# Autonomous Emergency Brake (AEB) in HGVs

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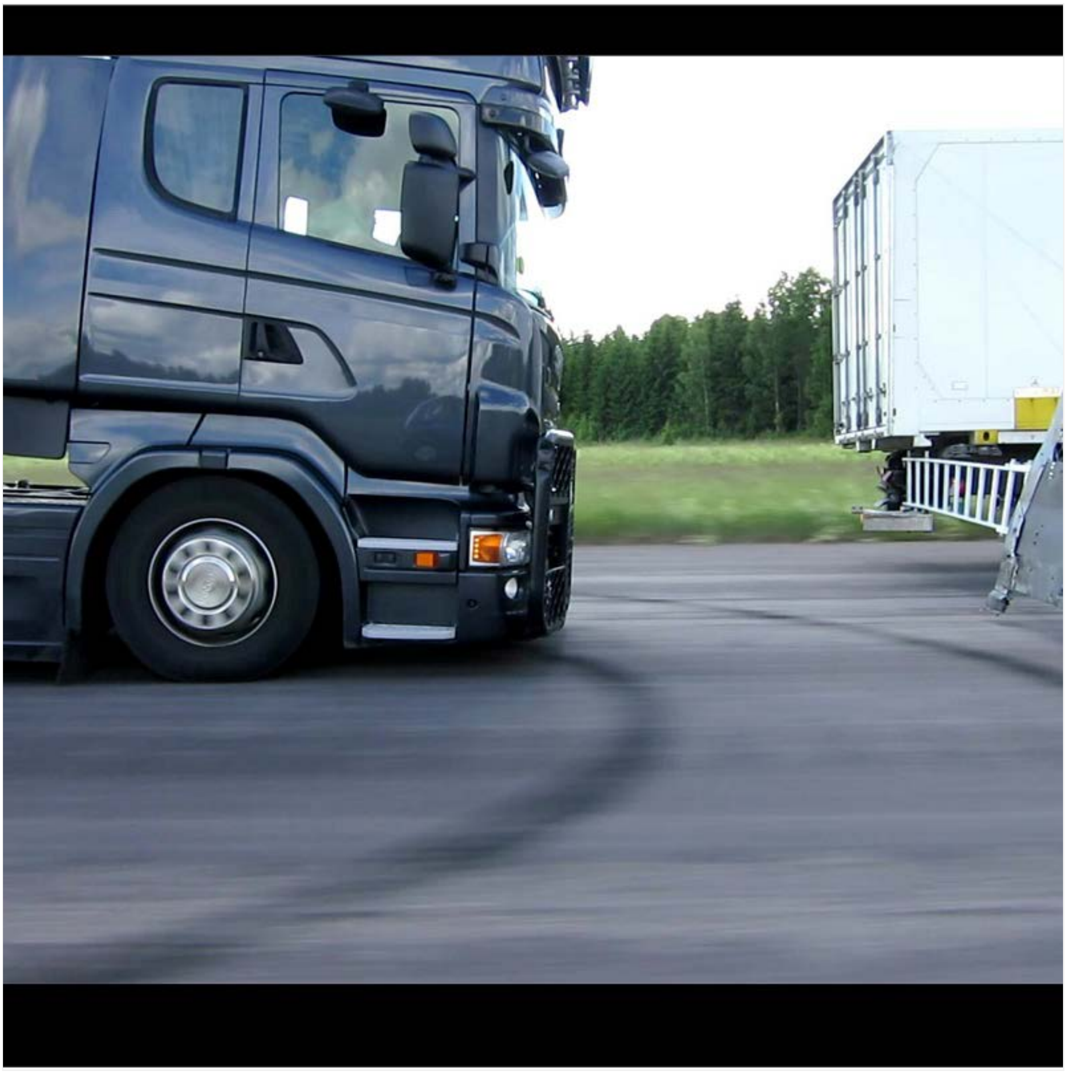

*Please note*: The studies included in this synopsis were selected from those identified by a systematic literature search of specific databases (see supporting document). The main criterion for inclusion of studies in this synopsis and the DSS was that each study provides a *quantitative effect estimate*, preferably on the number or severity of crashes or otherwise on road user behaviour that is known to be related to the occurrence or severity of a crash. Therefore, key studies providing qualitative information might not be included in this synopsis.

