

AUTOMATIC EMERGENCY BRAKING FOR PEDESTRIANS EFFECTIVE TARGET POPULATION AND EXPECTED SAFETY BENEFITS

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ABSTRACT

Automatic Emergency Brake (AEB) for pedestrians is a technology that automatically applies braking force to a vehicle when forward detection sensors determines that a collision with a pedestrian is imminent, thereby assisting in avoiding the collision altogether, or if it is unavoidable, reducing the impact speed of the crash and subsequently the risk of fatal/severe injury to pedestrians. The driver might be first notified about the danger by a tone or a visual warning or by an haptic feedback in the brake. If the driver does not act and if the impact is considered as inevitable, an automatic braking is applied. Notification step can also be skipped and the system brakes when the imminent collision is detected. Braking strategies vary across systems in terms of operating speeds range, adjusting the level of the braking force and the time when impact is considered inevitable. The value of deceleration is generally limited to 0.6 g.

The aim of this study is two-fold:

- Examine in which particular crash situations this kind of systems is relevant. In France, pedestrian crashes account for 15 % of injury crashes. However, there are a few considerations that might dramatically reduce this a priori aggregated target population: Performance of sensors varies across models and suppliers. A small range of different in-vehicle enhanced braking systems are currently available that involve differing activation processes and functionality, and likely to provide varying benefits in terms of fewer crashes and mitigations vehicle/pedestrian fatalities and serious injuries
- Propose an evaluation of the expected safety benefits of such systems

A detailed analysis of pedestrian crashes was carried out with the help of European in-depth crash data as well as police reports. Results show

that, pedestrian crashes happen more often in cities, in the daytime, whereas the pedestrian crosses the street. Expected effectiveness of AEB pedestrian, if 100 % of the fleet is fitted with a perfect system that never fails, would be a reduction of 15.3% of fatal pedestrian crashes and 38.2% seriously injured pedestrian crashes each year. These would amount to 1.3% and 3.8% of all fatal and serious injury crashes respectively that occur annually in France.

INTRODUCTION

Automatic Emergency Brake Pedestrian (AEBP) is a technology that automatically applies braking force to a vehicle when forward detection sensors determines that a collision is imminent, thereby assisting in avoiding the collision altogether, or if it is unavoidable, to reduce the impact speed of the crash and subsequently the risk of fatal/severe injury to vulnerable road users. (Bond et al., 2003). Although there are several variations of these systems (some providing full and others, partial braking), they all aim to reduce the speed and stopping distance of a vehicle prior to impact in an emergency.

The amount of brake force applied is a continuous function involving factors such as relative speed, relative distance, collision probability and target classification. To this effect, some AEBP's only apply partial (i.e. semi-automatic) braking, with other systems applying maximum braking force (Bond et al., 2003). The objective of these systems is not only to provide continuous braking control throughout a potential collision situation, but also to provide the driver with increased time to react and regain control of the vehicle.

The term Automatic Emergency Braking Pedestrians (AEBP) is used to cover a wide diverse range of systems available by different technology manufacturers (Grover et al. 2008). Studies of the benefits of AEBP in reducing fatalities and serious injuries on the road are rare as the technology is still not widely available in passenger cars.

DEVICE DESCRIPTION

The particular system of interest here involved automatic braking in emergency situation when the sensors detect a pedestrian. It comprises radar located in the very front of the vehicle and a frontal camera accommodated in the central rear-view mirror. The camera and the radar work together

with braking systems such as ESC (Electronic Stability Control) to help the vehicle stop quickly and either avoid the crash altogether or mitigate the injury to pedestrians.

The camera and the radar detect the target pedestrian and determine the collision speeds. The drivers might be notified about the danger by sound or visual warnings or by feedback in the brake. If the driver does not act and if the accident is considered as inevitable, braking is applied automatically to help to minimize the consequences of the accident.

