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Active Vehicle Safety Studies Based on In-Depth Accident Investigations – Possible or not?

Abstract

Since 2005 the German In-Depth Accident Study (GIDAS) also records aspects of active vehicle safety. This is done because vehicles are fitted with an increasing number of active safety devices which have undoubtedly an influence on the number, severity and course of accidents. Accident researchers expect that collecting active safety data will facilitate to assess and quantify the impact of these and future devices. It is the aim of this paper to outline benefits and limitations associated with the recording of active safety aspects within in-depth studies.

An overview about possible areas where active safety data can be useful will be given. For that purpose single safety or comfort systems will be selected to estimate the effects of an accident database which includes variables associated with these systems.

Questions with regard to the limitations of collecting active safety data will be addressed. Possible items are for example the usability of the data recorded, the real accident cause, the small number of relevant accidents, the time span needed to gather a sufficient dataset, the small share of vehicles equipped with a certain system or different functionalities of systems that are supposed to fall in the same category.

As a result user needs for a reasonable data collection of active safety elements will be elaborated.

Introduction

In 1973 German In-Depth Accident Studies were started at the Medical University Hannover on behalf of the Federal Highway Research Institute (BASt) to establish a database containing accident data. This database should help to support research analysing accident causations and thus improving passive vehicle safety, rescue or road infrastructure design. In the last years vehicles are fitted more and more with active safety systems like e.g. anti-lock braking systems (ABS), traction control or vehicle stability control (VSC) which are designed to enhance vehicle dynamics and to avoid accidents. Especially for VSC several studies show the positive impact of the system on accident statistics, e.g. see [1-6]. This development leads to the decision to record aspects of active vehicle safety in the German In-Depth Accident Study (GIDAS) as well. The data collection was started with the year 2005. Features like e.g. seat-belt reminder, park distance control or cruise control are included now. On the one hand it is recorded if the vehicle is fitted with some of these devices, on the other hand it is recorded how sophisticated the system is or which kind of functionality the system offers. It is the aim to be able to assess the positive or negative impact on traffic safety associated with these devices after several years of data collection.

Since active safety systems are developed to avoid accidents it seems to be an antagonism to detect effects in in-depth accident studies. Accidents which are avoided by these systems will not take place and thus will not appear in the database. However it might be possible to elaborate cases in which a certain vehicle segment is equipped with a safety device and a second comparable segment is not. Such a situation would allow to check if the segment of vehicles not being equipped is to a higher extent involved in special classes of accidents than the vehicles being equipped.

In the following sections the possibilities of collecting active safety data will be outlined. But also issues which limit the usability of in-depth studies recording variables of active safety will be taken into account.

Attributes of Active Safety

In a special record GIDAS collects the information of about 80 safety aspects associated with active safety. These systems address among others driving stability, braking performance, tyres visibility, lighting or ergonomics.

Some examples of active safety systems being recorded in GIDAS are:

- Cruise Control/Adaptive Cruise Control.

- Lane Keeping Assist/Lane Change Assist.
- Mirrors.
- Daytime Running Light.
- Advanced Frontlighting Sytems.
- Night Vision.
- Intelligent Stop Signal.
- Run-Flat Tyres.
- Brake Assist.
- Seat-belt Reminder.

The last example “Seat-belt Reminder” which in its effect actually is part of the passive safety is recorded together with active safety devices because wearing or not wearing a seat-belt is a decision taken far before an accident happens.

Also the function and operation of communication systems and comfort systems which enhance or at least influence the condition of the driver are part of the active safety record. It is for example checked how the phone or the navigation system can be operated, if a voice control is there, how the gear shift can be operated or where the buttons and switches for the engine brake or the distance control system are etc.

Some of the active safety systems can be found together with the primary information of the vehicle in another record of the GIDAS database. This is the case for technical failures, vehicle stability control systems or anti-lock braking systems. Information about active safety features is also available via the recorded questioning of the drivers or other participants of the accident. There it is asked how the reaction of the driver was with regard to steering or braking, how the visibility conditions were and what was done or operated before and during the course of the accident and why. The questioning comprises also if the driver has knowledge about certain safety features like ABS or brake assist which his vehicle is fitted with. The driver also should state if he had got some feedback from operating safety systems.

The GIDAS Codebook [10] yields a detailed listing of all active safety variables being recorded.

Examples

For each of the active safety variables a certain value is recorded in GIDAS indicating if the vehicle was equipped and – if yes – representing system properties.