# 1 Summary

Mettel, C., Niewöhner, W., March 2018

## 1.1 COLOUR CODE: LIGHT GREEN

The bibliographic review on autonomous emergency brakes in HGVs suggests that this type of countermeasure can be given the colour code **light green** (probably effective).. This conclusion is based on the fact that the studies only provided an estimate of the benefits of this active safety system. The real-world benefit is hard to determine, because the systems are relatively new, and it is hard to separate their benefit from other safety systems. Besides, there is a possibility to deactivate the system by a shutdown of the driver.

## 1.2 KEYWORDS

ADAS; AEB; autonomous emergency brake; active safety;

## 1.3 ABSTRACT

The autonomous emergency brake (AEB) system was first introduced by Daimler for HGVs in 2006. This system was mainly developed to reduce crashes between HGVs and the rear end of traffic jams. Due to the big mass of the HGV and the large differences in speed, this accident scenario has serious consequences for the vehicles in the traffic jam. EU Regulation No. 347/2012 specifies the technical requirements and test procedures for AEB systems, and the fitting of "Level 1" systems is mandatory for all new vehicles since 01.11.2015. The AEB system first warns the driver of a risk of collision, and if the driver does not react appropriately, the system itself initiates an emergency brake. The minimum system effect requested by the law is a speed reduction of 10km/h.
The high end AEB systems in trucks can not only detect moving or stationary vehicles in front of them, but they can also detect pedestrians and cyclists during turning manoeuvres.
Since these systems are relatively new, there is not much data available about the benefits of the AEB. Also because of the fast developments of new ADAS it is difficult to determine the effectiveness of current systems and their abilities.
However, there have been some in-depth analyses of accidents of HGVs and their avoidability had the HGV would have been equipped with an AEB. These analyses show a great potential of these systems: around 52% of all rear-end collisions could be avoided, and up to 50% of all fatalities in an accident with a HGV on motorways could be adressed.

## 1.4 BACKGROUND

### 1.4.1 Prevalence

Autonomous emergency brakes can influence road safety positively, especially in rear-end collisions on motorways. AEB systems can be characterised by their detection of moving or stationary vehicles or other road users. Depending on the type of AEB such systems could prevent many of heavy rear-end collisions or at least reduce the accident severity.

### 1.4.2 Definitions of safety effects

- **Crash avoidance:** According to the type of AEBS, crashes can be completely avoided.

- **Reduction of the injury severity:** Not in every crash scenario is it possible to avoid the crash, but because of the warning or the system stepping in, the collision speed can be reduced. In correlation with the reduction of the collision speed, the accident severity can be reduced. The minimum system effect for "Level 1" requested by the law is a speed reduction of 10km/h. A "Level 2" AEBS has to reduce at least 20km/h.

### 1.4.3 Measures of effect

The effect of AEB systems on road safety has been estimated by carrying out an in-depth analysis of accident databases. Study [8] shows a possible way to determine a target population for an HGV AEB system. Through applying multiple filters on an accident database a group of accidents can be determined, in which an AEB system would be effective. Different systems are applied to the accident scenarios and their effect on road safety compared.

### 1.4.4 Study methods

The studies selected for this synopsis are observational cross-sectional studies. The studies show to what extent different types of systems can affect the road safety positively. Observations are made regarding how AEB systems can influence the injury severity in a crash event.
There are more studies like for example study [9] regarding possible future applications of AEB systems, but because these studies referring to system functions which aren't part of the current AEB systems, they aren't part of this synopsis.