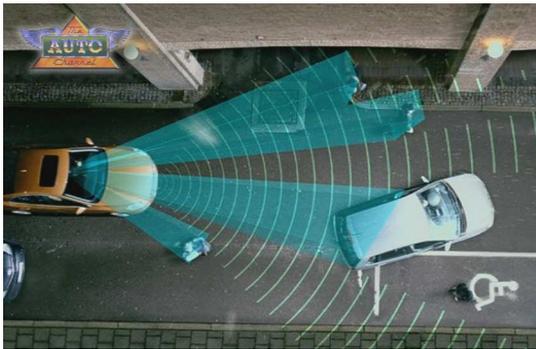


Figure 1. This is an example of the AEBP Pedestrian Technology of interest here.

Functionality

The literature shows that the AEBP declines differently according to the equipment manufacturers and the car manufacturers. So far, only Volvo cars propose AEB pedestrian on his models (S60, S80, V40, V60, V70, XC60, and XC70) as well as Lexus on the LS. Volvo claims that their system should help avoiding a collision with pedestrians at speeds up to 22 mph, and mitigate injuries at slightly higher speeds. The system is built on the safety city systems that helps preventing or mitigating rear-end crashes at low or moderate velocities. The driver is first alerted by a sound signal together with a flashing light in the windshield's head-up display. In order to prompt an immediate, intuitive reaction, the visual warning is designed to look like a brake light coming on. If the driver does not respond to the warning and the system assesses that a collision is about to happen, the car's brakes are applied with full braking force. The car only brakes if it is too late to steer away and applies the brakes less than a second before the calculated impact time. This feature uses a combination of a radar sensor and a camera to identify standing or moving pedestrians within a 60° field of view in daylight. A new dual mode radar detects objects of any shape and measure the distance to them. The camera determines what type of objects they are. To be able to classify an object

as a pedestrian the sensing devices need to read an entire contour line of a human. The body has to be 31 inches or taller. Note that the detection can be disturbed if the human shape is distorted by certain clothes or if the person is carrying something (Volvo web site, www.volvocars.com).

Mobileye also provides a Smartphone application with a few driving aids, including Mobileye PCW (Pedestrian Collision Warning) that alerts to a possible collision with a pedestrian or bicyclist ahead. This application is only a warning and works only with a smart phone camera.

For the purpose of this analysis, we did not refer to the existing systems. It was assumed that the system slows down the vehicle automatically if an obstacle is detected and a collision is unavoidable, at any initial speed of the vehicle. Initially, deceleration is limited to 0,6g (approximately 6m/s^2), depending on the difference of speed between the car and the pedestrian. When there is risk of collision with a pedestrian, a sound signal is emitted and a message appears on the multiple displays. Should the distance between the vehicle and pedestrian continue to decrease, the AEB system automatically brakes the vehicle at 60% of the optimal deceleration (0.6g), and the system tugs the seat belt two or three times, to further alert the driver. The warning signal sounds again and a message appears on the multiple displays. The levels of final braking adopted here are shown in Table 1.

PEDESTRIAN ACCIDENTS

Pedestrians are with two-wheelers, the most vulnerable road users. The road rules define the pedestrian as a person who walk on the road. Are also considered as a pedestrian:

- People who drive a car child, or invalid people, or other small vehicle without engine;
- People who push/pull by hand bicycle or moped;
- Disabled people in wheelchairs driven by themselves or moving at walking pace.

At the world level

In March 2010, the General Assembly of the United Nations launched a Decade of Action for Road Safety 2011-2020. The objective is to stabilize and reduce the expected number of fatalities due to road accidents in the world. According to the OMS, road accidents cause 1.2 million fatalities annually (2.2% of all fatalities and not less than 50 million injuries. Approximately 46% of people who die on the roads in the world are pedestrians, cyclists and drivers or passengers

of motorized two-wheelers, that is to say "vulnerable" road users. Pedestrians account for 22% of fatalities. China, India, Ethiopia, Russia, the Democratic Republic of Congo and Bangladesh alone accounts for 50% of pedestrian fatalities recorded in the world.

At the European level

In 2010, 6,051 pedestrians were killed in a road accident in the EU 27 countries. Pedestrians represent 19% of all fatalities. It is, in Europe, the main vulnerable road users and the second category of users most affected in terms of mortality in road accidents (after car passengers). They are therefore an important issue in the management of road safety for many European countries.

