# DESIGN AND ANALYSIS OF RAIN MACHINE FOR VEHICLE AUTONOMOUS EMERGENCY BRAKING (AEB) ON ROAD WEATHER TEST

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**Progress Report I**

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**AUGUST 2021**

**DECLARATION**

I declare that this project report entitled "Design and Analysis Of Rain Machine For Vehicle Autonomous Emergency Braking (AEB) On Road Weather Test" is the result of my own work except as cited in the references.

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Date : 13th August 2021

## SUPERVISOR'S DECLARATION

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Signature : ..................................

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Date : 13th August 2021

## DEDICATION

This project is dedicated sincerely to my beloved parents, Mr Othman Bin Mat Zin and Mrs Rahimah Binti Ab Rahman who have always been there for me during my studies at Universiti Teknikal Malaysia Melaka and have continued to support me spiritually, morally, and financially.

Besides from that, I want to dedicate my endeavour to my siblings, who have always been supportive of me academically, morally, and financially. I'd also want to dedicate this project to my friends who have assisted me in completing it by contributing their knowledge.

## ABSTRACT

Autonomous Emergency Breaking (AEB) system is one of the latest technologies which is equipped in most vehicle models sold in South-East Asia (SEA) countries. The technology is very beneficial to gain improved safety performance for vehicle occupants and surrounding road users (such as other vehicle occupants, pedestrians, and cyclists), by alerting driver or make an emergency brake when the vehicle about to collide with another vehicle or obstacle to prevent from collision while vehicle moves. ASEAN New Car Assessment Programmed (ASEAN NCAP) has established test protocol for AEB technology. Nevertheless, ASEAN NCAP AEB test only focused on dry and ambient weather conditions only. Hence, there is important need to access the AEB performances when subjected to raining weather condition. The main purpose of this project is to design and fabricate a prototype rain machine for AEB on-road test and to test rain machine during AEB on-road test. This study is conducted by producing conceptual design on rain machine for AEB test according to ASEAN NCAP AEB test protocol v.2020. The best rain machine concept design was later selected. Detailed design shall be created using SolidWorks software, including performing finite element analysis to assess the design structural performance. Then, the material and component for rain machine prototype will be selected. The prototype of the rain machine will be fabricated and tested based on actual AEB test protocol to determine its performance. The development of the rain machine is expected to help ASEAN NCAP in assessing the AEB test system more rigorously by simulating actual weather condition in South East Asia.

# ABSTRAK

Sistem Autonomous Emergency Breaking (AEB) adalah salah satu teknologi terkini yang dilengkapi dengan kebanyakan model kenderaan yang dijual di negara-negara Asia Tenggara. Teknologi ini sangat bermanfaat untuk mendapatkan prestasi keselamatan yang lebih baik untuk penghuni kenderaan dan pengguna jalan raya di sekitarnya (seperti penghuni kenderaan lain, pejalan kaki, dan penunggang basikal), dengan memaklumkan pemandu atau membuat brek kecemasan apabila kenderaan itu berlanggar dengan kenderaan lain atau halangan untuk mengelakkan perlanggaran semasa kenderaan bergerak. Asean New Car Assessment Programmed (ASEAN NCAP) telah menubuhkan protokol ujian untuk teknologi AEB. Walau bagaimanapun, ujian ASEAN NCAP AEB hanya tertumpu kepada keadaan suasana cuaca kering sahaja. Justeru, terdapat keperluan penting untuk menilai perestasi AEB apabila tertakluk kepada keadaan cuaca hujan. Tujuan utama projek ini adalah untuk mereka bentuk dan membina mesin hujan untuk ujian AEB di jalan raya dan menguji mesin hujan semasa ujian AEB di jalan raya. Kajian ini dijalankan dengan menghasilkan reka bentuk konsep mesin hujan untuk ujian AEB berdasarkan protokol ujian ASEAN NCAP AEB v.2020. Reka bentuk konsep mesin hujan terbaik kemudian dipilih. Reka bentuk terperinci hendaklah menggunakan program SolidWorks, termasuk melakukan analisis elemen terhingga untuk menilai prestasi struktur reka bentuk. Kemudian, bahan dan komponen untuk prototaip mesin hujan akan dipilih. Prototaip mesin hujan akan dibina dan diuji berdasarkan protokol ujian AEB sebenar untuk menentukan prestasinya. Pembangunan mesin hujan dijangka membantu ASEAN NCAP dalam menilai sistem ujian AEB dengan lebih teliti dengan mensimulasikan keadaan cuaca sebenar di Asia Tenggara.

# ACKNOWLEDGEMENT

Assalamualaikum and greetings to all that involved.

