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Priority Factor Influencing Public Interest in Owning Vehicle with AEB System

N. H. Mokhtar[*1,3], L. Hamzah[2,3], H. C. Mamat[2,3], M. K. M. Nor[1,4] and F. A. Munir[2,4]

[1]Center for Robotics and Industrial Automation, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2]Centre of Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[3]Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya 76100 Durian Tunggal, Melaka, Malaysia
[4]Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya 76100 Durian Tunggal, Melaka, Malaysia

[*]*Corresponding author: nurhazwani@utem.edu.my*

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Abstract – *The Autonomous Emergency Brake (AEB) is a part of autonomous vehicle technologies and the technology was developed to reduce human errors that lead to a road accident. This survey investigates the priority factor influencing the public in acquiring vehicles with the AEB system. In this study, the Analytic Hierarchy Process (AHP) framework was used to determine the public's rating of importance of the availability of the AEB system in their vehicles. Cronbach's alpha was used to check for reliability of survey items. With a score of 0.8, it suggested that the items had relatively high internal consistency. The results show that the top factors that influence public interest in having vehicle with AEB are the reduction of the severity of injury and crashes.*

Keywords: Autonomous Emergency Brake (AEB), Analytic Hierarchy Process (AHP), ASEAN NCAP, active safety

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1.0 INTRODUCTION

Road accidents are one of the major causes of death and injuries in Malaysia. According to the World Health Organization, Malaysia has one of the highest in traffic fatality rates in the world relative to its population (WHO, 2013). The report from the Malaysian Ministry of Transportation shows an increasing trend of road accidents in Malaysia from 2006 to 2017 (MOT, 2018). In order to reduce vehicular accidents caused by human errors, the autonomous vehicle technologies were developed and implemented in motor vehicles (Marchant & Lindor, 2012). Safety is regarded as a vital consideration in the consumer decision-making process when purchasing a used or new car (Abu Kassim et al., 2016).

The Autonomous Emergency Brake (AEB) system is a part of the autonomous vehicle technologies which were developed to reduce human error that lead to road accidents. The AEB is a system that alerts the driver and independently brakes if there is an absence of required human response during critical situations (Euro NCAP, 2018; Md Isa et al., 2015). Currently, the AEB system can be categorized into three categories; the AEB city system, the AEB intercity system and the pedestrian system.

Safety for the pedestrian is essential since the percentage of pedestrian killed on the European Union (EU) roads in 2013 was high at 22%. However, in Malaysia, the problem is with motorcycle users, which becomes the top category of fatalities in so many years. The motorcycle fatalities are three times higher than car fatalities, six times higher than pedestrian fatalities and nearly 50 times higher than bus passenger fatalities (Abdul Manan & Várhelyi, 2012). This shows that in Malaysia, motorcyclist safety is more critical compared to the pedestrian. Hence, the importance of safety features in the vehicle is crucial not only to the driver but with other road users and pedestrians (Abu Kassim et al., 2016). Therefore, this survey aimed to investigate the priority factors which influence the public in having vehicle with AEB system. In this study, the AHP framework was used to determine the rating of importance in public opinions.

2.0 SURVEY AND RESPONDENTS

The survey was designed to capture the Malaysian perspective in relation to the AEB system. The method used for the survey was using the Google survey form which then tabulated the data into a spreadsheet. This survey is targeted mostly to the person without any engineering background in order to capture the data in relation to the common Malaysian citizens and their opinions on the AEB system. The number of respondents for the survey was 55 individuals while the usable data was 54 after the data cleaning process was done. Out of 54 respondents, 43 were interested in owning vehicles with the AEB system.

