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Autonomous Emergency Brake (AEB) for Pedestrian for ASEAN NCAP Safety Rating Consideration: A Review

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REVIEW **Open Access**

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Abstract – *Road crossings are considered as an unavoidable part of walking in which the desirable route of pedestrians interacts with vehicles. This interaction may expose the pedestrians to risks or delays. Pedestrian-vehicle collisions are regarded as the most serious type of accidents since they incur high fatality rate of nearly 13 percent. This study has been carried out to fulfil two objectives. First, to identify the contributing factors to road crash, and second, to understand the implementation and effectiveness of a preventive device to reduce road crashes involving pedestrians. Collision avoidance and mitigation systems such as the AEB are intended to reduce accident risks by automatically applying the brakes prior to an accident. Understanding the human action, style and behaviour are the key elements in producing the ideal AEB Pedestrian for the future. This study sheds light on the future direction in the area of road safety by considering preventive actions to reduce the occurrence of road crashes, particularly among pedestrians.*

Keywords: Road safety, road user, road environment, crossing, preventive device, ASEAN NCAP

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1.0 INTRODUCTION

Pedestrian-vehicle collisions are regarded as the most serious type of accidents since they incur a high fatality rate. There are approximately 316,000 cases of road fatalities in the ASEAN Region which translates to a fatality rate of 17.0 per 100 000 populations. Such a rate is just below the global rate of 17.4. The Vulnerable Road Users (VRUs) which include pedestrians, motorcyclists and cyclists make up half of the road traffic deaths in the region with pedestrians accounting for 13% (UNHCR, 2015).

This tells us that pedestrians are among the most affected road users during a road accident. Various pedestrian- and vehicle-related activities in the urban areas are to blame for the pedestrians to be the most at risk in such areas. People walk as a part of the trip to their intended destination, regardless of their primary mode of transportation. With this in mind, designing safe, accessible, and comprehensive facilities for pedestrians is vital to reduce crashes involving pedestrians.

In the US, children and older pedestrians have registered an increasing fatal crash trends. Between 1997 and 2006, children under 15 years old accounted for about 21% of the U.S. population, and have been involved in 23% of fatal pedestrian crashes. Children 15 years old or less account for 8% of pedestrian fatalities. On the other hand, pedestrians over the age of 70 made up about 9% of the population but were involved in 16% of pedestrian deaths in 2007 (Chang, 2008). Death tolls in European roads have been at an all-time low over the past 20 years due to improvements made to the drivers' and passengers' protection. VRUs account for 47% of Europe's 26,000 road deaths. Real world crash data in the UK and Germany suggest that implementation of AEB system could prevent one in five fatal pedestrian collisions (Edwards et al., 2014).

In Malaysia, pedestrian fatalities register approximately 500 deaths each year. Records consistently show that fatal road traffic injuries among the elderly (<60 years old) are increasing from 24.4% (2006) to 44.2% (2013). In term of incident occurrence, statistics show that straight road contributed most of pedestrian fatalities followed by junction-type of road (Ariffin et al., 2010; Solah et al., 2017). According to Malaysian Institute of Road Safety Research (MIROS), frontal collisions are the most frequent type of accidents in Malaysia (Abidin et al., 2012).

There are a few factors for such collisions to happen. One of the most critical is speed management. Local road users often face difficulties when balancing mobility and safety. As average traffic speed increases, the probability of a crash will also rise especially for VRUs. An adult pedestrian has below than 20% chance of getting hit if a vehicle is moving at a relatively low speed of 50km/h. However, being struck at 80 km/h, his chance of survival is only 40%. With such information, AEB makers may have a general idea for setting specific speed limiter to trigger the braking mechanism, thus making the system more viable for future road users.

Apart from speed problem, distraction has become as a serious road safety threat in the recent years. This is parallel to the growth of mobile phone usage and other in-vehicle technologies that would cause the driver to lose focus on the road when driving. Visual, auditory, manual and cognitive distractions are created in the presence of a mobile phone (Law, 2011). These distractions impair driving performance by causing longer time to react when braking, not staying in the correct lane and having a dangerously short following distance.