In 2010, nearly 1 pedestrian fatalities out of 3 are in Slovakia (39%), Lithuania (36%), Poland (32%) or Latvia (32%). In 2010, the European countries that account for the highest percentage of pedestrian fatalities are still Poland and Romania with 31% of pedestrian fatalities in Europe. We observe in these countries the greatest risk of being killed as a pedestrian in comparison to the number of inhabitants and the number of vehicles in traffic. Countries of Northern Europe and Central Europe have the lowest percentage of pedestrian fatalities compared to all road deaths (10% for the Netherlands, 12% in Belgium and France, 13% in Germany, Finland and Luxembourg). Thus, for the Eu-27 pedestrian fatalities rate is 1.2 per 100 000 inhabitants.

In France

For over thirty years, in France as in many other European countries, the number of pedestrians involved in an accident tends to decline, but the issue remains important: 485 fatalities, 4,584 injured and hospitalized injured people, 7,502 light injured people in 2010. Accidents involving pedestrians represent at least in 2010, 18% of traffic accidents. In details, in France, in 2010, pedestrians represented 12% of fatalities, 15% of hospitalized injuries and 14% of slight injuries. Among all pedestrians involved in an injury accident in France (n = 12 797), 4% are fatalities, 36% are hospitalized, 58% are slight injuries and 2% are uninjured.

The number of pedestrian fatalities against other users has declined since 2009 except against heavy vehicles, public transport and especially against motorcycles. The percentage of these fatalities increased to 20% against motorcycles while the fleet increased to 2.7%. The risk of being killed as a pedestrian per 100,000 motorcycles increased from 1.1 in 2009 to 1.7 in 2010. Whatever vehicle

types against which he had an accident, the risk of being killed per 100 000 vehicles is about 1.

94% of pedestrian accidents in France take place inside urban areas. 71% of pedestrian fatalities, 93% of hospitalized and 97% of slight injuries are in urban areas. Approximately 74% of pedestrian accidents occur during the day and only 26% at night. However, according to the table below, we observe that more than half of those fatalities are at night. For all France, the risk of being killed as a pedestrian for 100 injuries is in urban areas 2.4 times higher at night than during the day and in rural areas 3.5 times higher. The risk of being severely injured is slightly higher at night than during the day, whatever the accident location (Table2).

Table 2.
Urban and rural pedestrian accident distribution in France

2010	Urban accident		Rural accident		Total
	Day	Night	Day	Night	
Accidents	71,4%	23,5%	2,5%	2,6%	100%
Fatalities	39,9%	31,6%	6,3%	22,2%	100%
Severe injuries	69,9%	23,5%	3,1%	3,5%	100%
Slight injuries	73,5%	23,5%	2,0%	1,0%	100%

The most frequent crash type is when the pedestrian crosses the street/road, from the right, and then from the left. In 30 % of injury crashes, the pedestrian is initially hidden, in other crashes, the pedestrian is lately detected or detected by the driver sufficiently soon but the driver does not expect the pedestrian to cross the street (Brenac et al., 2003).

METHODOLOGY

The objective of this study therefore was to estimate the crash injury benefits of AEB Pedestrian, for pedestrians in France. These benefits were examined in regards to the number and proportion of fatalities and hospitalized that could be saved per annum. As noted earlier, AEB Pedestrians is considered to be useful for reducing pedestrian crashes, thus the analysis, therefore, was confined to this crash types. We assume also that AEBP is working in all road condition types (brightness, weather conditions,...).

The HARM reduction method was used to establish the potential road safety benefits for AEBP. The HARM approach has been widely used by MUARC in previous similar studies for quantifying

road trauma reductions in terms of crashes saved and injuries mitigated. This method has been found to be particularly useful in assessing the benefits of new safety technologies. The most common method adopts a case-by-case analysis of a representative sample of crashes where the researcher selects crashes amenable to the technology and assessors what the crash outcome would have been had the vehicle(s) been fitted with the technology. The sum of these individual savings is then expressed as the benefit of the technology. This is outlined in more detail below.