### 1.4.5 AEBS Deactivation

The Supplement of the Vienna Convention requires that there is always a possibility to oversteer or deactivate an ADAS [5]. This condition is required to ensure that it is still the driver who has the responsibility. Oversteer means in this case that the system is deactivating itself when the driver starts an action which could not be supported by the AEB systems. If the AEBS system is detecting a steering manoeuvre than it will deactivate itself. Another type of deactivation is coming from the driver. This is often caused by lack of knowledge which ADAS in the truck is doing what [4]. Many drivers think that the AEB is starting to brake when the driver is reducing the distance to the vehicle in front (VIF) to start a following overtaking manoeuvre. They reduce the distance to spend less time for the overtaking manoeuvre. The drivers think the AEB system is hindering them to reduce the distance to the VIF. In reality the Adaptive Cruise Control (ACC) is acting not the AEB. An ACC is acting based on the distance to the VIF in relation to the absolute speed of the truck. An AEB is acting based on the speed difference in relation to the distance to the VIF. In theory without an ACC it would be possible to drive with a very small distance (e.g. 5m) without any speed difference to the VIF. Coming from the basic programming the AEB system will neither give a warning nor start to brake. In practice the ACC is starting to brake long before an AEB system will act. It is the ACC which is hindering the driver to do the planed manoeuvre.

## 1.5 NOTES ON ANALYSIS METHODS

The first selected study is from 2016. It gives an overview on accidents on motorways in Lower Saxony. Based on this database it carries out an in-depth analysis and estimates the benefits of different AEB systems.
The second study shows generally the way in which different ADAS can influence crash occurrences. It gives an estimate for reduction of accident severity.
The third study gives a general estimation to what extent a lane keeping assist, AEB and ESC combined can reduce the crash occurrence.

The fourth study is an update of the first completed by additional thoughts regarding the causes of possible deactivation of AEB systems.

All four studies are based on German accident databases, but transferability to other European countries can be partially considered. Most AEB-relevant accidents happen on motorways under same conditions and the underlying situations are similar, but regional conditions may differ like weather conditions and the AEB penetration rate of the vehicle fleet.

Study [8] is only transferable to a limited extend, because the roads in the USA differ from European roads and so the proportions of accident scenarios aren't the same. Also in this study heavy vehicles are defined as trucks heavier than 10 000 lbs, compared to German studies where heavy vehicles are usually defined as heavier than 7500 kg. In this study the results are compared to another investigation performed by the University of Michigan's Transportation Research Institute (UMTRI). Their results differ from the results of study [8], even though both show a significant positive effect. The difference between them can be explained by the usage of different filters for the target population. This problem is targeted for example by the (Prospective Effectiveness Assessment for Road Safety) P.E.A.R.S. group [10]. The group tries to establish a unified effectiveness evaluation of ADAS and active safety systems, so the results are comparable.

# 2 Scientific overview

## 2.1 LITERATURE REVIEW

Advanced driver assistance systems are becoming more commonly widespread in newly registered heavy vehicles. This is due on the one hand to technical advances and on the other hand to new regulations. One important system is the AEB. The AEB can detect possible dangers in front of the vehicle and warns the driver. If the driver does not react to the danger appropriately, the system itself initiates an emergency brake. This can significantly influence an accident scenario by preventing it completely or reducing the impact speed of the rear vehicle. But it is important to keep in mind that the AEB is a driver assistance system. Its main purpose is to warn a distracted driver and increase his attention to the road and traffic situation. The first intention is to bring back the driver in the loop. The AEB is only fully effective if the driver reacts to the situation. Only if the driver is not reacting in an adequate way then the system is starting to brake.

