Autonomous Emergency Braking AEB (pedestrians & cyclists)

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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

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1.1 COLOUR CODE: GREEN

The bibliographic review on the effectiveness of AEB pedestrian and cyclist systems suggests that these are effective. All studies establish that AEB has (or would have) a positive effect on road safety of pedestrians and cyclists.

1.2 KEYWORDS

Autonomous emergency braking; AEB; automatic brake; pedestrian; cyclist; vulnerable road user; VRU; effectiveness; passenger cars; SUV; van;

1.3 ABSTRACT

Autonomous Emergency Braking (AEB) for pedestrians and cyclists is an in-vehicle system that can avoid a crash with a pedestrian or a cyclist or mitigate its consequences by automatically applying the brakes. Depending on the system supplier or manufacturer, the system may give a warning to the driver and apply the brakes only in case of no driver reaction. Other parameters may vary from one system to another, depending on the sensing and braking technologies that were used by the manufacturer, thus influencing the outcome in terms of accident avoidance and mitigation.

This document presents a literature review of the benefits of AEB pedestrian and cyclist systems in terms of reduction in accident numbers and injury severity. A systematic literature search has been conducted and relevant studies have been analysed. Certainly due to the fact that the system is relatively recent and that the market penetration is still weak, most of the studies consisted of prospective analyses of the system's effectiveness by simulating the effect an AEB system would have had on the accidents' outcomes. Only one study comprises a retrospective analysis but the results were not statistically significant due to the small sample size. However, all results seem to agree that AEB is efficient in reducing pedestrian and cyclist accident numbers and severities. Effectiveness can vary from 2.2% to 84%. This is subject to the outcome definition and to the system parameters that were taken into consideration.

1.4 BACKGROUND

1.4.1 Introduction to measure and its effect on road safety

In 2014, 5,621 pedestrians and 2,112 cyclists were killed in road accidents in Europe, accounting respectively for 21% and 8.1% of the total number of road accident fatalities (ERSO 2016b; ERSO 2016a). AEB pedestrian and cyclist addresses pedestrian and cyclist accidents that occur with the front-end of a vehicle. This represents a substantial amount of pedestrians' and cyclists' accidents. By automatically applying the brakes, AEB can avoid a crash with a pedestrian or cyclist or mitigate the consequences of a crash by reducing the impact speed.

1.4.2 Definitions of measure

AEB pedestrian and cyclist has been studied from different perspectives that illustrate the effect of:

- One specific AEB system (Daimler-Chrysler's PROTECTOR & Volvo's CWAB-PD).

- All AEB systems combined.
- Various combinations of system parameters that represent theoretical systems.

1.4.3 Study methods

Two types of analyses were used in order to determine the efficiency of AEB pedestrian & cyclist: prospective and restrospective analyses. For the only retrospective analysis that was found, a case control study was conducted in order to evaluate the number of AEB equipped vehicles involved in crashes with pedestrians and cylists versus non AEB equipped vehicles. The prospective analyses used injury risk curves (probability of injury versus impact speed) in order to determine the probability of injury reduction after simulating the effect of the system.

1.4.4 Measures of effect

The effect AEB pedestrian and cyclist has on road safety has been evaluated through the reduction or increase in number of crashes or injuries of different severities for the whole body or for specific body regions. Mostly, one scale of injury severity was used: the Abbreviated Injury Scale (AIS). Sometimes the scale is only fatal injury or no fatal injury. In general, fatal injury could be defined as death occurring in the thirty days following the accident but this definition could change, depending on the database used in the study.

1.5 NOTES ON ANALYSIS METHODS

The selected studies are relatively recent (2010-2017) and deal with analyses performed on European data (Germany, Spain, Sweden, UK). Transferability to other countries can be considered but one should be very careful of the fact that the efficiency of AEB pedestrian and cyclist may be very sensitive to accident scenarios that are controlled by infrastructure (accident at a straight road, at a turning point, with vehicle at high speed, with the presence of environmental masks …).

Due to the fact that AEB pedestrian and cyclist still has very low market penetration, the retrospective analysis that was found was not statistically significant. The prospective analyses that used simulation techniques did not give any error measurement. However, all results seem to go in the same direction showing that AEB pedestrian and cyclist is efficient in reducing road casualties.