The respondents' demographics data is as shown in Table 1. ***Age group:*** The highest number of respondents comes from the age group of 30 to 39-year-olds which added up to 44.19 % of the total number of respondents while the lowest age groups are the 50-59 and 60-69 age ranges at 4.65% each. The main factor that contributed to this population breakdown might due to the method of the survey distribution which used the digital media as the platform. ***Gender:*** The respondents were evenly distributed along the gender lines as females numbered 55.81%. The difference in number between males and females was 11.62%. ***Education:*** The highest percentage of respondent has bachelor degree which covers 44.19% of the respondents. The sum of the respondents with bachelor degrees and higher was 85.37%. This group was more likely to be aware of the newest technology compared to the others. ***Employment:*** 79.07% of the respondents had a full-time job with the total rate of employment is 88.38%. This group was more likely to have the purchasing power to buy a new car. ***Driving experience:*** Most of the respondents possessed driving licenses. Only 9.31% lacked driving license or did not drive on their own. The majority of the respondents had 10 to 19 years of driving experience which contrasted to the percentage of the novice drivers at 23.26%. ***Vehicle ownership:*** From the survey, 67.44% of the respondents owned sedan cars which ranked as the most common car owned. The second highest percentage was compact cars at 30.23%. The lowest car type ownership was that of the pick-up truck at 2.33%. ***Car accident:*** 51.16% of the respondent was previously involved in car accidents. This affected more than half of the respondents.

Table 1: Respondents' demographic data

Independent Variables	Level	Percentage (%)	Mean
Age Group	1. 18 to 29	27.91	2.14
	2. 30 to 39	44.19	
	3. 40 to 49	18.60	
	4. 50 to 59	4.65	
	5. 60 to 69	4.65	
Gender	1. Female	55.81	1.44
	2. Male	44.19	
Education	1. Certificate	4.65	3.56
	2. Diploma	4.65	
	3. Bachelor Degree	44.19	
	4. Graduate Degree	25.58	
	5. PhD	18.60	
	6. Others	2.33	
Employment	1. Full time	79.07	1.56
	2. Self-Employed	6.98	
	3. Part-time	2.33	
	4. Unemployed	2.33	
	5. Full-time student	9.30	
Driving experience	1. Do not have a driving license	6.98	3.09
	2. 1 to 9	23.26	
	3. 10 to 19	39.53	
	4. 20 to 29	23.26	
	5. > 30	6.98	
	6. Do not drive	2.33	
Vehicle type	1. Sedan car	67.44	2.25
	2. Compact car	30.23	
	3. Minivan / Van / MPV	13.95	
	4. SUV (4WD)	4.65	
	5. Motorcycle / scooter	23.26	
	6. Pickup truck	2.33	
Car accident	1. Yes	51.16	1.49
	2. No	48.84	
The respondent has experienced the AEB system	1. No	90.70	1.09
	2. Yes	9.30	
The respondent general opinion on AEB system	1.Very Negative	0.00	4.30
	2. Negative	0.00	
	3.Neutral	18.60	
	4.Positive	32.56	
	5. Very Positive	48.84	

Since one of the AEB benefits is reducing the severity of an accident, this group made for a good source of feedback in relation to the possible effects of an accident. ***Experience with the AEB system:*** The majority of the respondent had never experienced the AEB system. Only 9.30% of the respondent had some experience with it. This is because the technology is still new, and the AEB system was newly introduced to the Malaysian market only for limited types of cars. Most of the AEB system came from a car with a price tag of over MYR 100, 000. The introduction of the AEB system on Perodua Myvi cars might boost this percentage in near future as Malaysian car manufacturers will start producing AEB system in the lower-priced car segment. ***The general opinion on the AEB system:*** 81.4% of the respondent had positive opinions on AEB system. This high percentage might be because most of the respondents had never experienced the AEB system in real life. This is supported by lack of negative feedback while 18.6 % of the respondents had neutral opinions of the AEB system.

3.0 METHODOLOGY OF ANALYTICAL HIERARCHY PROCESS

This study proposed the Analytical Hierarchy Process (AHP) approach in prioritizing public requirements. The framework of methodology of AHP is as shown in Figure 1. The initial step is to construct the hierarchy framework. At the top of hierarchy in Level 1, the goal of decision making is set. The main goal is supported by sub-goal or known as criteria at Level 2 of the hierarchy. Level 3 is the alternatives. In this study, Level 1 was set as a goal to prioritize the key factor influencing the public to own vehicles with the AEB system. Level 2 was the criteria required, for example, performance, safety, driver behavior, and price. Finally, Level 3 was the alternatives presented in survey questions. The hierarchy is as shown in Figure 2. The pairwise comparison scale is in Table 2. The scale is commonly used to show judgment or preference between alternatives, such as equal value, slightly more value, essential or strong value, very strong value, and extreme value.