Databases Used

Two datasets were used as part of the AEBP analysis. These included the French national accident database “Bulletin d’Analyse d’Accident Corporel (BAAC)” which supplies descriptive data per pedestrian and vehicle occupant crash. Data from 2005 to 2009 was provided for this analysis, containing a total of 761,960 cases at an average of 152,392 per annum. In addition, the European Accident Causation Survey in-depth database (EACS) from 1995 to 2001 was used for the case analysis comprising an average of 270 cases per year from Germany, Finland, Italy, the Netherlands, Spain and France. Together, these two databases were used to assess the likely reductions in crashes and injuries had AEBP technology been on-board.

The US National Automotive Sampling System, Crashworthiness Data System (NASS CDS) database was also used to construct injury risk curves, given its extensive case numbers across the investigated crash types. Data from 2000 to 2006 was used for this analysis, involving 73,153 vehicle occupants and pedestrians at an average of 10,450 collisions per annum. These in-depth data are a weighted representative sample of police-reported crashes that occur in the US each year, with detailed information regarding the crash, the vehicle involved and its occupants collected from a variety of sources.

Analysis Procedure

Using the Harm method presented briefly earlier, a detailed case-by-case analysis was used to calculate the crash and injury benefits of AEBP across the crash types of interest. First, relevant crash cases of pedestrian within the EACS database were identified, based on the type of crash reported by the crash investigators as specified by the EACS crash protocol. Given the focus on fatally and seriously injured pedestrians, cases with no injuries were excluded. All cases were entered into an Excel spreadsheet together with key variables including the accident, vehicle and occupant numbers, occupant age and sex, whether the

vehicle braked or not, the braking distance, initial estimated speed and impact speed, road surface condition (wet, icy or dry) and the Injury Severity Score, calculated using the appropriate formula. For braking cases, whether or not ABS was present was also recorded. Braking and non-braking cases were treated separately. For cases where the brakes had been applied pre-crash, the relevant AEBP deceleration rate was applied, according to the road surface condition. Normal deceleration was assumed from when the brakes were applied, until 0.6 sec prior to the crash, after which the full AEBP deceleration rates were applied according to the specifications in Table 1.

Table 1.
Deceleration according to the surface adherence and braking system

Braking system	Surface adherence		
	Dry Road	Wet Road	Icy Road
If ABS used	-7m/s ²	-5m/s ²	-1m/s ²
If ABS not used	-5m/s ²	-3m/s ²	-1m/s ²
With AEBP	-10m/s ²	-6.5m/s ²	-2m/s ²

For non-braking cases, it was specified that AEBP would only operate for the final 0.6 sec before the collision. For the first 0.3 sec, half the maximum deceleration specified in Table 1 was applied (time to prepare the brake system), thereafter, full braking deceleration was allowed for the remaining 0.3 sec. For both braking and non-braking cases, a revised impact speed for each of these cases was computed assuming AEBP performance criteria, using the geometric calculations in Equation 1. In some cases, these figures showed that the crash could have been avoided completely (a negative impact speed was computed):

$$V_2 = \sqrt{V_1^2 + 2a * s} \quad (1)$$

Where:

- V2** = Revised impact speed (m/s)
- V1** = Pre-crash travel speed (m/s)
- a** = acceleration (m/sec²), the maximum obtainable, given friction coefficient.
- s** = Braking distance (m)

For a positive revised impact speed, injury risk curves were then employed to estimate what the likely injury outcome would have been for the crash case. Figure 2 and 3 shows the probability risk curves used for pedestrian by impact severity.