As AEB consists of a forward-looking system, all samples used in the studies were accidents where pedestrians or cyclists were hit by the front-end of a vehicle.

As a consequence of different study designs (different outcomes and exposures), the scientific overview part will be constituted of a literature review. No vote-count analysis or meta-analysis could have been achieved.

2 Scientific overview

2.1 LITERATURE REVIEW

In the European Union, the latest road safety measures seemed to be less beneficial for pedestrians and cyclists when compared to other road users. More precisely, during the decade 2005-2014, pedestrian and cyclist fatalities were reduced respectively by 35% and 30% while the total number of traffic-related fatalities was reduced by almost 42% (ERSO 2016b; ERSO 2016a). Among the measures taken in order to reduce pedestrian and cyclist casualties, vehicle-related measures were implemented, especially regulations (directive 2003/102/EC & regulation N° 78/2009) making new vehicle's front-end designs more compatible with pedestrian crash configurations. European regulation N° 78/2009 even made the active safety system "brake assist" mandatory as it was proven to significantly increase the level of pedestrian protection when combined with changes to passive safety requirements. Actually, due to their potential benefit, autonomous emergency braking (AEB) systems are encouraged to be fitted to more and more vehicles especially by consumer organisations like Euro NCAP who started to rate new vehicles according to their capacity of avoiding or mitigating rear-end crashes (as of 2014) and crashes with pedestrians (as of 2016). AEB cyclist is certainly on the list of new systems to be tested as of 2018 as projects like CATS (https://www.tno.nl/en/focus-areas/urbanisation/mobility-logistics/safe-mobility/cats-cyclist-aeb-testing-system-development/) have developed relevant test protocols based on car-cyclist accident scenarios. Despite the fact that Euro NCAP test scenarios may represent the most relevant accident scenarios, statistical studies based on real accident data have been achieved in order to demonstrate the effectiveness of the AEB system in preventing or reducing pedestrian and cyclist injuries. Paragraph 3.1.1 illustrates the systematic literature search that was conducted in order to find AEB effectiveness studies. At the end of the searching process, six studies were found relevant (see **Table 3.2**). Certainly due to the fact that the market penetration of the AEB pedestrian and cyclist systems is still weak, five studies (out of six) undertook a prospective analysis of the potential benefit of these systems. Only one study (Ohlin, Strandroth, and Tingvall 2017) comprises a retrospective analysis of the effectiveness of the AEB pedestrian system in preventing crashes with pedestrians or cyclists. They achieved a case-control study, thus classifying crashes involving pedestrians or cyclists as sensitive (cases) and rear-end crashes as non-sensitive (controls) to AEB with pedestrian detection. The sample involved only cars equipped with low speed AEB (AEB city) so as to not introduce this system as a confounding factor. The study found that AEB with pedestrian detection is 70% effective at reducing crashes with pedestrians and cyclists. However, this result is not statistically significant due to the small number of crashes involving AEB equipped vehicles (numbers given in **Table 2.1**).

Table 2.1 Number of crashes involving AEB equipped vehicles (Ohlin, Strandroth, and Tingvall 2017).

	With pedestrian detection	Without pedestrian detection
Crashes with bicyclists or pedestrians	2	52
Rear-end crashes	18	140

