

Taking into consideration the response time (1s) and assuming a moderate deceleration of 7m/s2, the 3.8s resulting from the simulation actually yield a time to collision (TTC) of 4.8s. This is the time it takes an alert driver applying moderate braking force to decelerate the car on the major road to standstill. However, the simulation shows that this is not necessary. It is just a matter of ensuring that the car on the minor road has completed the left turn before the other car reaches the intersection. This will be ensured already if the driver applies moderate braking force from t=23.5s, so that (assuming a response time of 1s) a TTC of 1+2.4=3.4s is required. Driver assistance systems which execute emergency braking reliably and usually respond much faster than human drivers achieve a TTC of around two seconds in the simulated scenario, thus preventing an accident by braking. Evasion is an alternative crash avoidance manoeuvre.

Intersection assistant

The intersection assistant presented herein uses cameras and radar sensors to cover the short, mid- and long ranges. In addition, the system also scans the sides of the vehicle. The sensors of the Mercedes-Benz S500 Intelligent Drive research vehicle, which scan the car's surroundings, may serve as a reference. Due to the complex situations at intersections, intersection assistants must meet high requirements in terms of scanning a vehicle's surroundings. This explains the lack of systems suitable for series production. In situations where time is extremely short, active intervention by the system, e.g. auto braking, may be an option. However, there should be a warning first. Assuming optimal conditions, sensor-based intersection assistants scanning a vehicle's surroundings may prevent 28 percent of all accidents resulting in personal injury [2]. However, a purely sensor-based intersection assistant has the same limitations as the human eye: other road users, structures, plants etc. impairing visibility are a major problem. This is where C2X (C2C and C2I) comes in. We will present this approach in the further course of our study.

The simulation in CarMaker comprised two joining/crossing traffic scenarios with intersection assistants. For the sake of clarity, however, we will describe only one of said scenarios here.

Figure 5.16: Intersection assistant designed to prevent accidents joining/crossing traffic.
Red cone: LRR, yellow cone: MRR.

The most frequent accident scenario of this type is shown in Figure 5.16. A crash is prevented because the other car is detected early by the long range radar and the mid-range radar. Even the detection by the MRR after 22.8 seconds means a remaining TTC of 3.1 seconds, i.e. sufficient time to prevent the collision (based on the calculations in section 4.4). Plus, the LRR recognises the other car already after approx. 18 seconds and can alert the driver from that moment on.

Car-to-car communication

Car-to-car communication, or C2C for short (also abbreviated as V2V), is a very interesting approach towards increased road safety. The connected car concept was already tested in a large-scale field experiment called "simTD - Sichere Intelligente Mobilität Deutschland".

C2C is a warning system relying on sensors to detect critical situations in traffic by scanning the car's surroundings. These sensors vary from one vehicle to another. However, to ensure the system's safe operation, there should be a standard. In the simTD field experiment, the system had a range of 580m measured on a straight extra-urban road and urban ranges, even with buildings in the way, of no less than 100m. TTC and the reliability of data transmission were very satisfactory in most cases, which means the system is basically ready for the market.

For the CarMaker simulation, the ego vehicle was equipped with the four sensors already used for the intersection assistant. These sensors scan the surroundings of the car and were used to cover the vehicle front. However, we did not mark the detection areas with cones in various colours, not least because the C2C in the scenarios analysed was always the driver assistance system that first detected the other road user. An exact simulation of its function was not feasible, however. To indicate our own location by periodic signalling, we flashed the left reversing light. Even under the pessimistic assumption of a signal range of 200m, the 5.3s remaining in the joining/crossing traffic scenario when braking extremely late and at only 5 m/s2 are still sufficient to stop the ego vehicle completely before entering the intersection. The other car would take 5.9s to get there. However, a longer signal range (cf. simTD) and earlier braking of the ego vehicle are realistic. Due to the long range of C2C, the accidents joining/crossing traffic considered are easily avoidable even in the case of objects impairing visibility.

FINDINGS AND OUTLOOK

One important finding of this study is that a large number of road accidents can be mitigated or prevented by driver assistance systems. Driver assistance systems also proved to be an important element in ADAC statistics. We compared the safety potential of each driver assistance system by an extensive analysis of the existing literature. It also turned out that active safety offers even much more potential for development and innovation than passive safety. At the same time, testing becomes more demanding, too, as new systems keep entering the market, many of them differing in functional details. ADAC will continue to test all driver assistance systems as realistically as possible so as to be able to provide advice to car buyers. Therefore, it will be essential to develop and improve test conditions and criteria.

Outlook

Pedestrians and cyclists are rarely involved in the accident scenarios presently analysed, but frequently appear in the totality of accidents, especially in urban accident scenarios. Subsequent studies could focus on this aspect and analyse the corresponding scenarios as well as simulate them in CarMaker. Customer acceptance will play an important role in the success of novel driver assistance systems. In this connection, surveys and assessments by test subjects are important tools which are available to ADAC and should keep on being used. An automated test routine could be written for CarMaker in the form of an easy-to-use graphic user interface or programme. Should ADAC continue to test driver assistance systems by simulation, CarMaker could be a useful tool.

With a few exceptions, the test procedures for driver assistance systems are not very far advanced. Therefore, the suggestions made by this study are no more than that. Rather, they serve as guidelines for the actual test.

Limitations of the study

Since the IPG CarMaker vehicle dynamics simulation provides no model for damage to the ego vehicle, it does not allow simulation of the actual crash. Therefore, it is also impossible to assess the deformation of the bodywork and the severity of the accident victims' injuries. A dummy was used, for example, in the VISAPS research project[1], but dummies are not always available. The present study focuses exclusively on passenger cars, which predominate much more in the ADAC UFO than in the totality of accidents. Moreover, scenarios involving motorcycles can only be simulated using MotorcycleMaker. CarMaker5 allows moving pedestrians to be simulated and detected by the vehicle sensors. Therefore, this version should be used to simulate accidents involving pedestrians.

LITERATURE

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