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Effectiveness of low speed autonomous emergency braking in real-world rear-end crashes

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A B S T R A C T

This study set out to evaluate the effectiveness of low speed autonomous emergency braking (AEB) technology in current model passenger vehicles, based on real-world crash experience. The validating vehicle safety through meta-analysis (VVSMA) group comprising a collaboration of government, industry consumer organisations and researchers, pooled data from a number of countries using a standard analysis format and the established MUND approach. Induced exposure methods were adopted to control for any extraneous effects. The findings showed a 38 percent overall reduction in rear-end crashes for vehicles fitted with AEB compared to a comparison sample of similar vehicles. There was no statistical evidence of any difference in effect between urban (≤60 km/h) and rural (>60 km/h) speed zones. Areas requiring further research were identified and widespread fitment through the vehicle fleet is recommended.

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1. Introduction

Advanced crash avoidance technologies are increasing rapidly in passenger and commercial vehicles as industry, government and the community focus on improved vehicle safety systems. One of the more promising safety technologies that is starting to appear as standard equipment on modern passenger cars and sport utility vehicles (suv) is autonomous emergency braking (AEB). Autonomous emergency braking systems apply the vehicle brakes when a collision is eminent in spite of any reaction by the driver. In some technologies, the system forewarns the driver with an acoustic signal when a collision is still avoidable, but subsequently applies the brakes automatically if the driver fails to respond.

There are at least two versions of these systems, namely low-speed or "City" systems or high-speed "Inter-Urban" systems that operate at different speed thresholds. These systems commonly consist of an automatic brake function and a forward collision warning sensor and vehicles may offer either single of both functionalities (Euro NCAP, 2014). The AEB "City Safety" system was first introduced by Volvo cars in their XC60 sport utility vehicle around 2009 (ITS International, 2013) and more recently, extended the technology as standard equipment in all its passenger vehicles. In recent years, other manufacturers, primarily in European and Japanese models, also offer versions of similar systems in their modern vehicles. The technology operates for vehicle speeds up to 30 km/h or 50 km/h in some vehicle models.

It is claimed that autonomous emergency braking systems offer substantial reductions in crash avoidance or injury mitigation as shown in Table 1. It should be noted with some caution that many of these studies used a range of different technology functionalities and assessment methods.

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Table 1
Published studies of benefits of AEB technology.

AEB report	AEB type	Assessment method	Crash reductions	Injury reductions			
				Fatalities	Serious	Slight	Injuries
Sugimoto and Sauer (2005)	CMBS	Simulation rear-end crashes	38%	44%			
Page et al. (2005)	EBA	Case analysis Forward crashes		7.50%			11%
Najm et al. (2006)	ACAS	FOT responses	6–15%				
Breuer et al. (2007)	BAS+	Simulation ped/rear crashes	44%				
Kuehn et al. (2009)	CMBS	Case analysis front/rear crash	40.80%	n.a.	n.a.	n.a.	n.a.
GDV (2011)	EBA2	Case analysis rear-end crashes	13.90%	2.20%	9.40%	35.70%	
Grover et al. (2008)	AEB	Case analysis sensitive crashes	30%				
Kusano and Gabler (2012)	AEB	Case analysis rear-end crashes	7.70%	50%			
HLDI (2011)	AEB	Insurance claims	22–27%				51%
Döcke et al. (2012)	AEB	Case analysis rear-end crash	25–28%				
Chauvelet al. (2013)	AEB	Case analysis pedestrians	4.30%	15%	37%	n.a.	n.a.

While many of these evaluations claim substantial benefits, most are based on desk-top evaluations of expected crash and injury outcomes. Unfortunately, there is only limited evidence of their real-world effectiveness in reducing crashes or injuries. Single country crash databases, traditionally used for conducting real-world evaluations, are limited by the slow take-up rates of these new technologies, limited crash data, and lower crash rates by owners of new safer vehicles. New systems are also commonly available on only a few car models and sometimes optional which increases the time needed to assess their real-world effectiveness. One way of potentially speeding up the evaluation process is to adopt a wider approach to collecting and analyzing crash data, rather than simply relying on one country's analysis from their limited crash numbers.