First and foremost, I would like to praise and thank Allah S.W.T, whom all praise is due for His grace and goodness to give me the strength and courage to complete this final year task. Without his permission, nothing is possible.

I would like to express my sincere gratitude to my supervisor, Dr. Muhd Ridzuan bin Mansor from the Faculty of Mechanical Engineering, University Teknikal Malaysia Melaka (UTeM) for the guidance and his overwhelming attitude towards the completion of this project. His helpful comments, responses, and interaction upon completing this project really helped me a lot to successfully coordinate my project. This project would not been completed without being assisted by him. I really appreciated his full cooperation and his willingness to spend his time to supervise my final year project. In a simple word, she did his responsibilities well as a supervisor.

Besides, I owe a deep sense of thanks to all supportive lecturers who have shared their knowledge and instructions from the beginning until the end. Not to forget, deepest gratitude to my parents and family for their encouragement and support for the completion of this report. Lastly, thanks to all those who contributed directly or indirectly. Their entire companion is truly appreciated as it was a great pleasure to know them. I will be grateful forever for your love. Thank You.

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# LIST of ABBREVIATIONS

| | |
|---|---|
| WHO | World Health Organization |
| AEB | Autonomous Emergency Breaking |
| AOP | Adult Occupant Protection |
| COP | Child Occupant Protection |
| SA | Safety Assist |
| MS | Motorcyclist Safety |
| MIROS | Malaysian Road Safety Research Institute |
| Global NCAP | Global New Car Assessment Program |
| ASEAN NCAP | ASEAN New Car Assessment Program |
| Euro NCAP | Euro New Car Assessment Program |
| CCRs | Car-to-car-rear stationary |
| CCRm | Car-to-car-rear moving |
| VUT | Vehicle Under Test |
| EVT | Euro Vehicle Target |
| GVT | Global Vehicle Target |
| PBC | Peak Braking Coefficient |
| DGPS | Differential Global Positioning System |
| OEM | Original Equipment Manufacturer |
| FEA | Finite Element Analysis |
| PDS | Product Design Specification |
| PVC | Polyvinyl Chloride |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

The Global Status Report on Road Safety by the World Health Organization (WHO) highlights that the number of annual road traffic deaths has reached 1.3 million people die each year on the world's roads, and between 20 and 50 million sustain non-fatal injuries. This show that road traffic injuries remain an important public health problem, particularly for low income and middle-income countries. Pedestrians, cyclists, and motorcyclists make up almost half of those killed on the roads, highlighting the need for these road users to be given more attention in road safety programs. Road conditions with reduced friction (e.g., wet, snowy, icy surfaces) contribute to a higher accident rate. (WHO.2021)

Many manufacturers or car companies install a safety feature in their new car which is called Autonomous Emergency Breaking (AEB). AEB is a system designed to assist the driver when driving. It has become an essential technology for vehicles equipped to reduce road accidents and fatalities. AEB is a safety feature that could save life and prevent collision. It steps in automatically to prevent a collision and is a vital piece of kit we should have on new car. Autonomous Emergency Breaking (AEB) has become one common thing that have on new car these days. Leading safety expert's rate AEB as one the most important road safety advance of recent years and has become as important as seatbelt.



ASEAN NCAP tests whether a car has AEB or not, and how sophisticated the system is, as a key part of its assessment of every new car. The third assessment protocol (2021-2025) that ASEAN NCAP has launched last year consist of four pillars of assessment namely Adult Occupant Protection (AOP), Child Occupant Protection (COP), Safety Assist (SA) and

Motorcyclist Safety (MS). Under SA domain, ASEAN NCAP will test the effectiveness of AEB system fitted in the car.

ASEAN NCAP will be assessing two types of AEB system in the upcoming protocol that are AEB City and AEB Inter-Urban. The most basic AEB systems work at low speeds to prevent or reduce the severity of minor urban collisions. More sophisticated systems work across a wider speed range, so they protect against more serious accidents where there is the potential for severe injury or death. AEB City is a system that work mostly at the lower speed which is from 10 to 60 km/h that are travel forward to another stationary vehicle, while the other system which is AEB Inter-Urban is a system that work mostly at higher speed which is 30 to 60 km/h that are travel forward toward another vehicle which travel at constant speed.