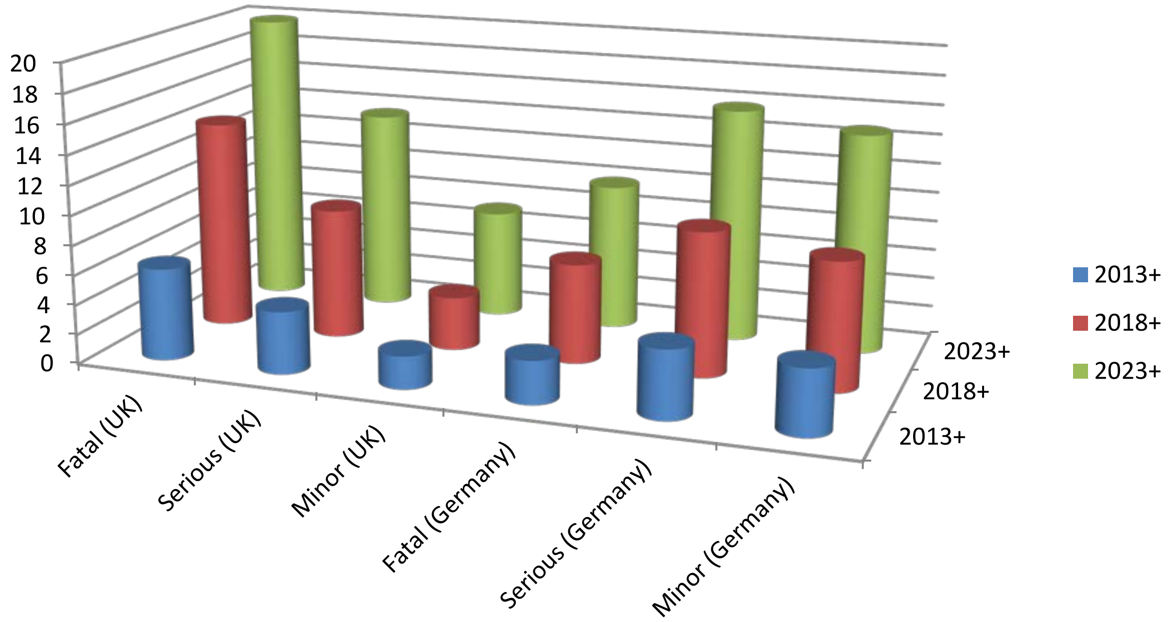
As mentioned previously, the remaining five studies (Paez, Furones, and Badea 2015; Edwards, Nathanson, and Wisch 2014; E Rosén 2013; Lindman et al. 2010; Erik Rosén et al. 2010) consisted of prospective analyses. They used detailed accident databases referred to as "on the spot" or "in-depth". This enables the reconstruction and replay of accidents while simulating the effect an AEB pedestrian or cyclist system would have had on the accidents' outcomes. Thereafter, by using different combinations of simulation parameters, corresponding to various AEB systems, different outcomes were noticed. Paez, Furones, and Badea (2015) and Lindman et al. (2010) used only one combination of system parameters corresponding respectively to Daimler-Chrysler's PROTECTOR system and Volvo's CWAB-PD system. Unfortunately, no comparison could be made between the effectiveness of the PROTECTOR or the CWAB-PD systems because each study used a different outcome definition. In Paez, Furones, and Badea (2015), the velocity and the location of pedestrian head impact on the vehicle was obtained before (in the real accident) and after simulating the AEB system and AIS 3+ head injury probability was estimated by using laboratory test data. In 44% of the cases, the reduction of the probability of head injury severity was greater than 80%. Only 10% of the cases presented a reduction less than 10 % of head injury probability and in another 10% of the cases an increase in head injury probability was noticed. It was found that this was due to change in the head impact location to a stiffer area of the vehicle front-end. More details about these results can be found in **Table 3.4**. Lindman et al. (2010) used injury risk curves (injury probability versus impact speed) in order to deduce the reduction in fatality risk after speed reduction by the AEB system. They found that the relative difference in injury outcome with and without the AEB pedestrian system is estimated to be 24%. Pedestrian injury curves were the same as in Erik Rosén et al. (2010). It is important to note that in Paez, Furones, and Badea (2015) and Lindman et al. (2010) the results represent only the sample selected for the study as no weights were attributed in order to be representative of a wider population. Furthermore, in Paez, Furones, and Badea (2015) the sample size consisted only of 50 accidents and in Lindman et al. (2010) no information on sample size was given. Therefore, these two studies are more interesting on the level of the methodology they used and the results should be taken as a qualitative evaluation that gives a certain trend for the effectiveness of the AEB pedestrian. E Rosén (2013); Erik Rosén et al. (2010) used the same method as the previous studies but with a detailed and relatively large sample. Four different injury curves (probability of injury versus impact speed) were used, in order to determine pedestrian fatality risk, pedestrian risk of getting a severe injury, cyclist fatality risk and cyclist risk of getting severely injured. German In-Depth Accident Study (GIDAS) Pre-Crash Matrix was used which consisted of German reconstructed accidents and detailed pre-crash data (vehicle and pedestrian/cyclist trajectories, speeds, accelerations or decelerations ...). Thus, AEB pedestrian & cyclist were simulated on these vehicles and the outcomes of the simulated crashes (impact speed) were compared to the outcomes of the real crashes. Efficiency E was calculated as in Equation 1 with P the injury probability corresponding to the injury curve that was used, v_i and v_i' the original and new impact speeds and w_i the weight factor for the i$^{\text{th}}$ pedestrian or cyclist.