In the following some examples of the values for four single safety systems are presented. In addition the number of vehicles equipped with the system in the GIDAS database 2005 is given in brackets. This number allows to get an impression how often certain active safety systems can be found in traffic and also in accident data. At the same time one can estimate if it is worth to evaluate the database with regard to a special safety device or if it is needed to wait for several further years of data collection. In total 1268 vehicles were involved in the accidents stored.

The variable “seat-belt reminder” can get the values:

0) not applicable	(214)
1) yes (without add. info)	(38)
2) no	(677)
3) only driver	(18)
4) driver and front pass.	(40)
5) first and second row	(1)
8) others	(0)
9) unknown	(155)

That means only 97 vehicles had a seat-belt reminder for at least one seat.

The variable “daytime running light” can get the values:

0) not applicable	(83)
1) yes (without add. info)	(68)
2) no	(858)
3) mandatory	(12)
4) switched on manually	(63)
8) others	(1)
9) unknown	(61)

Thus 144 vehicles drove with daytime running light.

The variable “run flat tires” can get the values:

0) not applicable	(80)
1) yes (without add. info)	(1)
2) no	(949)
3) with support ring	(0)
4) reinforced side wall	(0)

5) repair kit (1)

8) others (0)

9) unknown (115)

The result shows that one vehicle was equipped with run flat tires and for one vehicle a tire kit was used. Although all vehicle models of several series of one German car manufacturer are fitted with run flat tires standardly for more than one year nearly no relevant vehicle can be found in the database.

The variable “bend lighting” can get the values:

0) not applicable (117)

1) yes (without add. info) (1)

2) no (991)

8) others (0)

9) unknown (37)

Also the bend lighting is recorded only in one accident although some premium class cars can be purchased with the system. But here the problem is not the equipment rate alone but it might also be difficult to detect if the headlights comprise a swivelling mechanism.

In Figure 1 for a selection of the active safety variables the number of vehicles equipped with a device is illustrated for the GIDAS dataset of the year 2005.

The result shows that some safety or comfort devices like right mirrors, phone or cruise control occur frequently in the dataset promising successful future evaluations of the GIDAS database with regard to active vehicle safety. However, even when the figures are high they do not tell anything about the cause of the accident or if the safety system had any influence on it.

Other systems like collision mitigation or collision warning do not appear in the dataset. Either only few vehicles are equipped with these (sometimes expensive) systems up to now or the systems are not available because research and product development have not finished yet.

Benefits of Recording Active Safety Data

To collect active safety data within in-depth accident studies is based on expectations that the data will be suitable to show the impact of any safety, comfort or communication device on traffic safety, either positive or negative. To know these impact will enable researchers or policy makers to carry out cost-benefit assessments for the introduction of safety measures and to take corresponding actions. The latter was done in the past mainly for passive safety devices like seat-belts or airbags. Now the