Table 2: Importance scale for pair-wise comparison analysis

Relative Intensity	Definition
1	Equal value
3	Slightly more value
5	Essential or strong value
7	Very strong value
9	Extreme value
2, 4, 6, 8	Intermediate values between two adjacent judgements
Reciprocals	Reciprocals for inverse comparison

Next, the AHP method was used to compare each of the elements with another on a pairwise basis. The common hierarchy and nine-point scale were used to construct pairwise comparison matrices. To calculate the priority vector, first the principal eigenvector of the comparison matrix, A was obtained. The principal eigenvector of the comparison matrix equation is as shown in Equation (1). The priority vector is the vector that normalized component of the eigenvector corresponding to the eigenvalue λ_{max} as shown in Equation (2) (Saaty & Hu, 1998). The comparison matrix, A, eigenvalue is used to indicate the degree of inconsistency of matrix A. The consistency index (CI) and consistency ratio (CR) can be computed from equation (3) and equation (4).

$$A = \left(a_{ij}\right)_{n\times n} = \begin{bmatrix} a_{11} & a_{12} & \cdots a_{1n} \\ \vdots & 1 & \cdots \vdots \\ a_{n1} & a_{n2} & \cdots 1 \end{bmatrix} \qquad (1)$$

Where a_{ij} = k automatically implies that $a_{ij} = {}^{1}/_{k}$ and $i, j = 1, \cdots, n$ and $i \neq j$.

$$A\omega = \lambda_{max}\omega \tag{2}$$

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{3}$$

$$CR = \frac{CI}{RI(n)} \times 100\% \tag{4}$$

λ_{max} is the maximum eigenvalue of the comparison matrix, n is the dimension of the matrix and RI (n) is a random index. RI (n) value is based on n as shown in Table 3. The pairwise judgment is acceptable if the calculated consistency ratio is less than 10%.

Table 3: Random index (RI (n)) of the random matrix [39]

n	3	4	5	6	7	8	9	10	11	12	13	14	15
RI(n)	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