$$E = 1 - \frac{\sum_{i=1}^{n} P(v_i')\, w_i}{\sum_{i=1}^{n} P(v_i)\, w_i} \qquad \text{Equation 1}$$

Weight factors were used in order to be representative of German national data as GIDAS data were accidents collected only from the cities of Hanover and Dresden and their surroundings. In Erik Rosén et al. (2010), effectiveness of only AEB for pedestrians was estimated for different fields of view of the AEB system. It was established that the effectiveness at reducing fatally injured pedestrians reached 40% at 40° of field of view (FoV) while reaching 44% at a maximum angle of 180°. Effectiveness at reducing severe injuries was 27% at a 40° FoV and reached 33% at 180° of FoV. E Rosén (2013) tried different combinations of parameters varying not only the field of view but also the time before collision (TTC) at which the brakes must be applied, the maximum brake deceleration, the ramp-up time from onset of brakes until maximum brake deceleration, the time that the system takes in order to classify the pedestrian or cyclist and detect a collision, and other system variables. It was assumed that six different combinations of these variables would make a reference system, a maximum performance system, a system that works only in daylight, another one that works only for vehicle speeds less than 60 km/h, one with minimal braking performances and finally a system with all minimal requirements. This approach is interesting for two reasons: first, costs may considerably vary from one system to another and the gain in efficiency may not account for the cost difference. Second, applying brakes to the maximum of their performance limits may generate secondary effects such as rear-end accidents especially in the case of a false activation so the gain in effectiveness must be capable of compensating the possible costs of increased secondary effects. Results show that the predicted effectiveness for both pedestrians and bicyclists were highly sensitive to system parameters defining the brake capacity as well as functionality in darkness and high speeds. The system with minimum requirements (which combined minimum braking, functionality only in daylight and at low speeds) is ten times less efficient than the reference system. Detailed results can be found in **Table 3.4**.

Edwards, Nathanson, and Wisch (2014) also used in-depth data from GIDAS (Germany) and "On The Spot" (UK) and extrapolated results to national data. Accident scenarios were mapped into simulation scenarios which in their turn were backed-up by real test results. Three combinations of system parameters were used in the simulations that represent three generations of AEB systems (current generation 2013+, second generation 2018+, and reference limit generation 2023+). Three injury risk curves (fatal injury risk, serious injury risk, and slight injury risk) were used in order to determine injury probability before and after the system simulation. Results were given for Germany and the UK and are illustrated in **Figure 2. 1**. It is shown that current generation AEB pedestrian (2013+) is less efficient than second generation AEB pedestrian (2018+) that is in its turn less efficient than the reference limit generation (2023+). For UK data, **Figure 2.1** shows that the three generations of AEB are more efficient at reducing the number of fatal injuries while for German data they are more efficient at reducing serious and minor injuries. No explanation was given for this difference in efficiency between injury severity categories for the two countries.

Figure 2. 1 Estimated percentage of reduction in number of fatal, serious and minor injuries for UK and Germany for different generations of AEB pedestrian systems.



3 Supporting document

3.1 METHODOLOGY

3.1.1 Literature search strategy

Three databases have been searched: ***ScienceDirect***, ***Scopus***, and CEESAR's internal database that is based on *Greenstone* and that includes articles and reports from different road safety journals and conference proceedings. The search was limited to articles' titles, abstracts, and keyword fields and afterwards filtered in order to get only recent articles published after the year 1999. Six combinations of keywords were used for the search. **Table 3.1** illustrates these combinations and the number of hits they generated in ScienceDirect and Scopus. **Table 3.2** gives the number of studies to screen and the number of coded studies.