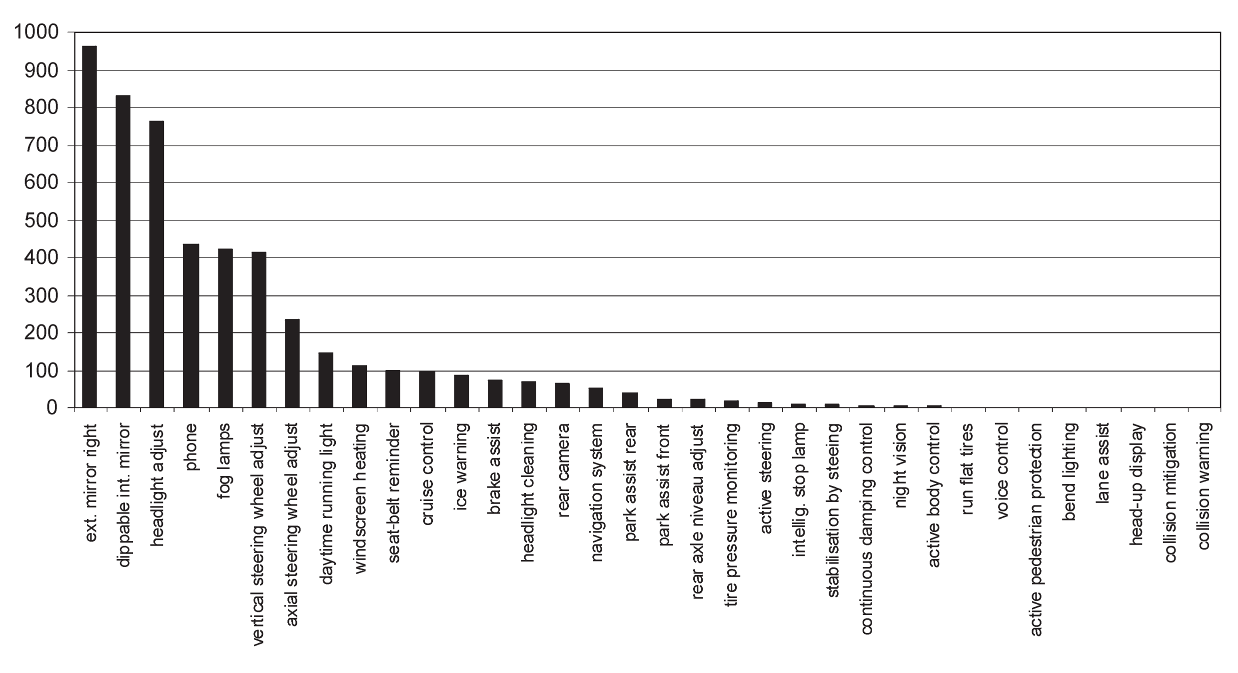

Figure 1: Number of selected active safety devices recorded in GIDAS 2005; in total 1268 vehicles were involved in the accidents stored

analyses should be extended to measures concerning longitudinal and lateral control of vehicle dynamics, vision, conspicuity or ergonomics. Knowledge about the real safety benefits will on the one hand help to optimise the systems and on the other hand to support legislation.

Researchers in the area of vehicle safety therefore hope to be able to answer questions like e.g.:

- In how far does Adaptive Cruise Control reduce (severity of) rear end accidents?
- What is the influence of lane keeping or lane change assist on accidents with vehicles in the adjacent lane?
- Does a head-up display reduce accidents due to eye distraction?

The importance of gaining information about active safety will increase in the next years since progress in vehicle safety will more rely on accident avoiding systems rather than on classical passive safety measures.

Examples

To outline what might be possible in future we did a preliminary check of the database with regard to the right exterior mirror. Since the data basis for active safety is still small, as was shown above, first evaluations would not yield usable results for systems with low equipment rate. Thus the right mirror was selected because most of the vehicles are fitted with it. The right mirror should have an influence on accidents with vehicles driving parallel in the same direction (German accident type 6 and kind of accident 3). 325 accidents were of this type and kind. But only one of these accidents was caused by a vehicle without a right mirror. Fortunately this accident dataset involved comments on the course of the accident which revealed that the accident happened between two bicycles.

How the evaluation of accident data with regard to active safety could work successfully is demonstrated by means of four examples. The first one was elaborated by BASt (Federal Highway Research Institute). The others were taken from literature.

Improved lighting

The first case addresses a safety device being part of the vehicle's lighting. It was examined by BASt using the national accident statistics of Germany. The active safety device which is dealt with here is anonymised to avoid conclusions with regard to the manufacturer.

To analyse the effectiveness of the device changes in accident numbers before and after introduction of the device are examined. Accidents which might be influenced by the safety system (relevant accidents) are the focus group for the analysis. To assess changes in accident numbers it is necessary to have a comparison group which should have a similar structure as the focus group. This guarantees to be able to eliminate effects which change accident numbers but are not due to the safety device. The ideal case is that the safety device only affects accidents of the focus group and not of the comparison group.

In the study on hand only accidents with vehicles which got their first registration in the same year are regarded. In year 1 of the study no vehicle was equipped with the system. In year 2 some of the vehicles were equipped with the system.

The focus group comprises relevant accidents with vehicle types which were equipped with the system in year 2 and accidents with the same vehicle types (being not equipped since the device was not available) in year 1.

The comparison group comprises all other accidents in year 1 and year 2 with the vehicle types mentioned above.

Table 1 gives an overview about the four groups of accidents taken into account and the associated accident numbers.