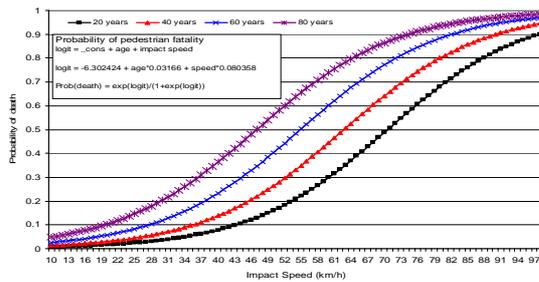


Figure 2. Age-adjusted pedestrian fatality risk curve, given impact speed (Source: Fitzharris & Fildes, 2007)

The revised probability of fatality curves showed the likely improvement in outcome that could be attributed to the technology. The equation derived from the best-fitting trend-line was applied to the fatal EACS cases to calculate a probability of death value for both pre- and post-AEBP (i.e. for pre-AEBP, the initial impact speed was included, with the AEBP impact speed used for establishing the post-AEBP probability of death). In order to derive the predicted percentage reduction in fatalities for AEBP, the values for each case were added for AEBP pre-AEBP and post-AEBP probability of death, with the following equation then applied:

$$X = 100 - (P_2/P_1) * 100 \quad (2).$$

Where:

- X** = percent reduction in fatalities due to AEBP
- P₂** = Added total for probability of fatality for all dead occupants, post-AEBP
- P₁** = Added total for probability of fatality for all dead occupants, pre-AEBP

The revised injury severity outcome in terms of Injury Severity Score (ISS) was then estimated from a Figure 4 derived again from the NASS/CDS database and used to categorize the degree of injury for those cases that now survived.

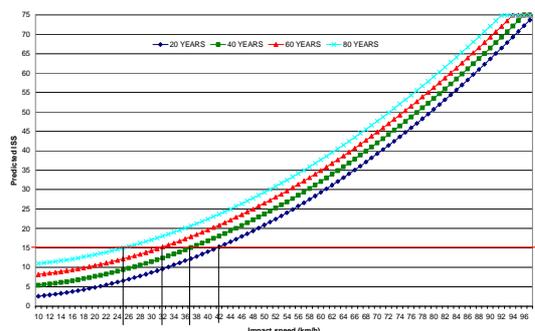


Figure 3. Predicted ISS on the basis of impact speed (Source: Fitzharris & Fildes, 2007)

These figures for each EACS case were then summed to estimate the proportional reduction in crashes, fatalities, serious and minor injury and no injury were then determined for AEBP from the

EACS database, assuming 100% fitment to all French passenger vehicles. In computing the overall benefit if every passenger vehicle in France was fitted with AEBP, the proportional savings from the EACS crashes were applied to the French national crash statistics (BAAC), adjusted based on the relevant proportional differences of each crash type between EACS and BAAC.

CASE STUDY

To assist in understanding the procedure for estimating the benefits of this new technology, a single exemplar pedestrian case from the EACS database was employed and the various steps undertaken are illustrated below. Care needs to be taken in understanding these outcomes using this prospective approach given the assumptions necessary in making these computations. The case chosen involved an 8 year old boy who was struck by a braking vehicle traveling initially at 110km/h that was braking on a dry road for 43 meters prior to the collision at a deceleration rate of just around 5m/s² and struck the boy at 81km/h. He sustained fatal injuries from the crash with an Injury Severe Score (ISS) of 75 (max) and died at scene. The following outlines the procedure adopted to estimate what the outcome would possibly have been had the vehicle been fitted with an Automatic Emergency Braking System. Using Equation 1, the pre-AEBP deceleration rate was calculated at 4.97m/s² and the time to collision over the 43 meters from the moment of braking was 1.41 seconds. In calculating the new deceleration rate, it was assumed that over the first 0.81 seconds, the normal deceleration rate of 4.97m/s² would have applied, and the vehicle's velocity would have reduced from 110km/h to 94km/h when the AEBP intervened. From then on, the vehicle would have braked more severely at 10m/s² (it was noted to be a dry road) reaching a final velocity of 70km/h at the moment of impact. The crash would still have happened however, and the effect of the AEBP technology for this crash would have been a reduction in impact severity from 81km/h to 70km/h, a reduction of 11km/h or 86% of the original value.