Most of the time, an accident happens due to the driver's inability to react in time. An effect popularly known as looked-but-failed-to-see has been the major reason for an accident. Such a situation occurs when the brain cannot perceive an object even if the object was fixated by the eyes. The human field of view comprises the foveal area with an angle of opening of 2° and the parafoveal area which opens at an angle of about 8°. Only moving and high contrast objects are perceived outside these field of views. Two main visual tasks for car drivers are continuous scanning and anticipation of surrounding, and specific observation for events such as walking pedestrians. Therefore, active pedestrian protection system like AEB plays a significant role in helping the driver to detect and react to risk factors that the human mind sometimes fails to do so.

A few relevant factors and issues have been mentioned in the above discussion despite many other factors that can affect the severity of a pedestrian crash. These pedestrian-related factors relate to the pedestrian, driver, vehicle, roadway, and/or to a range of social/demographic factors that affect the amount and manner in which people travel. In this study, we tend to focus more on the behaviour of pedestrians as they are the fundamental elements of AEB pedestrian system functionality.

2.0 DISCUSSION ON PEDESTRIAN BEHAVIOUR, EFFECTIVENESS, IMPLEMENTATION, AND PUBLIC PERCEPTION OF AEB

2.1 Pedestrian Behaviour

When determining the sufficient remaining time before reaching to a pedestrian during road crossing, a pedestrian has to do traffic detection, combining data from different directions and adapt his action to the continuous perception of oncoming vehicles. The essential ability is to determine the available time (depending on time gaps between vehicles) and relate it to the time needed to cross (depending on environmental factors such as road width, and personal factors such as walking speed and ability to accelerate).

In principle, crossing is only possible if the crossing time is lower than the available time given, but usually allowance for safety margin is done by pedestrians. The functional variable for managing road crossing is the time gap, whose minimal length considered acceptable by the pedestrian should be constant in a given situation. Many studies have investigated the behaviour of pedestrians during road crossing. The factors influencing the overall behaviour of pedestrians have been identified. Such factors are then categorized as pedestrians, road environment and traffic factors. Long waiting time or delays have significantly affected a pedestrian behaviour. High tendencies to jaywalk by pedestrian are shown after a long waiting time. They often lose their patience while waiting to accept safe gaps. Instead of waiting for safer gaps (greater loss of time), a pedestrian may opt to use rolling gaps across several lanes (Brewer et al., 2006). The time spent waiting for safer gaps depend on whether the pedestrian is alone or in groups. If a member of the group initiates the illegal crossing, other pedestrians have an urge to follow suit. From observations made, male pedestrians are more likely to cross on red compared to females (Holland & Hill, 2010).

In addition to this, pedestrians' behaviours are largely affected by the number of pedestrians in a group. Larger groups have higher tendencies to make more illegal crosses compared to small groups (Holland & Hill, 2010). Each pedestrian has his own perception on choosing the safest gap. Taller pedestrians often prefer smaller gaps compared to shorter pedestrians due to the former's ability to walk faster (Goh et al., 2012).

According to research, it is found that walking speed decreases as age increases, even when specific mobility impairments are factored out. Older people are more sensible in adjusting their walking speed to take account of traffic conditions. They adapt walking speed and choice of gap to the traffic conditions in a similar manner to the way younger pedestrians do, but the very oldest pedestrians frequently select gaps that are too small for them (Lobjois & Cavallo, 2007).

Clearly, pedestrians' decisions are complex in nature. Several matters have to be addressed such as when to stop or wait and where to cross in a limited period of time. The decision is influenced by many factors including comfort level, convenience to cross as well as safety. In addition, pedestrian flow, traffic volume, footpath width, road width, surface condition and walkway obstructions were found to significantly affect pedestrian comfort and safety. Furthermore, pedestrian behaviour is not constant and often changes according to the pedestrian's environment.