Whatever the level of sophistication, all AEB systems use sensors to detect obstacles ahead and assess whether a collision is likely. The unit will usually start by warning the driver that a collision is likely and that they need to brake, using dashboard warning lights or an audible alarm. If the driver fails to act, the 'autonomous' part of the system will kick in and apply the brakes automatically. (www.aseanncap.com,2021)



## 1.2 Problem Statement

Models with innovative safety features were quickly adapted by manufacturers to remain competitive and comply with strict regulatory reform. Somehow, these features are quite new, and their safety could not be fully guaranteed. To verify that the features are sufficiently safe, the car should be tested. The New Car Assessment Program (NCAP) is responsible for these tests. For this scope of project, the NCAP is Southeast Asia based, and it is known as ASEAN NCAP. ASEAN NCAP is an automotive safety rating program established jointly by the Malaysian Road Safety Research Institute (MIROS) and the Global New Car Assessment Program (Global NCAP).

Since 2018, ASEAN NCAP has been undertaking om-road effectiveness testing of active collision avoidance technologies including AEB to demonstrate the function, benefits, and limitation of system. ASEAN NCAP conducted the AEB development on-road test was on sunny and clear day. Meanwhile, based on data in Malaysia, more than 250,000 accidents occur every year. Of these, around 10 percent are weather related, which means, around 25,000 accidents occur due to bad weather conditions. Most of these accidents happen when the roadways are wet.

AEB system effectiveness testing on-road on normal day and rainy day or bad weather condition might be different due to coefficient of friction on tire with the road. The effectiveness of grip on tire with the road due to slippery condition might be less effective. In Malaysia based on weather forecast, the weather was uncertain which is sometime rain and sunny, the creation of rain machine might solve this problem.



Based on literature review, current AEB on-road test as conducted by EuroNCAP and ASEAN NCAP only focused on dry and ambient weather conditions only. Hence, there is an important need to also access the AEB performance when subjected to raining weather condition. To perform the evaluation with the inclusion of raining condition, a dedicated rain making solution is necessary. The rain machine also must be portable to be easily used in AEB testing for any road type and location, as well as able produce various rain intensity situation (light rain, moderate rain, heavy rain, very heavy rain) to reflect actual weather environment. (www.aseanncap.org,2020)

## 1.3 Objectives

The objectives of this project are as follows:

i. To design and analysis rain machine for AEB on-road test.

ii. To perform rain machine structural analysis using finite element analysis (FEA).

## 1.4 Scope Project

i. To produce conceptual design, select best concept design and detail design of rain machine for AEB test according to ASEAN NCAP AEB test protocol v.2020.

ii. To perform rain machine structural analysis using finite element analysis (FEA).

iii. To perform material and component selection for the rain machine prototype.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Background

This chapter mainly discuss on the concept of AEB system. Based on the concept it clearly shows on how the mechanism of the system works. Beside that, it will AEB study that related on snowy weather condition. Aside from that, it will show on how the climate and weather affects the performance of the systems. This chapter then briefly introduces vehicle type that have AEB system which is sold in Malaysia.

## 2.2 Autonomous Emergency Braking

Automatic emergency braking is an active safety system that activates a car's brakes when a potential collision is detected. As its name suggests, it works automatically, without the driver actually touching the brake pedal. It can also increase braking force if the driver is applying the brakes, but not enough to prevent a collision. All AEB systems detect vehicles, and many can sense pedestrians and cyclists. The purpose of AEB is to mitigate crashes by initiating braking when hazardous conditions arise or if the driver brakes insufficiently.



It's surprising when an automobile comes to a complete stop on its own. As a result, AEB is frequently used in conjunction with forward collision warning (FCW). A sound, a visible indication, or tactile feedback are frequently used to identify FCW. FCW activates a split second before AEB in most vehicles. This alerts the driver when a collision is approaching, giving them time to react and apply the brakes. AEB intervenes if insufficient action is taken.

When AEB hits the stoppers, how does it know when to do so? Radar sensors are installed in the front grille, bumper, or air vents of some automobiles. Others rely on cameras, which are normally positioned behind the rearview mirror in the windshield. Some people utilize both. Software constantly evaluates crash potential based on sensor data, regardless of the detection mechanism. The software activates FCW and AEB when certain parameters are met.

Some AEB systems are only effective for vehicles and not for pedestrians. As technology advances and sensors become more finely tuned to read whatever impediments may lie ahead, this is becoming less typical. While driving, the automatic emergency braking and forward collision warning systems are tailored to identify other vehicles in front of you. Not all features, however, will be able to recognize motorbikes, bicycles, and other vehicles that are smaller than a car. Automatic emergency braking is usually set to engage at highway speeds if the forward collision warning sensors detect a vehicle ahead. In towns, newer systems operate at a slower speed. However, not all autonomous emergency braking systems can bring the vehicle to a complete stop. Automatic emergency braking may be able to help slow a vehicle down sufficiently to avoid a hazard at speeds higher than regular highway speeds.