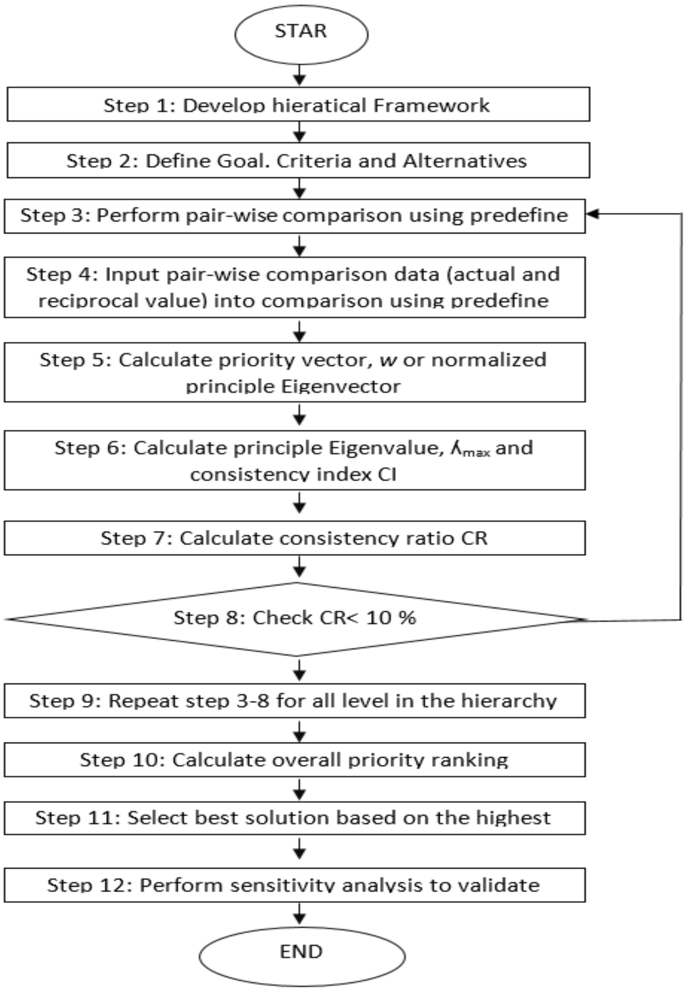

Figure 1: The AHP methodology framework of prioritizing public requirement

4.0 RESULT AND DISCUSSION

4.1 Reliability Test

The reliability test used to validate the survey question is Cronbach's alpha. The reliability test is to check whether the survey questions are reliable. Cronbach's alpha which is based on the average correlation within items was used in this study. The value of Cronbach's alpha of 0.70 or higher is considered acceptable and the items studied in each element are correlated to another (Coakes et al., 2009; Cotterill, 2012; Cramer, 2010). The value of Cronbach's alpha is 0.8 and was considered high, suggesting that the items had relatively high internal consistency. Therefore, the selected items were reliable to be used throughout this research.

4.2 Development of Hierarchical Framework

In this section, a hierarchy model for structuring key factor decisions using AHP was introduced. There were three-level hierarchy decision processes used in this study as illustrated by Figure 3. The top of the hierarchy represented the objective of the decision. Followed by Level 2 which represented the main criteria affecting the public interest in owning a vehicle with AEB system. The main criteria were categorized into four aspects: performance (PR), safety (SF), driver behavior (DB) and price (PC). Finally, the alternatives were represented at the third level of the hierarchy. The list of alternatives in Table 1 were based on survey response.

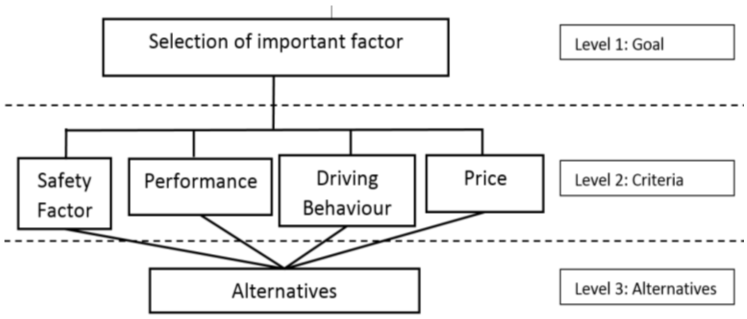

Figure 3: The hierarchy framework in prioritizing customer requirements

Table 4: List of alternatives

Alternatives	
Performance in poor weather	PR-1
Interaction with others vehicle on road	PR-2
Performance in an unexpected situation	PR-3
Roughness during breaking	PR-4
Safety consequences of equipment or system failure	SF-1
Reduce severity in injury and crashes	SF-2
Motorcyclist safety	SF-3
Increase driver alertness	DB-1
Reduce driver load	DB-2
Reduce insurance rate	PC-1
Willing to pay additional price	PC-2

4.3 Prioritizing Public Requirement

AHP method was used to perform the pairwise comparison between the defined goal, criteria and alternatives within the AHP framework developed in the earlier stage. The pair-wise comparison is a method to decide on the relative importance between criteria with respect to goal and between alternatives with respect to the alternatives.

The alternatives in Table 4 were compared based on a pairwise basis with respect to the overall goal, performance (PR), safety (SF), driver behavior (DB) and price (PC). In this study, a nine-point scale as illustrated in Table 2 were used in the evaluation. The higher scale indicates the alternative was more important than the other pair with respect to overall goal, performance (PR), safety (SF), driver behavior (DB) and price (PC), ranging from equally important to extremely important. The survey response data was used as a reference to assist in the pair-wise evaluation. The pairwise comparison matrix of alternatives using AHP is shown in Table 5. From all the comparison matrices, the criteria and weights of the alternatives were calculated by obtaining the eigenvectors, eigenvalues and also the priority vectors. The priority vector result was as illustrated in Figure 4. The consistency ratio for the comparison matrix of the alternatives was less than 10%, at 5.6% to be exact.