2.2 Effectiveness of AEB Pedestrian

Collision avoidance and mitigation systems including the AEB are intended to reduce or prevent accident risks, by automatically applying brakes prior to an accident. It is said that this system has worked effectively, by diminishing the number of injured pedestrians and providing efficient protection to VRUs (Chomchai et al., 2013). The objective of AEB system is to automatically mitigate or avoid an accident in case a driver fails to react in time. Mitigation can be achieved by lessening the impact speed and thereby decreasing the risk of injury to a pedestrian. In an ideal scenario, speed reduction would ultimately avoid a collision completely.

Technological advancement in the area of exterior sensors such as Radar, Lidar and Optical have been the main contributors to the practical application of the AEB system. These advances have provided other risk reducing features such as Lane Departure Warning (LDW), Forward Collision Warning (FCW) and Adaptive Cruise Control (ACC). One safety feature that integrates AEB with FCW is the Collision Warning with Full Auto Brake and Pedestrian Detection (CWAB-PD). It was launched alongside the Volvo S60 2011 with the ability to provide warning, brake support and full automatic emergency braking up to 10 m/s^2 in pedestrian accidents as well as automatic collision avoidance (Coelingh et al., 2010).

Autonomous vehicle can be successfully achieved if effectiveness of the AEB is fully understood. The overall workflow in estimating the effects of AEB starts with inputs from in-depth accidents data and collision analysis that defines the potential risk factors and outlines the pre-impact scenarios (Lindman et al., 2010). Studies have been made to account several variables such as initial and collision speed, as well as moving patterns of pedestrian-car when determining crash severity.

The next step in the workflow would be to define the functionality. Taking the CWAB-PD system as an example, it uses a combination of long-range radar and a forward-viewing wide-angle camera to continuously monitor the area in front of the vehicle. It also reduces the risk of detecting false targets and increases the confidence in, and data accuracy of the detected target by fusing data from two sensors with different characteristics. For a pedestrian to be reliably detected, he or she needs to have a pedestrian shape, with the head, shoulders and legs. This means that a sitting pedestrian or a pedestrian who is partially occluded is less likely to be detected. Also, the camera is unable to detect pedestrians in the dark. This is important to bear in mind in order to allow for hard and early braking in accident scenarios while simultaneously keeping the risk of false brake interventions at an acceptably low level (Lindman et al., 2010).

The data processing phase involves preventive system model application on scenarios based on accident data to calculate the changes of speed during impact. Real world accident scenarios are reconstructed for analysis using simulators. The test scenarios would run several times, setting the first trial as the baseline reference for impact time and velocity. The next few trials would be done with the activation of AEB to establish a speed reduction baseline. Evaluations are then made by comparing the two results. By establishing those baselines, we are able to estimate the severity of injury outcome to the pedestrian. According to Korner (1989), an injury outcome is the product of injury risk as a function of crash severity and crash severity distribution (Komer, 1989). As a result, calculation of accidents avoided and mitigated can be made. Information on the average speed reduction with the help of AEB can also be determined based on the analysis. With the system being activated, crash severity distribution and probability take up a new value that would be useful in determining the effectiveness of this active safety system (Lindman et al., 2010).

However, developing systems that address pedestrian accidents are very challenging from a technological point of view. This is because pedestrians are able to change their direction immediately, thus their movement unpredictable. The pedestrians is relatively smaller compared to a vehicle for sensors to detect and classify as a potential risk factor. A majority of pedestrian accidents takes place in cross-traffics situation. Therefore, perpendicular accident speed and starting position have to match the function of velocity difference as in longitudinal accidents (Seiniger et al., 2015).

2.3 Worldwide Implementation

2.3.1 AEB Implementation in Europe

The implementation of Autonomous Emergency Braking System began with the release Euro NCAP Road Map 2010-2015. The low speed AEB City system was directly linked to whiplash prevention and was an addition to the Adult Occupant Protection (AOP). Whereas the high speed AEB Inter-Urban system was included to the Safety Assist (SA) pillar as it offers wide ranging benefits compared to the other protocols. Other fields of assessments such as Child Occupant Protection (COP) and Pedestrian Protection (PP) were also introduced along with the new rating scheme (Euro NCAP, 2015).