Table 3.1 Keywords combinations used for the literature search and the number of hits it generated in each database .

Search no.	Search terms / operators / combined queries	Number of hits (ScienceDirect)	Number of hits (Scopus)
#1	Autonomous AND emergency AND brak* AND pedestrian	6	37
#2	Autonomous AND emergency AND brak* AND cycl*	1	6
#3	Autonomous AND emergency AND brak* AND vulnerable AND road AND user*	1	9
#4	Automatic AND emergency AND brak* AND pedestrian	1	25
#5	Automatic AND emergency AND brak* AND cycl*	0	4
#6	Automatic AND emergency AND brak* AND vulnerable AND road AND user*	0	4

Table 3.2 Screening process.

Screening	Number of studies
All studies to screen (ScienceDirect + Scopus + internal database) after removing duplicates	115
Studies left after title and abstract screening	13
Grey literature (articles found in references, ...)	2
Relevant studies (coded)	6

3.1.2 Analysis of study designs and methods

The selected studies are very heterogeneous in sample size and sample selection. They also investigated different exposures and outcomes. **Table 3.3** gives a quick summary of study designs, methods, outcomes, and exposures. Only exposures dealing with AEB pedestrian or cyclist have been kept for analysis in this document.

Table 3.3 Quick summary of the studies' designs.

Author(s), Year, Country	Sample info	Method of analysis	Outcome(s)	Exposure(s)
Ohlin, Strandroth, and Tingvall (2017) Sweden, Australia	Swedish STRADA database (police records & hospital admission data) from 01/01/2003 to 31/03/2014; All cars were equipped with AEB "city"	Retrospective analysis.	Cases: crashes with pedestrians or cyclists (sensitive to exposure) Controls: rear-end crashes (non-sensitive to exposure)	AEB pedestrian & cyclist
Paez, Furones, and Badea (2015) Spain, UK	50 accidents from Madrid between 2002 and 2006;	Prospective analysis. Accident reconstruction & replay with simulated system functions.	- Increase in AIS 3+ head injury probability - Reduction in AIS 3+ head injury probability	AEB pedestrian (Daimler-Chrysler's PROTECTOR system)
Edwards, Nathanson, and Wisch (2014) UK, Germany	British "On The Spot" 2000-2010 data extrapolated to national level using STATS19 2008-2010 data. German GIDAS 2000-2012 data extrapolated to national level using German national road statistics 2000-2012.	Prospective analysis. Accident reconstruction & replay with simulated system functions.	- Fatal injury - Serious injury - Slight injury	- Current generation AEB pedestrian (2013+) - Second generation AEB pedestrian (2018+) - Reference limit AEB pedestrian (2023+)
E Rosén (2013) Sweden	German GIDAS 1999-2012 data extrapolated to national level using German national road statistics 1999-2012.	Prospective analysis. Accident reconstruction & replay with simulated system functions.	- Fatal injury - Serious injury	Different AEB pedestrian & cyclist configuration parameters
Lindman et al. (2010) Sweden, Germany	German GIDAS 1999-2007 data	Prospective analysis. Accident reconstruction & replay with simulated system functions.	Fatal injury	AEB pedestrian (Volvo's system CWAB-PD)

Erik Rosén et al. (2010) Sweden, US	German GIDAS 1999-2003 data.	Prospective analysis. Accident reconstruction & replay with simulated system functions.	- Fatal injury - Serious injury	Two different AEB pedestrian field of view angles

3.2 DETAILED SUMMARY OF RESULTS

Table 3.4 Detailed summary of results.