AEB has a clear benefit: preventing or reducing the severity of a collision that is unavoidable. There are, however, some AEB disadvantages to consider. One is the possibility of making a mistake. A false positive may cause you to slam on the brakes needlessly, producing unnecessary panic and increasing the risk of colliding with a vehicle behind you. A defect in an AEB system, on the other hand, could go undetected and lead it to fail just when it's needed. Another potential drawback of AEB is that it may lull drivers into complacency because the driver not paying attention if they know their automobile will stop automatically. Figure 2.1 below shows that AEB system on vehicle and pedestrian.

(a) (b)

Figure 2.1 : AEB system on (a) vehicle (b) pedestrians (www.euroncap.com)

To support the driver in avoiding nose to tail crashes, car manufacturers offer avoidance technology that warns, supports adequate braking, and ultimately stops the vehicle. The systems that work mostly at lower speed are referred to as AEB City systems whereas those that function at higher speed are called AEB Inter-Urban systems. This protocol specifies the AEB City and AEB InterUrban test procedures which are part of the Safety Assist assessment, respectively. For AEB City, only the car-to-car-rear stationary (CCRs) scenario is applicable where the AEB functionality at lower speed is tested as shown in Figure 2.2 below. For AEB Inter-Urban, the system is tested in one scenario car-to-car-rear moving (CCRm) as shown in Figure 2.3 below. For this type of AEB system, the AEB functionality is assessed. (www.euro.ncap.com)

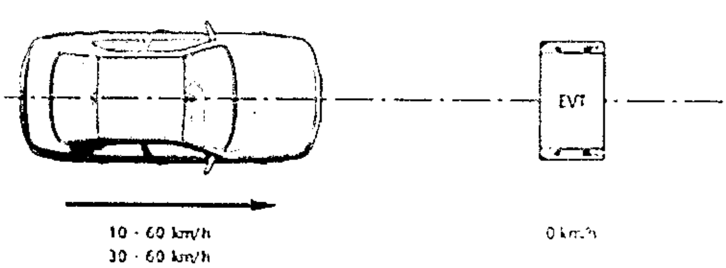

Figure 2.2: CCRs scenario

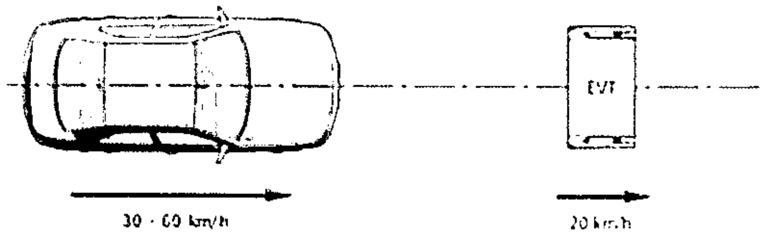


Figure 2.3: CCRm scenario

## 2.3 AEB Study Related to Snowy Road Condition

### 2.3.1 Background

Current automatic systems, such as the AEB, do not adjust vehicle control strategies in response to road friction, such as on snowy roads. Because winter precipitation is linked to a 19% rise in traffic crashes and a 13% increase in injuries when compared to dry circumstances, incorporating friction in the control algorithm could greatly improve the ability of traditional AEB to prevent collisions. (www.WHO.com,2015)

Because human drivers would not be required to monitor the driving environment at all times, higher automated functions will have to adapt to the current tire–road friction. In order for automated driving features to be employed, new systems must achieve high levels of perceived safety and confidence among occupants. In order to obtain knowledge for the design of future driving functions, the application case of an AEB is employed to evaluate drivers' evaluations based on road conditions.

### 2.3.2 Methods

The standard, nonadaptive AEB was tested in a driving simulator on dry roads with high friction ($\mu$= 1) and snowy roads with reduced friction ($\mu$ = 0.3). In addition, for this investigation, an AEB system suited to road friction was developed and compared to a traditional AEB on snowy roads with reduced friction. In the simulator, 96 drivers (48 men and 48 women) were divided into five age groups (20–29, 30–39, 40–49, 50–59, and 60–75 years old). In response to an impending rear-end collision at an intersection, the drivers witnessed and evaluated the AEB's braking actions.