By opening the rating scheme to new technologies, Euro NCAP also introduced an award system called Euro NCAP Advanced to promote new important technologies, explain their safety potentials and learn how they are evaluated by the carmakers themselves. Among other technologies, AEB systems from several manufacturers were proposed for Euro NCAP Advanced reward. The accident analyses carried out to support their applications suggest that AEB systems could reduce rear end crashes by more than 38% (Fildes et al., 2015).

Euro NCAP tested three scenarios for pedestrian detection. The test scenarios comprised scenarios where the pedestrian crosses the path of the test vehicle, and one in which the pedestrian is walking in the same direction as the vehicle (Edwards et al., 2014). The end result of all these scenarios would lead to fatal injuries to the pedestrian if the AEB system did not intervene with or mitigate the crash. The crossing scenarios included: an adult running from the driver's side of the vehicle; an adult walking from the passenger's side (two tests were performed for this scenario); and a child running from between parked cars on the passenger's side of the car. In the longitudinal scenario, two tests were done: one with the pedestrian aligned with the center of vehicle, the other with the pedestrian offset to one side. The longitudinal scenario and one of the crossing scenarios were repeated in low-light conditions, as this was the situation in which many pedestrian accidents occurred (Edwards et al., 2014).

The earlier series of AEB system tests showed that the system was capable to intervene and support drivers during imminent rear-end crashes. A positive real-world benefit can be expected despite differentiation of performance between systems by different manufacturers. Although activation may not be sufficient or timely enough to avoid a crash completely, impact speed was significantly reduced. However, AEB technology is just a support system and should not be overly relied upon.

2.3.2 AEB Implementation in Japan

Recent years have seen these systems continuing to spread from cars to large vehicles including trucks and buses. In Japan, there is a movement to mandate all new cars be equipped with the technology. The Japanese Ministry of Land, Infrastructure and Transport uses the official name "Collision damage mitigation braking" for AEB. However, ordinary people refer to AEB as "automatic braking," and this name is also used in advertisements. New international standards for systems for daytime and night time pedestrian detection utilizing an automatic braking system to reduce the chance of collisions between vehicles and pedestrians have been issued based on the proposal filed by Japan to the International Organization for Standardization (ISO). These standards are expected to contribute to popularizing vehicles with built-in preventive safety functions that even work effectively in low-light or dark conditions, where the pedestrian casualty rate involving car accidents is particularly high, thereby decreasing the number of pedestrians involved in such accidents.

Although the number of car accidents has been constantly decreasing, 34.4% of the total vehicle-related fatalities in the first half of 2017 involved pedestrians who are vulnerable road users, and approximately 70% of those accidents occurred at night. In light of this situation, in recent years, some automobile companies have introduced collision-prevention safety features into vehicles on the market in which built-in cameras and sensors detect pedestrians, and alarms or emergency braking systems alert the driver or stop the vehicle if collisions become likely, so as to decrease the occurrence of car accidents. Aiming to establish an environment in which customers are able to select safe vehicles and automobile companies are able to manufacture and market such vehicles, the National Agency for Automotive Safety & Victims' Aid (NASVA) has been conducting an effort titled "Type-based Test for Assessing Preventive Safety Functions of Vehicles," in which it conducts in-vehicle tests (which currently only target the daytime performance), and releases the results to the public.

Key points in the issuance of new standards (ISO 19237 : Pedestrian detection and collision mitigation systems) are as follows (Geared, 2013). The standards stipulate performance requirements of the systems and testing procedures (daytime and night time). They also stipulate references to other international standards for specifications of mock pedestrian used for performance tests, an achievement developed in collaboration with another ISO working group.

In December 2013, the Society of Automotive Engineers of Japan, Inc. (JSAE) submitted a proposal of new standards to ISO/TC204 (intelligent transport systems)/WG14 (vehicle/roadway warning and control systems), in which Japan serves as the secretariat (Komer, 1989). In response, WG14 developed new standards for ISO 19206-2 which specifies details of mock pedestrians to be used for vehicle performance tests in mutual collaboration with ISO/TC22 (road vehicles)/SC33 (vehicle dynamics and chassis components)/ WG16 (active safety test equipment), and on December 8, 2017, the ISO finally issued the new standards.