Autonomous Emergency Braking AEB (pedestrians & cyclists)

Author	Exposure	Outcome	Effects on road safety
Ohlin, Strandroth, and Tingvall (2017)	AEB pedestrian & cyclist	Cases: crashes with pedestrians or cyclists. Controls: rear-end crashes.	Effectiveness = 70%. Positive effects on road safety.
Paez, Furones, and Badea (2015)	AEB pedestrian (Daimler-Chrysler's PROTECTOR system)	Increase in AIS 3+ head injury probability.	10% of the AEB pedestrian group have increased head injury probability.
Paez, Furones, and Badea (2015)	AEB pedestrian (Daimler-Chrysler's PROTECTOR system)	0-10% reduction in AIS 3+ head injury probability	10% of the AEB pedestrian group have between 0 and 10% reduction in head injury probability.
Paez, Furones, and Badea (2015)	AEB pedestrian (Daimler-Chrysler's PROTECTOR system)	11-20% reduction in AIS 3+ head injury probability	0% of the AEB pedestrian group have between 11 and 20% reduction in head injury probability.
Paez, Furones, and Badea (2015)	AEB pedestrian (Daimler-Chrysler's PROTECTOR system)	21-30% reduction in AIS 3+ head injury probability	2% of the AEB pedestrian group have between 21 and 30% reduction in head injury probability.
Paez, Furones, and Badea (2015)	AEB pedestrian (Daimler-Chrysler's PROTECTOR system)	31-40% reduction in AIS 3+ head injury probability	2% of the AEB pedestrian group have between 31 and 40% reduction in head injury probability.
Paez, Furones, and Badea (2015)	AEB pedestrian (Daimler-Chrysler's PROTECTOR system)	41-50% reduction in AIS 3+ head injury probability	6% of the AEB pedestrian group have between 41 and 50% reduction in head injury probability.
Paez, Furones, and Badea (2015)	AEB pedestrian (Daimler-Chrysler's PROTECTOR system)	51-60% reduction in AIS 3+ head injury probability	0% of the AEB pedestrian group have between 51 and 60% reduction in head injury probability.
Paez, Furones, and Badea (2015)	AEB pedestrian (Daimler-Chrysler's PROTECTOR system)	61-70% reduction in AIS 3+ head injury probability	0% of the AEB pedestrian group have between 61 and 70% reduction in head injury probability.
Paez, Furones, and Badea (2015)	AEB pedestrian (Daimler-Chrysler's PROTECTOR system)	71-80% reduction in AIS 3+ head injury probability	2% of the AEB pedestrian group have between 71 and 80% reduction in head injury probability.
Paez, Furones, and Badea (2015)	AEB pedestrian (Daimler-Chrysler's PROTECTOR system)	81-90% reduction in AIS 3+ head injury probability	2% of the AEB pedestrian group have between 81 and 90% reduction in head injury probability.
Paez, Furones, and Badea (2015)	AEB pedestrian (Daimler-Chrysler's PROTECTOR system)	91-100% reduction in AIS 3+ head injury probability	42% of the AEB pedestrian group have between 91 and 100% reduction in head injury probability.

Edwards, Nathanson, and Wisch (2014)	Current generation AEB pedestrian (2013+) UK data	Fatal injury	Fatal injuries have been reduced by 6.2%
Edwards, Nathanson, and Wisch (2014)	Current generation AEB pedestrian (2013+) UK data	Serious injury	Serious injuries have been reduced by 4.2%
Edwards, Nathanson, and Wisch (2014)	Current generation AEB pedestrian (2013+) UK data	Minor injury	Minor injuries have been reduced by 2.2%
Edwards, Nathanson, and Wisch (2014)	Current generation AEB pedestrian (2013+) German data	Fatal injury	Fatal injuries have been reduced by 2.2%
Edwards, Nathanson, and Wisch (2014)	Current generation AEB pedestrian (2013+) German data	Serious injury	Serious injuries have been reduced by 2.9%
Edwards, Nathanson, and Wisch (2014)	Current generation AEB pedestrian (2013+) German data	Minor injury	Minor injuries have been reduced by 4.6%
Edwards, Nathanson, and Wisch (2014)	Second generation AEB pedestrian (2018+) UK data	Fatal injury	Fatal injuries have been reduced by 14.1%
Edwards, Nathanson, and Wisch (2014)	Second generation AEB pedestrian (2018+) UK data	Serious injury	Serious injuries have been reduced by 8.8%
Edwards, Nathanson, and Wisch (2014)	Second generation AEB pedestrian (2018+) UK data	Minor injury	Minor injuries have been reduced by 93.6%
Edwards, Nathanson, and Wisch (2014)	Second generation AEB pedestrian (2018+) German data	Fatal injury	Fatal injuries have been reduced by 6.7%
Edwards, Nathanson, and Wisch (2014)	Second generation AEB pedestrian (2018+) German data	Serious injury	Serious injuries have been reduced by 9.7%
Edwards, Nathanson, and Wisch (2014)	Second generation AEB pedestrian (2018+) German data	Minor injury	Minor injuries have been reduced by 8.6%
Edwards, Nathanson, and Wisch (2014)	Reference limit AEB pedestrian (2023+) UK data	Fatal injury	Fatal injuries have been reduced by 19.9%
Edwards, Nathanson, and Wisch (2014)	Reference limit AEB pedestrian (2023+) UK data	Serious injury	Serious injuries have been reduced by 13.6%
Edwards, Nathanson, and Wisch (2014)	Reference limit AEB pedestrian (2023+) UK data	Minor injury	Minor injuries have been reduced by 7.3%