Probability of Death

From Figure 2 using the appropriate curve (20 years was chosen from the 3 available), the probability of death for the initial impact speed of 81km/h was estimated to have been 0.70 (70% probability or for every 100 such crashes, 70 of them would have resulted in a death for this impact speed). This is a high value and consistent with the boy having been killed in the crash. Now that the revised impact speed has been estimated to be only 70km/h with AEB technology,

this equates to a probability of death of 0.5, that is, a 50% likelihood of being killed. It would be expected that at this probability level (a 1 in 2 chance), the child could possibly have not been killed in this crash, although he would still have been seriously injured.

Serious Injuries

There was a reasonable chance that the 8 year old subject here may have survived the crash with a reduced 70km/h impact speed, but would still have been seriously injured. To estimate what his injury severity level would have been, we refer to Figure 4 that was NHTSA cases. Using the formula for translating impact speed in a pedestrian crash to Injury Severity Score, we found a revised ISS value from 75 (max ISS for a death) to around 40 at the lower impact speed.

It is important to note that ISS is not a continuous scale as it is derived from adding the maximum AIS scores (squared) for up to 3 body regions. Hence, it is technically impossible to get certain numbers and fractions (it is a non-monotonic). More details on ISS and AIS are available on request.

An ISS value of 40 is still considered to be a serious life-threatening injury. Had the boy survived this crash, he would have still sustained very severe injuries. Trauma specialists report that injuries at these levels are associated with long stays in hospital and survival is determined by the type of injury, where it occurred and whether it can be properly treated as well as the patient's ability to recover. Moreover, injuries of this level can be associated with a degree of ongoing permanent disability.

Computing AEBP Benefits

The prognosis for this particular case post-AEBP using the assumptions specified was good in terms of a potential life saved but with a severe injury outcome and the possibility of ongoing long term impairments. Had the case been one of initial survivable injury, it is likely that this would have translated to a lesser severity injury from the reduction in impact speed. We would then have interpreted this as a percentage of injury saved by AIS or a "shift" in injury severity that could be attributed to the technology.

From the in-depth EACS case analysis, we can determine what the number of fatalities saved by summing these across the total cases and determine the percentage reduction in deaths and then apply these percentages for the total fleet in the French National database (BAAC data) to estimate the annual fatality benefit. Thus, while the outcome for this fatality was positive (the child would have lived), nevertheless, the injuries sustained need to

be subtracted from the total injury saved to arrive at the true benefit from the technology. In this calculation, we simply subtracted this percentage outcome (assumed it would have been classified as Severe in this analysis) to what we finally determined to be the total injury severity saved, to arrive at the overall total benefit.

RESULTS

The number of fatalities and seriously injured occupants in France from 2005 to 2009 is shown in Table 3.

Table 3.
Fatal and severely injured persons (BAAC Database)

French National Crash Statistics						
	2005	2006	2007	2008	2009	Average
Fatalities	5,318	4,709	4,620	4,275	4,273	4,639
Hospitalized	39,811	40,662	38,615	36,179	38,813	38,816

Pedestrian crashes

As shown in Table 4, 15.3% of pedestrian would be expected to be saved each year in France if every vehicle was fitted with AEBP.

Table 4.
Expected fatal and serious injured pedestrian crashes affected by AEBP

Outcome	Savings
Number of fatal Crashes Survived (n=379)	58
Percent fatal pedestrian crashes saved	15.3%
Percent fatal crashes saved in France	1.3%
Number serious injury crash saved (n=3959)	1,514
Percent serious injured pedestrian crashes saved	38.2%
Percent serious injured crashes saved in France	3.8%

Of the 379 fatal pedestrian crashes in pedestrian to passenger car crashes that occur in France each year (2005-2009 average), 58 (15.3%) were estimated would have been saved by the widespread fitment of AEBP technology. Based on an average of 4,639 road fatal crashes that occurred each year in France between 2005 and 2009, these estimated savings equate to 1.3% reduction overall in French road fatal crashes from AEBP. For 62% of these previous fatal cases, the computed level of injury would be downgraded to serious, 24% to

minor or no injury and 14% of the crashes would have been avoided altogether. Of the 3,959 seriously injured pedestrian crashes annually in France, it was estimated that 1,514 crashes (38.2%) would have been influenced by AEBP equating to a 3.8% potential saving in the total number of 38,816, serious road injury cases in France each year. Of the 1,514 crashes affected, 88% would have been reduced to minor injury crashes, while the remaining 12% involved no injury or the crash was avoided.