The new standards may cause entities worldwide to introduce both the daytime- and night time-performance requirements of vehicle braking systems and test procedures thereof into their vehicle assessments, considering the high death rate in car accidents involving pedestrians after dark. These efforts are expected to contribute to popularizing vehicles with more high-quality preventive safety features and decreasing the number of such accidents involving pedestrians. Through these efforts, the number of pedestrian deaths and injuries from car accidents may decrease globally and the goal set by the United States SDGs may be achieved by 2020, whereby member countries should halve the number of global deaths and injuries from road traffic accidents.

2.3.2 AEB Implementation in Malaysia

Malaysia has acknowledged road safety as a critical problem that should be urgently addressed. The New Car Assessment Program for Southeast Asian Countries (ASEAN NCAP) in its press release has listed the induction of AEB as a requirement in their New Rating Protocols for 2017-2020 (Tan, 2017). Deriving from this, it is important for the AEB real-time implementation to be done and expanded in Malaysia.

In Malaysia, due to the high-pricing of the aforementioned models in Malaysia, this technology has yet to benefit the general masses (Hong et al., 2013). Currently AEB systems are not developed in Malaysia. No AEB system is offered by the two dominant automakers in Malaysia namely Proton and Perodua in all their car models. Hence, they should pay attention to the AEB research area in these coming years. In the design of AEB system, several factors should be put into consideration.

In recent years, there is encouraging sign of manufacturers deploying innovative and Advanced Safety Assist Technologies (SATs) into the market and increasing initiative of autonomous vehicle worldwide. ASEAN NCAP intends to develop tests which complement any legislative requirements in order to be able to rate Advanced SATs in more detail in the future. In the meantime, as an encouragement for manufacturers to fit these systems more broadly, ASEAN NCAP has included these Advanced SATs into its rating starting in 2017 where established test protocols are used to demonstrate the functionality and/or performance of the systems (Lee, 2017).

Currently, ASEAN NCAP will not perform any field test to assess the functionality and performance of Advanced SATs. Nevertheless, it is the responsibility of ASEAN NCAP to ensure that the system works and functions as intended. Therefore, as an alternative and to promote the fitment of Advanced SATs in the region, ASEAN NCAP assesses the compliance based on the “Functional Definitions”. If needed, the manufacturer is requested to perform full demonstration of the proposed technologies to ASEAN NCAP.

2.4 Public Perception of AEB

People may be able to name specific automotive manufacturers and product names, but very few have an accurate understanding of the details of the different automatic braking systems. A survey was conducted in Japan, asking road users about their perception of this technology using the term “automatic braking systems” without explaining the methodology of the research (Shimazaki et al., 2017). The aim of the research was not to clarify the acceptance, concern, willingness, and popularization forecast of the public regarding automation systems. Rather, the objective was to clarify what people thought automated systems could do (or not do). Questions regarding functionality and reliability explored the understanding of road users on the behaviour of the automated system. However, it only questioned “reliability” of the system in general, but not to a specified system function. The survey attracted the participation of 210 people, covering all road-using citizens regardless of whether they held a driver's license in order to uncover the general population's perception of the system.

Most of the survey participants were aware of the existence of automatic braking systems, but due to lack of user experience, their perception of the technology was quite limited. An increase in autonomous braking system that provided pedestrian detection can be observed in the recent years. Apparently, it was not well known to the public. In reality, the automatic braking systems produced by most manufacturers promote driver awareness by alerting them via audio or a display. However, this fact was apparently not yet widely known. Surprisingly 63.8% people had a perception that AEB systems would completely stop a vehicle rather than reducing the vehicle speed, indicating that the role of such systems was perceived more strongly as bringing vehicles to a halt rather than merely reducing their speed. The survey suggested that the public was being too dependent in the functionality of such system.