Table 2.1 : Drivers' subjective ratings of safety and trust in the conventional and adaptive AEB.

| AEB type Tire-road grip | Conventional AEB High Friction ($\mu$= 1) | | Conventional AEB Reduced Friction ($\mu$ = 0.3) | | Adaptive AEB Reduced Friction ($\mu$ = 0.3) | |
|---|---|---|---|---|---|---|
| Descriptive data | M | SD | M | SD | M | SD |
| Safety ratings :- | | | | | | |
| Male drivers | 5.19 | 1.21 | 2.25 | 1.77 | 5.21 | 1.05 |
| Female drivers | 4.36 | 1.78 | 1.70 | 1.28 | 4.49 | 1.46 |
| Total | 4.78 | 1.57 | 1.98 | 1.56 | 4.85 | 1.31 |
| Trust in automation | | | | | | |
| Male drivers | 4.06 | 1.73 | 2.27 | 1.70 | 4.60 | 1.33 |
| Female drivers | 3.83 | 1.75 | 2.36 | 1.69 | 4.21 | 1.57 |
| Total | 3.95 | 1.73 | 2.26 | 1.69 | 4.41 | 1.46 |

### 2.3.3 Results

The results indicate that on snowy roads, drivers' safety, and trust in conventional AEB were much lower, and the nonadaptive autonomous braking method was deemed less appropriate than on dry roads. The adaptive AEB braking approach was found to be more suitable for snowy conditions than the nonadaptive strategy, as expected. Drivers' subjective safety and trust were greatly increased when driving with the adaptive AEB compared to the conventional AEB when friction was reduced. When AEB was braking, women felt less secure than males. There were no statistically significant differences between age groups.

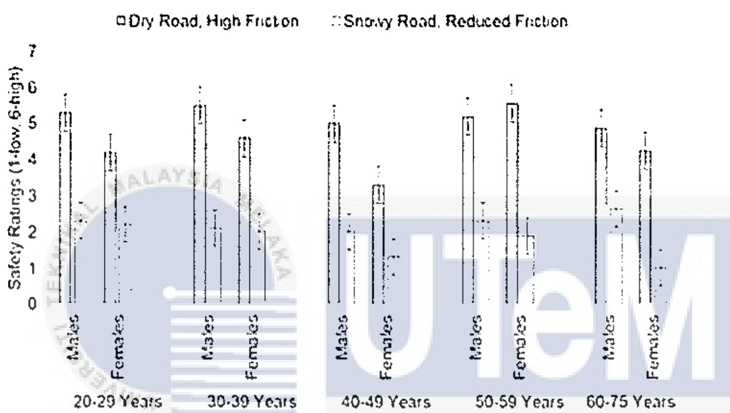


Figure 2.4 : Mean safety ratings for the conventional AEB on dry and snowy roads.



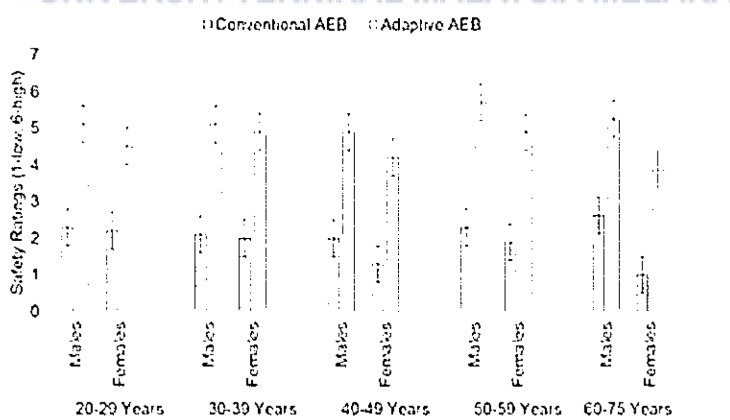


Figure 2.5 : Mean safety ratings for the conventional AEB and adaptive AEB on snowy roads with reduced friction.

### 2.3.4 Conclusion

Winter precipitation, such as snow, is linked to a 19 percent increase in traffic collisions and a 13 percent rise in injuries when compared to dry circumstances (Black and Mote 2015). Traditional AEB systems are not obliged by law to adapt to road friction, but it might considerably improve their ability to prevent collisions. At SAE level 3 and higher, human considerations such as occupant trust and safety in autonomous functions under various driving circumstances must be taken into account when designing adaptive functions.

In comparison to the standard AEB, more drivers thought the adaptive AEB was useful on snowy roads. Furthermore, when compared to the standard AEB, fewer drivers thought the adaptive AEB deployed the brakes too late and too weakly on icy roads. On snowy roads, drivers trusted the adaptive AEB more and felt safer with it than with the standard AEB.



## 2.4 The Effects of Climate and Weather

`Based on data from National Highway Traffic Safety Administration, there are more than 5,760,000 vehicle accidents annually and a roughly of 22 percent of the accidents are weather-related with slick pavement. About 19 percent of the accidents left injured are from weather-related and 16 percent of crash fatalities are from weather-related (Hamilton, 2016). Figure 2.6 illustrates the data in pie chart form.