Adjusted Benefits

It should be noted, however, that these savings are independent and do not include the additional increase in serious and minor injury cases from the downgrading of fatal cases to less serious injury outcomes. That is, the 58 pedestrian fatal crashes would no longer be fatal outcomes.

The expected fatal and serious injury crash reduction benefits for AEBP were then combined to reveal the final KSI outcome benefits for AEBP among pedestrian and rear-end crashes. According to the proportional benefits indicated above, the benefits and redistribution of these cases, due to the influence of AEBP, are shown in Tables 5.

Table 5.
Combined fatal and serious injury outcomes for pedestrian cases with AEBP

Injury Outcome	Fatal Cases (n=379)	S. I. Outcome (n=3959)	S. I. Outcome (adjusted)	Adjusted Savings
Fatalities	321	-	-	58 (1.3%)
Serious Injuries	36	2445	2481	1478 (34.1%)
Minor/non-injured or crash avoided	22	1514	1478	2802 (64.6%)

From these data, it was found that with an average of 4,338 KSI crashes (Killed and Seriously Injured) pedestrian injury cases per annum in France, the combined outcome showed a saving of 58 fatal and 1,478 serious injury crashes. While there would be some overflow increase in minor injury crashes from the downgrade of KSI cases, these would also be offset by savings in minor injuries, non-injured crashes and additional crashes avoided altogether from AEBP which were not calculated here.

DISCUSSION

The focus of this study was constrained to estimating only fatal and serious injury crash savings for AEBP technology described earlier in pedestrian crashes. These were considered to be the major crash types likely to be influenced by the technology where most of the benefits would accrue.

Pedestrian crashes

The results of this analysis show a potential important estimated reduction in fatal and serious injuries to pedestrians resulting from the fitment of AEBP technology to all vehicles in France. Fifty-eight (15.3%) of fatal pedestrian crashes each year and 1,514 (38.2%) seriously injured pedestrian crashes would be saved in France each year, based on the average number of these crashes that occurred during 2005 to 2009. These would amount to 1.3% and 3.8% of all fatal and serious injury crashes respectively that occur annually in France. These figures are of course very much dependant on the assumptions we made about a generic operation of such system.

While there would be a small increase in serious injury outcomes from the redistribution of fatal case outcomes, nevertheless, there would still be a sizeable reduction of 1478 serious injuries from the widespread use of this technology. There would also be additional reductions expected in minor injury and non-injury crashes as well as crashes avoided, although these computations were not the focus of this study. Furthermore, these benefits would be cumulative benefits each year.

Several earlier studies on the benefits of Brake Assist alone BAS (activated by emergency pedal action) have been carried out. One predictive study by Page et al. (2005) looking at fatal car crashes with pedestrians found that Brake Assist alone could reduce pedestrian fatalities by 10 to 12 percent in cases where the driver braked with a maximum braking force of 7m/s². Assuming that non-braking cases usually account of around 40% of pedestrian crashes (Fitzharris and Fildes 2007), this savings would reduce to around 6 to 7 percent of fatal crashes. Other studies of BAS technology reported similar benefits in reduced fatal and serious injury crashes (Hannawald and Kauer 2004; Lawrence et al 2006; Fitzharris and Fildes 2007). This would be expected though as Brake Assist alone is reliant on the driver braking before the crash to gain any benefit. For AEBP, the added benefits of the system self-operating 0.6 seconds before the crash would add additional benefits beyond those from superior braking and account for these differences.