Autonomous Emergency Braking AEB (pedestrians & cyclists)

Edwards, Nathanson, and Wisch (2014)	Reference limit AEB pedestrian (2023+) German data	Fatal injury	Fatal injuries have been reduced by 9.9%
Edwards, Nathanson, and Wisch (2014)	Reference limit AEB pedestrian (2023+) German data	Serious injury	Serious injuries have been reduced by 15.8%
Edwards, Nathanson, and Wisch (2014)	Reference limit AEB pedestrian (2023+) German data	Minor injury	Minor injuries have been reduced by 14.8%
E Rosén (2013)	AEB pedestrian (maximal performance)	Fatal injury	Effectiveness = 82%. Positive effect on road safety.
E Rosén (2013)	AEB cyclist (maximal performance)	Fatal injury	Effectiveness = 84%. Positive effect on road safety.
E Rosén (2013)	AEB pedestrian (maximal performance)	Serious injury	Effectiveness = 76%. Positive effect on road safety.
E Rosén (2013)	AEB cyclist (maximal performance)	Serious injury	Effectiveness = 67%. Positive effect on road safety.
E Rosén (2013)	AEB pedestrian (reference performance)	Fatal injury	Effectiveness = 48%. Positive effect on road safety.
E Rosén (2013)	AEB cyclist (reference performance)	Fatal injury	Effectiveness = 55%. Positive effect on road safety.
E Rosén (2013)	AEB pedestrian (reference performance)	Serious injury	Effectiveness = 42%. Positive effect on road safety.
E Rosén (2013)	AEB cyclist (reference performance)	Serious injury	Effectiveness = 33%. Positive effect on road safety.
E Rosén (2013)	AEB pedestrian (reference & limited to 60 km/h)	Fatal injury	Effectiveness = 29%. Positive effect on road safety.
E Rosén (2013)	AEB cyclist (reference & limited to 60 km/h)	Fatal injury	Effectiveness = 27%. Positive effect on road safety.
E Rosén (2013)	AEB pedestrian (reference & limited to 60 km/h)	Serious injury	Effectiveness = 35%. Positive effect on road safety.
E Rosén (2013)	AEB cyclist (reference & limited to 60 km/h)	Serious injury	Effectiveness = 28%. Positive effect on road safety.

Autonomous Emergency Braking AEB (pedestrians & cyclists)