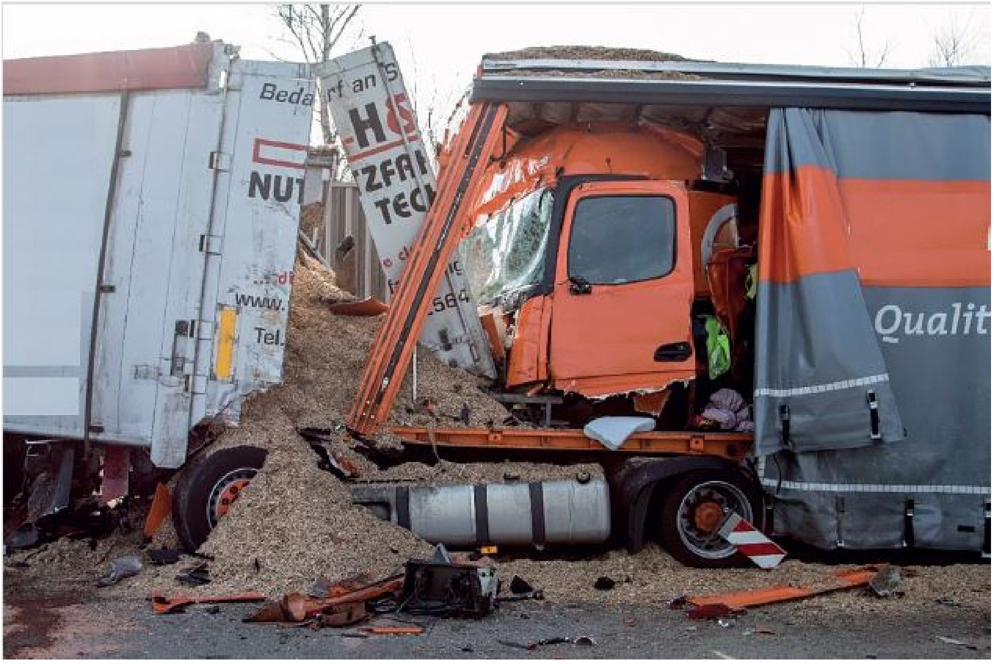

Fig. 1: Rear-end collision between a broken down truck and another HGV. [1]

The AEB was initially developed by Daimler to prevent rear-end accidents between HGVs and passenger cars in a traffic jam. In the study [1] 47 % of the accidents on motorways caused by HGVs are of this type.
High end AEBs in trucks are able not only to detect moving or stationary vehicles in front of them, even pedestrians and cyclists during turning manoeuvres can be detected.
An analysis of the traffic accidents on motorways in Lower Saxony in 2015 show, that 25 % of the rear-end collisions involving a HGV could have been prevented with an AEB that only detects stationary vehicles. An AEB that can also detect moving vehicles could prevent up to 86 % of the rear-end collisions on motorways. Also 35 % to 100 % of the fatalities in AEBS-relevant crashes could be prevented.

According to study [2] a system that can only detect moving vehicles could prevent 6.1 % of all HGV accidents.
In comparison, an AEB system which can detect moving and stationary vehicles could prevent 12 % of all HGV accidents. In particular, accidents resulting in a minor injury could be reduced by 17.5 % (compared to all accidents with a minor injury involving a HGV).
If all HGVs were equipped with an AEBS, LKAS and ESC, 50 % of all rear-end accidents, lane-changing accidents and leaving the driveway on roads outside built-up areas could be prevented.