Whether the active safety system is effective can be seen by comparing the ratios of accident numbers between relevant and other accidents. This ratio

	vehicle types fitted with the safety device in year 2	
	year 1	year2
focus group (relevant accidents)	n11=63	n12=94
comparison group (other accidents)	n21=455	n22=617

Table 1: Accident numbers before and after the introduction of an active safety device

should have become smaller in year 2 if there is an improvement due to the safety device. For the system examined here this is not the case: the ratio is 0.15 in year 2 and 0.14 in year 1. So it was not possible to demonstrate the benefit of the safety system. However, the result is not significant (on a 5% level) so that a positive impact of the safety device cannot be excluded on the basis of the existing accident numbers. This also holds for a negative impact which however is highly not assumed to occur.

There are several reasons why it was not possible to elaborate significant statements. In year 2 about 400,000 accidents with personal injuries or severe property damage were recorded. But only 94 accidents were relevant for the safety device. With this amount of data significance for the effectiveness of the safety system would have been achieved if the focus group developed 35% better than the comparison group. Another problem is that the national accident statistics only contains accidents with personal injuries or severe property damage and a big amount of accidents with only light damages is not included and could therefore not be analysed.

So an effectiveness of the safety device could not be proven and not be excluded. But on principle national accident statistic as well as in-depth studies are suitable to be applied to active safety systems. This statement is strongly supported by the next two examples.

ESP effectiveness

With the same method as described above Y. Page and S. CUNY [9] determined the effectiveness of ESP (electronic stability program) on French roads. They looked at ESP relevant accidents involving cars of the type Renault Laguna and calculated an effectiveness of ESP of 43%. In the calculation they also took confounders like driver age and gender, vehicle age, pavement status and year of accident into account. However it was assumed that other safety systems introduced at the same time like tire pressure monitoring systems did not influence the accidents considered and thus did not bias the result. To avoid a bias effect due to emergency brake assist an accident subset was selected for which braking did not apply.

GRÖMPING et al. [7] used the example ESP to show how to determine the safety impact of a rarely fitted system on accident risk. Using GIDAS data they calculated that 44.13% of loss of stability accidents among non-ESP vehicles could be avoided if all these vehicles were equipped with ESP. Taking covariates like driver age, weather or time of the day into account they were able to elaborate the influence of ESP for different scenarios. E.g. for a young driver with a car with worn tires on a rainy night ESP has an estimated accident avoidance potential of 35.6%. For a 60 years old driver with new tires on a dry day ESP has an accident avoidance potential of only 12.5%.

Brake assisting system in pedestrian accidents

In [8] L. HANNAWALD has outlined a method how to estimate the potential of primary and secondary safety measures. The method was exemplarily shown for the active safety system “brake assist” (BAS) in pedestrian accidents. Injury risk functions were calculated using logistic regression depending on the collision speed. Since the GIDAS (German In-Depth Accident Study) database includes initial speed, mean braking deceleration and the real collision speed derived from accident reconstruction it was possible to determine the benefit of BAS for the reduction of fatalities and injuries of pedestrians.

Brake assisting system and automatic emergency braking

BUSCH et al. [11] describe a method how to calculate prognoses of the safety benefit of accident avoiding systems on the basis of in-depth studies. They used data of GIDAS together with a computer simulation for the courses of the single accidents to estimate the impact of BAS and automatic emergency braking. The probabilities for injuries depending on the delta-v of the collisions are calculated with and without the safety system. The difference of the probabilities representing the safety gain of the system for one accident then is used to estimate the total safety benefit of the active safety measure by means of the national accident statistics.

As result the widespread use of BAS would reduce road traffic fatalities in Germany of about 3% and severe injuries of about 4%. The benefits are not only related to the passengers of motor vehicles but are especially high for bicyclists and pedestrians.

For a combination of BAS with an automatic emergency braking the estimated benefits are a reduction of both fatalities and severe injuries of about 6%.

Limitations

The possibility to benefit from collecting active safety data while analysing accidents at the roadside depends on the usability of the data recorded. A general and obvious prerequisite is that the physical figures and facts are ascertained correctly and the questions to the participants are answered truly.

Since active safety devices are entering the market at the moment the equipment rates of vehicles are still small. As a consequence one will not find these systems in many vehicles involved in the accidents of the database. Additionally in in-depth accident studies it is only feasible to record a limited number of accidents per year so that the probability to find an accident which includes a vehicle with the active safety system is small. Even more rarely will be the case that the safety device would have had an essential influence on the course of the accident.

That means that the time span to gather a sufficient dataset will be at least several years or even up to ten years. Evaluations carried out too early face the risk to detect short term effects of the active safety system only. More likely is the situation that the number of relevant accidents is so small that significance can scarcely be achieved (see example with regard to lighting given above).