There are just a few studies that have looked at the potential of AEBP to prevent or mitigate pedestrian injuries. A study by Rosén et al (2009) claimed even greater benefits from a case-by-case analysis of German GIDAS in-depth data – a 40% reduction in all fatal and a 27% reduction in serious injury pedestrian crashes using sensors with field of views between 180° and 40° and autonomous brake

activation times up to 2 seconds pre-crash. For activation times closer to those used here (0.6 seconds), they predicted effectiveness values closer to those found here (approximately 20% for fatal and 10% for severely injured pedestrian crashes). Furthermore, they did not make any adjustment for road condition and it is questionable if such large pre-crash distances would be realistic for drivers who did not brake.

Robinson et al. looked at the British data to estimate the potential of AEBP in preventing pedestrian injuries. They considered a generic system that brakes automatically when a pedestrian is detected, without any prior warning strategies. The system operates in good light conditions, excluding nighttime crashes and crashes occurring in the fog, snow or rain. It works in an un-cluttered environment and on straight roads only. They considered three different systems, the first one acting at a maximum 2 seconds prior to impact, the second one at 1 second and the third one at 0.6 second prior to impact. The system activates at any speed and deceleration is supposed to be a uniform 0,7 m/s². Depending on assumptions, results show a potential of reductions of pedestrian serious injuries around 50 % for first system, 45 % for system 2 and 20 % for system 3.

An improved method to assess the safety benefits of active safety systems, and especially AEB pedestrian, has recently been proposed but not yet applied (or published) (Schramm et Roth, 2009). It is based on the generation of accident scenarios as well as the simulation of driver behavior but its efficient applicability still needs to be demonstrated. Other studies have generated accident scenarios or accident clusters either to identify typical crashes that might be concerned by an AEBP or to propose tests to assess their performance (Lenard et al, 2011; Niewöhner et al, 2011; aspects EU-funded project). For Lenard et al, a baseline scenario is where a pedestrian steps out from the kerb without obstruction of the driver's line of sight. A second one is where the pedestrian is smaller and at least partially obscured. A third scenario occurs in adverse meteorological conditions with adult pedestrians. Niewöhner et al. reported about the outcomes of the vFSS working group (Advanced Forward looking Safety System). The target of the group is to develop proposals for test procedures for forward-looking safety systems based on the results of accident analysis.

Niewöhner et al. propose a classification of main pedestrian crashes into 6 main configurations: first scenario considers a car moving ahead at around 50 km/h that is hitting an adult pedestrian that crosses from the right at a normal pace. The driver reacts and brakes. The second one considers a car moving

ahead at around 60 km/h, which is hitting a child crossing from the left and running. The driver reacts and brakes. This scenario frequently occurs at dusk/dawn. These are the two principal scenarios out coming from the vFSS and cover two-third of all severe or fatal injuries caused by a frontal collision with a passenger car. More than 40 % of pedestrian crashes involve an obstruction, most of them being a vehicle. One third of car drivers do not brake. Based on the accident analysis, the group proposed 4 test procedures based on whether the crossing pedestrian is an adult/child, whether he is obstructed or not. They also propose initial velocities of cars, velocities of pedestrian dummies and distance of visibility by the driver of the crossing pedestrian.

Other Aspects on the Analysis

It should be pointed out that the benefits obtained in this study did make a number of assumptions: in particular, that these full benefits would apply for 100% market penetration of the technology, that drivers would not attempt to interfere with the system, that the deceleration levels specified were adhered to in its operation, and that the system is fully functional (no allowance was made for any sub-optimal functioning of the technology). In addition, the results reported here only considered benefits to pedestrian crashes. It is conceivable that the technology may have additional benefits in other crash modes too, such as frontal and side impact collisions with other vehicles (Chauvel et al, 2012) (but the technology for these crash types is not yet mature). While to date, it appears that the only current system with the necessary sophisticated sensors seem to be that offered by the Volvo XC60. This is likely to change in future. Any benefits in other crash would potentially increase the benefits of the AEBP technology over that reported here and warrants further research.

Finally, this analysis focused on the benefits to crashes that occurred in France alone, based on the patterns of crashes in that country. Other European or international countries have likely to have different crash patterns that will influence the benefits reported here. Ultimately, the real benefits of AEBP technology will only be confirmed from a post-production validation analysis, based on real-world crashes which needs to be undertaken in future research.

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