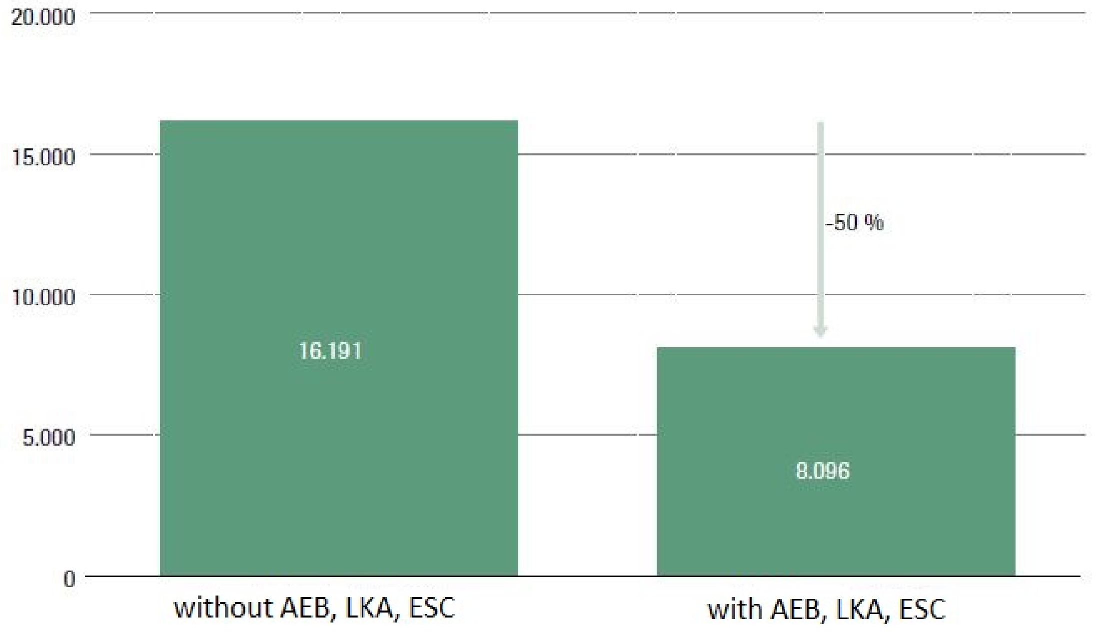


Fig. 2: HGV-accidents on roads outside of built-up areas due to rear-end, lane changing and leaving the driveway (per year in Germany) [3]

Study [8] estimates a possible positive effect of an accident reduction of 3,36 % ± 1,23 % relative to all heavy vehicle accidents, reduction of 6,37 % ± 2,5 of all injuries in heavy vehicle accidents and 4,23 % of all fatalities. The number differs from the other numbers, because of the in 1.5 named reasons.
These studies are only estimations about the safety effect of this active safety system. The systems installed in the actual vehicle fleet are only capable of reducing the impact speed and are only fully effective if the driver interacts appropriately. The minimum system effect requested by the law is a speed reduction of 10km/h. Most modern systems can achieve a higher speed reduction than the required minimum. Also other factors can influence the accident, for example the driver can bypass the AEB trough "kick-down" of the throttle like in Fig. 1. Or the driver can completely deactivate the system. According to study [7] at least 2 % (up to 10 %) of all HGVs equipped with an AEB involved in an AEB-relevant accident have deactivated the system.
But they show, that autonomous emergency brake systems can have a significant positive effect on road safety.
The deactivation is a big influencing factor regarding the benefit of the AEBS in trucks.
According to [11] only 8 to 10 % of all rear-end crashes in Lower Saxony in 2015 were caused by HGVs with an AEBS, even though the equipment rate is over 25 %. It can be concluded that this number shows the effectiveness of AEB systems in trucks, even though it's not clearly proven by statistics.

# 3 Supporting document

## 3.1 METHODOLOGY

### 3.1.1 Literature search strategy

Limitations/ Exclusions for literature search (all literature regarding “trucks” searched in database):

- Search field: ALL (due to the small no. of references)
- Expert search
- published: 1970 to current
- Document Type: ALL
- Source type: Journals, Conference Proceedings, manuals, studies
- Subject Area: Engineering
- Language: English or German

Table 1: Literature search strategy, database: Literaturdatenbank Dekra Unfallforschung

| search no. | search terms / operators / combined queries | hits |
|---|---|---|
| #1 | "truck” and “lkw” | 460 |
| #2 | "heavy truck” | 60 |
| #3 | “light truck” | 13 |
| #4 | “HGV” | 33 |
| #5 | “Heavy goods vehicles” | 15 |
| #6 | “ADAS” | 47 |
| #7 | “AEB” | 31 |
| #8 | “AEB” and “truck” | 5 |

Table 2: Literature search strategy, summary

| | |
|---|---|
| Total of records after initial screening | 664 |
| | |
| **Eligible papers** | 5 |

Searches in other databases like Elsevier and Science Direct don’t provide additional papers. Probably because most of the papers regarding this topic aren’t peer-reviewed.