A different survey was conducted by Shen & Du (2012) on six different demographics which included participants from China, India, Japan, U.S., U.K., and Australia with a total of 3,255 respondents. The main objective of the survey was to gain a better understanding on opinions, concerns and general acceptance by the public about autonomous and self-driving vehicle in those countries. The survey had a particular question asking the respondent on the likeliness of a set of benefits when using a completely self-driving vehicle. The result showed that 88% respondents from China believe that self-driving cars would improve emergency response to crashes, 81.1% of Japanese respondents believe it would lead to fewer crashes, and 73.5% Australian respondents agreed that it could reduce the severity of crashes in the future.

However, when asked about how concerned the respondent would be about driving a vehicle with autonomous technology, the results were surprising. The most frequent response varied by country, with "very concerned" being most frequent in India, "moderately concerned" in the U.S. and Australia, and "slightly concerned" in China, Japan, and the U.K. These trends can simply be explained by the amount of exposure in those countries toward autonomous technology such as the AEB system, with the U.K., China and Japan spearheading such technologies. Based on the survey, a few other conclusions can also be made. Respondents expressed a desire to have autonomous technologies in their vehicles but the majority was unwilling to pay more for the technology with the exception of respondents from China and India. On the other hand, a large number of respondents from the U.K, the U.S., Japan and Australia expressed that they were unwilling to pay extra for autonomous technologies.

3.0 CONCLUSION

AEB system has its pros and cons in the area of pedestrian crash mitigation and avoidance as previously shown in a few researches. Crash trends suggest that such a system is needed in reducing fatalities for VRUs particularly pedestrians. Developing ASEAN countries such as Malaysia experience heavy traffic in junction-type roads in the urban areas, thus leading to a lot of accidents. However, pedestrian collision is not the most critical problem in this region, as motorcycle type accidents are far more common as reported by the WHO (UNHCR, 2015).

To develop a more viable AEB pedestrian system for ASEAN countries, AEB makers need to understand the constraints and limitation of the system. This requires the system to understand that certain speed requires certain braking power in order to mitigate or avoid collision without harming both the driver and pedestrians. The system must be able to differentiate humans from vehicle, which is a hard task as humans are less perceptible by the sensors, as they are smaller in size. Drivers also have limited field of view in detecting potential risks as they are more focused on the driving than the surrounding. Active safety system like the AEB might be of good use in this situation. The point of having a system like the AEB is not to undermine the role of driver in mitigating a crash, but to assist when the driver fails to do so.

Understanding the human behaviour is the key element in developing the ideal AEB pedestrian for the future. Variables such as gender, age, physical characteristics and intentions make humans less predictable. This is true when taking pedestrian crossing into example. The decision-making process largely depends on the capability of the pedestrian to determine whether he/she can cross the road on time. A majority of collisions occur when the pedestrian miscalculated his/her ability. In busy traffic such as in Kuala Lumpur, pedestrians might be impatient while waiting for the green light and therefore resort to illegal crossing.

Effectiveness of the system can be measured by performing multiple test simulating real world events. In-depth accident data and collision analysis are crucial in defining the potential risk factors and outline the pre-impact scenarios. Reconstructed crashes are performed several times with and without the presence of AEB as benchmarking. Crash severity distribution and probability have been determined through the test that would later be used in calculating the overall effectiveness of the system.

The implementation of AEB by countries from Europe and Japan would be an indication that AEB is the next step in car safety. Malaysia is poised to follow but multiple considerations must be taken before taking the leap. A survey in Japan, which is a leader in the automotive industry, suggested that users are aware of the existence of the technology but their perception of the system is a bit off track due to lack of user experience. The public often relies too much on the functionality of the system; hoping that it would perform most of the manoeuvring and pre-collision braking. A similar situation is predicted for ASEAN countries like Malaysia regarding AEB implementation. With the two dominant automakers in Malaysia namely Proton and Perodua not offering AEB in their cars, this would suggest that Malaysia requires a few years of adapting to the technology before AEB can be fully implemented.

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