For the assessment of the impact of many of the active safety features it is necessary to know the accident causation. The real reasons of an accident are mostly found out by reconstructing the course of the accident. This makes it possible to gain insight into the mechanisms behind and allows to interpret the calculated effects of a safety system. The importance of accident reconstruction especially for active safety is illustrated by the example with the brake assist [8].

Another issue that has to be considered in this context is that the safety systems might work different in similar but not equal situations. This will be the case with collision mitigation or collision avoidance systems which also take data from environment like detection of obstacles into account. Equal objects that have to be detected will never have exactly the same properties so that the reaction of the safety system might be different.

Anyway, two active safety systems aiming at one and the same situation (or being called the same) and whose data are therefore collected in the same category might have different functionalities. This would lead to the situation the effects calculated are false or allocated to the wrong device. This situation occurs likely if different manufacturers produce similar active safety devices but implement their own control strategy or philosophy. E.g. VSC systems of different manufacturers or even in different vehicle models of the same manufacturer are not identical. In accident studies therefore the group of relevant accidents which the safety system is pertinent in has to be selected carefully.

As it is often the case when doing statistics effects do not depend on one single variable but on a bundle of covariates. For accident studies these are e.g. driver age and gender, road conditions, weather and visibility conditions, mass and power of the vehicle etc.

The results of an analysis with regard to a safety system also might be biased by some side effects: new vehicles with a special safety system might e.g. have a different (perhaps more careful) driver population or the effect of the safety system is compromised by misuse (driving in darkness with the night vision picture only). Also active safety systems are mostly not introduced alone but the new car model is fitted with a combination of safety measures which in some cases even can only be bought as a bundle. Thus it will be difficult to allocate positive impacts to the appropriate safety system. Such side effects have either to be accepted or to be eliminated by selecting the right accident subsets as in [9].

Table 2 summarises the limitations and restrictions for collecting and evaluating active safety data in-depth accident studies.

Real accident causations unknown
Accident reconstruction is missing
Small numbers of relevant accidents occur
Long time span needed to fill the database
Few vehicles equipped with interesting safety systems
Active safety systems act depending on manufacturers' philosophies
Result biased
Covariates and their influence unknown
Results often not significant

Table 2: Limitations for collecting and evaluating actice safety data

Conclusion

Since active safety systems are expected to have a significant and increasing influence on reducing accidents, fatalities and injuries in the future this should show up in accident databases as well. In-depth studies therefore began to include active safety issues as new variables and to collect corresponding data. An assessment of the impact of active safety measures by means of accident analyses should help to optimise the systems and give advice for policy making with regard to vehicle safety.

For such an impact assessment it is necessary that accident data can offer information about the following items:

- Was the vehicle equipped with the safety system of interest?
- If yes, was the system enabled?
- If yes, did the system influence the course of the accident?
- Could a system which was not fitted to the vehicle have had an accident avoiding or mitigating effect if it was fitted?

To be able to answer these questions and as a consequence to determine the safety benefits of a system the user of the accident database needs as much cases and as detailed figures as possible. A sufficient number of cases will be reached earlier if more vehicles are equipped with the relevant systems. For the majority of active safety devices this will require to wait for several years.

Another prerequisite is that the real accident causes are known. Only with this knowledge it can be assessed if the active safety system has had a chance to interfere and do its beneficial job. Especially the case examining the effect of a brake assisting system mentioned above shows that accident reconstruction as a part of in-depth study is indispensable especially for active safety issues.

Although the number of recordings for active safety is still small and biasing effects do not allow for carrying out statistical evaluations the examination of single cases already helps to get insight into the accident avoiding mechanisms and the possible benefits of active safety devices. Especially for vehicle or system manufactures information gathered from these single cases can therefore be useful already at the time being.

As the examples for ESP show in-depth accident studies can already be used to evaluate the safety benefits for a few systems. For other systems some time of data collection will be needed. But if the demonstration of safety benefits will be possible for a safety system only fitted to a minority of vehicles now this would indicate a big potential for traffic safety since a coming high market penetration would lead to a high safety gain in the future. Under the assumption that the equipment rates grow linearly the effects in accidents and accident databases should increase nearly to the square since the vehicles being equipped once will remain in the stock for years.

There is no doubt that starting to collect active safety data was a necessary and sensible step but patience is needed for searching for effects in in-depth accident databases.

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