1.1. Meta-analysis

Classic meta-analysis, commonly used by the medical fraternity, typically combines the findings of various existing published randomized control trials of a common theme to produce a much larger pool of research data, leading to a more robust assessment (Cochran Collaboration, 2013). This approach typically relies on *retrospectively* published studies that meet established criteria, and while they are very useful for helping establish general trends and outcomes, they are commonly assembled from evaluations (clinical trials) already published in the scientific literature and thus still subject to long delays.

An alternative *prospective* approach involves a planned collaboration of independent aggregate analyses from data analysts using a common study design. This brings together a much larger pool of data than any one country, has available, speeds-up the process of evaluating safety technologies, and provides a more internationally relevant assessment of the safety benefits than any one single country can provide. In a recent published study (MUNDS) it was shown that it is possible to increase the available relevant crash data by combining data from a number of countries using meta-analyses and thus obtain robust statistical evaluations more quickly (Fildes et al., 2013).

Meta-analysis has the additional advantage of circumventing the need to work with unit-level data. In ideal circumstances, regression models could be fitted to unit-level data, allowing for more efficient estimation and control for potential confounders. In practice, road safety agencies and police are reluctant to hand over their data at this level to external parties, but are willing to summarise their data at an aggregated level suitable for a meta-analysis.

With Euro NCAP's initiation, a technical group of researchers from government, industry and research organizations was assembled (the Validating Vehicle Safety through Meta-Analysis or VVSMA group) to evaluate the effectiveness of low speed autonomous emergency braking technology (AEB city), using this new approach. The objective was to measure the likely reductions in important rear-end injury crashes for vehicles fitted with this safety technology. Case and control vehicles were agreed upon by the whole group and these are listed in Appendix A.

1.2. Low speed AEB technology

CarAdvice (2014) noted that low speed AEB or City Safe technologies are marketed under a variety of names, including City Brake Control (Fiat), Active City Stop (Ford), City Emergency Brake (Volkswagen) and City Safety (Volvo). As their names suggest, this type of AEB technology is geared towards low speed situations, generally under 30 km/h. These systems rely on radar sensors detecting an emergency situation and apply the brakes as needed. They tend to work most effectively over short distances.

Low speed AEB technology, such as the City Safety system fitted to new Volvo vehicles, operates at speeds between 30 and 50 km/h. As the name implies, the system is designed to only offer protection in rear-end crashes in mainly urban areas. Low-speed AEB systems use sensors to monitor the road ahead, typically 6–8 m. One common technology is a LIDAR (light detection and ranging) sensor, typically mounted at the top of the windscreen, which determines whether or not there is an object in front of the car which presents a risk. If there is, the AEB system will, typically, pre-charge the brakes so that the car will provide its most efficient braking response, should the driver react. If the driver does not respond, the car will automatically apply the brakes to avoid, or in some cases to mitigate, the accident. If, at any point, the driver intervenes to avoid the accident, by hard braking or avoidance steering, the system will disengage (Euro NCAP, 2014).

1.3. Induced exposure

An induced exposure approach was used in the present paper, as the true exposure with low-speed AEB may be difficult to obtain in different countries, and could be also associated with some confounding factors. An analysis using induced exposure can be used when the true exposure is not available or not suitable, as argued in Evans (1998),Hautzinger (2003) and Lie et al. (2006).

Induced exposure approaches to estimating risk attempt to quantify on-road exposure using counts of crash involvements. The crash types used for these risk estimates generally focus on events where the driver of a given vehicle could be considered to be passively involved in the crash. Such crash events, therefore, are conceptualised as a sampling mechanism and the counts of the crashes are assumed to be proportional to the amount of driving undertaken by a given driver group or vehicle type. Validation of

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