### 3.1.2 Analysis of study designs and methods

The selected studies are heterogeneous in sample size and sample selection, but homogeneous in the conclusion. They investigated accidents in different regions and on different roads. **Table 1** gives a quick summary of study designs, methods, outcomes, and exposures.

| Author(s), Year, Country | Sample & study design | Method of analysis | Outcome(s) | Exposure(s) |
|---|---|---|---|---|
| (Petersen et al. 2016) Germany | Lower Saxony motorway accident data;<br><br>Outcome → Exposure; | Comparison of absolute values → absolute proportion (AP) | Crash avoided Cases: avoided, reduced, injury avoided Controls: all | Types of AEB |
| (Petersen et al. 2016) Germany | Lower Saxony motorway accident data;<br><br>Outcome → Exposure; | Comparison of absolute values → absolute proportion (AP) | Crash occurence Cases: yes Controls: all | No AEB |
| (Kühn 2011) Germany | UDB data;<br><br>Exposure → Outcome | Comparison of absolute values → absolute proportion (AP) | Crash avoided | Cases: AEB type Controls: all |
| (VDA 2010) Germany | Daimler AG data;<br><br>Exposure → Outcome | Comparison of absolute values → Odds Ratio (OR) → Relative Risk (RR); | Consequence of an accident | Cases: accident type Controls: all types |
| (NHTSA 2017) USA | FARS & GES<br><br>Exposure → Outcome | Comparison of absolute values → Percent accident reduction | Crash occurence | AEB Cases: exposed Controls: non-exposed |

**Table 1: Quick summary of the studies designs.**

The selected studies revolve around the same topic. The study **[1]** gives an estimate on the safety effect of AEBs in HGVs on motorways. For this purpose it uses the data from Lower Saxony of 2015. The study **[2]** shows the possible benefits from ADAS, based on an in-depth analysis of the UDB (Unfalldatenbank der Versicherer). Study **[3]** gives a general outlook about the future development of trucks.

## 3.2 DETAILED SUMMARY OF RESULTS

The studies use statistical models in order to deduce absolute proportions (or AP) and percent accident reduction/change (PAR). **Table 2** summarises the results of these studies.

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| Author | Countermeasure | Outcome | Effects for road safety | Interpretation of results |
|---|---|---|---|---|
| **Petersen et al. (2016) Germany** | no | Crash occurrence | HGV >3.5t involved<br>Accident severities<br>Fatal=AP=0.1987<br>Severe injury=AP=0.8013<br>Street condition<br>Dry=AP=0.8013<br>Wet=AP=0.1589<br>Slippery=AP=0.0331<br>Injury severities<br>Minor injury=AP=0.3722<br>Severe injury=AP=0.5205<br>Fatal=AP=0.1073<br><br>HGV >7.5t involved<br>Accident severities<br>Fatal=AP=0.1986<br>Severe injury=AP=0.8014<br>Street condition<br>Dry=AP=0.8082<br>Wet=AP=0.1575<br>Slippery=AP=0.0342<br>Injury severities<br>Minor injury=AP=0.3787<br>Severe injury=AP=0.0,5113<br>Fatal=AP=0.1100<br><br>HGV >3.5t caused<br>Accident severities<br>Fatal=AP=0.2353<br>Severe injury=AP=0.7647<br>Street condition<br>Dry=AP=0.8588<br>Wet=AP=0.1176<br>Slippery=AP=0.0235<br>Injury severities<br>Minor injury=AP=0.4175<br>Severe injury=AP=0.4660<br>Fatal=AP=0.1165<br><br>HGV >7.5t caused<br>Accident severities<br>Fatal=AP=0.2346<br>Severe injury=AP=0.7531<br>Street condition<br>Dry=AP=0.8642<br>Wet=AP=0.1111<br>Slippery=AP=0.0123<br>Injury severities<br>Minor injury=AP=0.4221<br>Severe injury=AP=0.4623<br>Fatal=AP=0.1156 | These results show the distribution of the accidents depending on accident severity, road condition and injury severity and if the HGV is involved or the main cause of the accident. |
| **(Petersen et al. 2016) Germany** | AEB | Crash avoided | Caused by HGV<br><br>EU2-AEBS<br>Avoided=AP=0.3<br>Reduced=AP=0.7 | All three systems show a significant possible reduction of accidents and accident severities. |