E Rosén (2013)	AEB pedestrian (reference & limited to daylight)	Fatal injury	Effectiveness = 21%. Positive effect on road safety.
E Rosén (2013)	AEB cyclist (reference & limited to daylight)	Fatal injury	Effectiveness = 42%. Positive effect on road safety.
E Rosén (2013)	AEB pedestrian (reference & limited to daylight)	Serious injury	Effectiveness = 21%. Positive effect on road safety.
E Rosén (2013)	AEB cyclist (reference & limited to daylight)	Serious injury	Effectiveness = 24%. Positive effect on road safety.
E Rosén (2013)	AEB pedestrian (minimum brake time & amplitude)	Fatal injury	Effectiveness = 11%. Positive effect on road safety.
E Rosén (2013)	AEB cyclist (minimum brake time & amplitude)	Fatal injury	Effectiveness = 19%. Positive effect on road safety.
E Rosén (2013)	AEB pedestrian (minimum brake time & amplitude)	Serious injury	Effectiveness = 7%. Positive effect on road safety.
E Rosén (2013)	AEB cyclist (minimum brake time & amplitude)	Serious injury	Effectiveness = 8%. Positive effect on road safety.
E Rosén (2013)	AEB pedestrian (minimal performance)	Fatal injury	Effectiveness = 3%. Positive effect on road safety.
E Rosén (2013)	AEB cyclist (minimal performance)	Fatal injury	Effectiveness = 6%. Positive effect on road safety.
E Rosén (2013)	AEB pedestrian (minimal performance)	Serious injury	Effectiveness = 3%. Positive effect on road safety.
E Rosén (2013)	AEB cyclist (minimal performance)	Serious injury	Effectiveness = 5%. Positive effect on road safety.
Lindman et al. (2010)	AEB pedestrian (Volvo's CWAB-PD)	Fatal injury	Effectiveness = 24%.
Erik Rosén et al. (2010)	AEB pedestrian (reference performance)	Fatal injury	Effectiveness = 40%.
Erik Rosén et al. (2010)	AEB pedestrian (reference performance)	Serious injury	Effectiveness = 27%.
Erik Rosén et al. (2010)	AEB pedestrian (reference performance & augmented field of view)	Fatal injury	Effectiveness = 44%.

Autonomous Emergency Braking AEB (pedestrians & cyclists)

Erik Rosén et al. (2010)	AEB pedestrian (reference performance & augmented field of view)	Serious injury	Effectiveness = 33%.

3.3 FULL LIST OF STUDIES

Edwards, M, A Nathanson, and M Wisch. 2014. "Estimate of Potential Benefit for Europe of Fitting Autonomous Emergency Braking (AEB) Systems for Pedestrian Protection to Passenger Cars." *Traffic Injury Prevention* 15. Taylor and Francis Inc.: S173–82. doi:http://dx.doi.org/10.1080/15389588.2014.931579.

ERSO. 2016a. "Traffic Safety Basic Facts 2016 - Cyclists."
———. 2016b. "Traffic Safety Basic Facts 2016 - Pedestrians."

Lindman, M, A Oedblom, E Bergvall, A Eidehall, B Svanberg, and T Lukaszewicz. 2010. "Benefit Estimation Model for Pedestrian Auto Brake Functionality." In *4th Expert Symposium on Accident Research (ESAR)*. Hanover, Germany. http://trid.trb.org/view.aspx?id=1147420.

Ohlin, M, J Strandroth, and C Tingvall. 2017. "The Combined Effect of Vehicle Frontal Design, Speed Reduction, Autonomous Emergency Braking and Helmet Use in Reducing Real Life Bicycle Injuries." *Safety Science* 92. Elsevier B.V.: 338–44. doi:http://dx.doi.org/10.1016/j.ssci.2016.05.007.

Paez, Francisco Javier, Arturo Furones, and Alexandro Badea. 2015. "BENEFITS ASSESSMENT OF AUTONOMOUS EMERGENCY BRAKING PEDESTRIAN SYSTEMS BASED ON REAL WORLD ACCIDENTS RECONSTRUCTION." In *The 24th ESV Conference Proceedings*. https://www-esv.nhtsa.dot.gov/Proceedings/24/files/24ESV-000141.PDF.

Rosén, E. 2013. "Autonomous Emergency Braking for Vulnerable Road Users." In *2013 IRCOBI Conference Proceedings - International Research Council on the Biomechanics of Injury*, 618–27. International Research Council on the Biomechanics of Injury. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84896657530&partnerID=40&md5=c106859a0fa3b40abd02f4b10df9a2f3.

Rosén, Erik, Jan Erik Källhammer, Dick Eriksson, Matthias Nentwich, Rikard Fredriksson, and Kip Smith. 2010. "Pedestrian Injury Mitigation by Autonomous Braking." *Accident Analysis and Prevention* 42 (6): 1949–57. doi:http://dx.doi.org/10.1016/j.aap.2010.05.018.