| | | | | |
|---|---|---|---|---|
| | | | Fatality avoided=AP=0.4<br>Severe injury avoided=AP=0.74<br>Minor injury avoided=AP=0.68<br><br>Opt.AEBS'15<br>Avoided=AP=0.89<br>Reduced=AP=0.11<br>Fatality avoided=AP=1<br>Severe injury avoided=AP=0.94<br>Minor injury avoided=AP=0.94<br><br>AEBS '18 + AW<br>Avoided=AP=1<br>Fatality avoided=AP=1<br>Severe injury avoided=AP=1<br>Minor injury avoided=AP=1<br><br>HGV is involved<br><br>EU2-AEBS<br>Avoided=AP=0.24<br>Reduced=AP=0.71<br>Fatality avoided=AP=0.35<br>Severe injury avoided=AP=0.8<br>Minor injury avoided=AP=0.34<br><br>Opt.AEBS'15<br>Avoided=AP=0.86<br>Reduced=AP=0.1<br>Fatality avoided=AP=0.94<br>Severe injury avoided=AP=0.96<br>Minor injury avoided=AP=0.9<br><br>AEBS '18 + AW<br>Avoided=AP=1<br>Fatality avoided=AP=1<br>Severe injury avoided=AP=1<br>Minor injury avoided=AP=1 | |
| **(Kühn 2011) Germany** | AEB | Injury level | AEBS 1<br>All=PAR=6 %<br>Fatal=PAR=3.5 %<br>Severe injury=PAR=4 %<br>Minor injury=PAR=7.4<br><br>AEBS2<br>All=PAR=11.9 %<br>Fatal=PAR=4.9 %<br>Severe injury=PAR=8.4 %<br>Minor injury=PAR=17.5 % | AEBS can have a significant positive effect on road safety. It could prevent over 10 % of all HGV accidents and reduce 17,5 % of all minor injuries during an accident between HGVs and other road user. |
| **(VDA 2010) Germany** | Safety Package (LKAS,AEBS;ESC) | Crash avoided | Exposed=PAR=50 % | A combination of LKAS, AEBS and ESC could prevent up to 50 % of all lane changing accidents, rear-end accidents and accidents due leaving the driveway. |

| | | | | |
|---|---|---|---|---|
| **(VDA 2010) Germany** | ACC | Crash avoided | Rear-end collisions=PAR=70 % | With an ACC in every truck, it's estimated, that the rear-end collisions on motorways could be reduced by 70 %. |
| **(NHTSA 2017) USA** | AEB | Crashes addressed | Heavy vehicle accidents<br>Only damage=PAR=3.36 %<br>Injury=PAR=6.37 %<br>Fatal=PAR=4.23 % | With an AEBS a significant number of all heavy vehicle accidents can be addressed and positively influenced. |

**Table 2:** Summary of the results with absolute proportion (AP) and percent accident reduction (PAR).

## 3.3 FULL LIST OF STUDIES


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[6] Alexander Berg, Erwin Petersen. 2017. " Notbremsassistenzsysteme für schwere Güterkraftfahrzeuge – historische Entwicklung, aktuelle Vorschriften, Einblicke in Unfallgstatistiken und Einzelfälle, Diskussion und Vorschläge. Teil 1". VKU – Verkehrsunfall und Fahrzeugtechnik. December 2017.

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