The overall priority vectors were as shown in Figure 4 below. The three top factors that influenced public interest in having a vehicle with AEB are the reduction of severity in injury and crashes (SF-2), the safety consequences of equipment or system failure (SF-1) and the reduction of driver load (DB-2). The public influence factor can be subjective and easily influenced by surrounding factors. However, the AHP analysis method offered a consistent evaluation, which can help the decision-makers to check for the consistency of the judgment as shown in Figure 1.

Table 5: Pairwise comparison matrix of alternatives using AHP

	SF-1	SF-2	SF-3	PR-1	PR-2	PR-3	PR-4	DB-1	DB-2	PC-1	PC-2
SF-1	1.00	5.00	9.00	3.00	3.00	5.00	7.00	3.00	5.00	5.00	9.00
SF-2	0.20	1.00	5.00	0.20	0.33	1.00	3.00	0.20	0.33	0.33	5.00
SF-3	0.11	0.20	1.00	0.14	0.14	0.20	0.20	0.11	0.14	0.20	3.00
PR-1	0.33	5.00	7.00	1.00	3.00	5.00	5.00	0.33	3.00	5.00	9.00
PR-2	0.33	3.00	7.00	0.33	1.00	3.00	5.00	0.33	3.00	3.00	7.00
PR-3	0.20	1.00	5.00	0.20	0.33	1.00	3.00	0.20	0.33	0.33	5.00
PR-4	0.14	0.33	5.00	0.20	0.20	0.33	1.00	0.20	0.20	0.33	5.00
DB-1	0.33	5.00	9.00	3.00	3.00	5.00	5.00	1.00	3.00	5.00	9.00
DB-2	0.20	3.00	7.00	0.33	0.33	3.00	5.00	0.33	1.00	3.00	7.00
PC-1	0.20	3.00	5.00	0.20	0.33	3.00	3.00	0.20	0.33	1.00	7.00
PC-2	0.11	0.20	0.33	0.11	0.14	0.20	0.20	0.11	0.14	0.14	1.00
	3.17	26.73	60.33	8.72	11.82	26.73	37.40	6.02	16.49	23.34	67.00

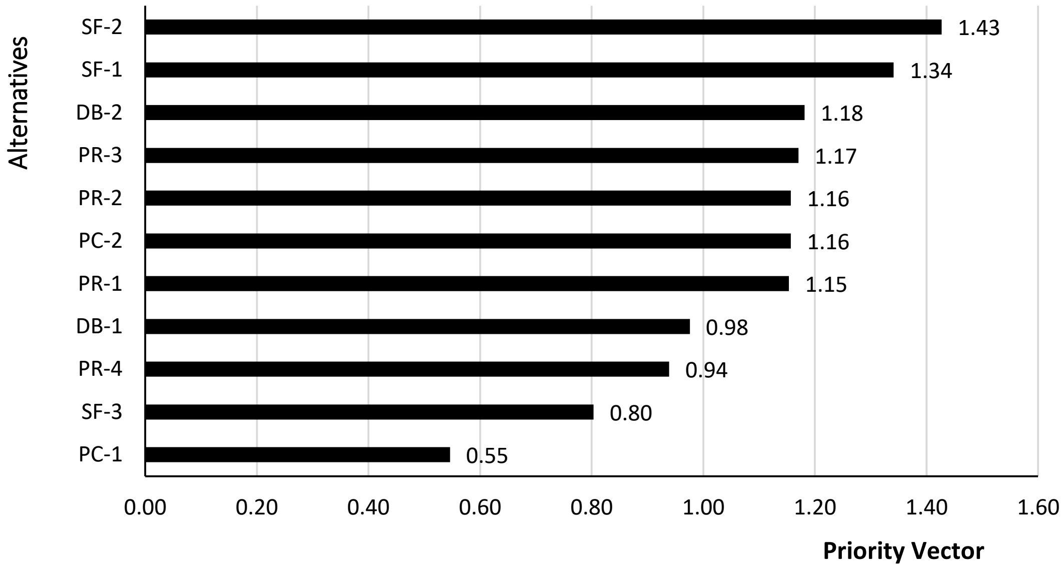

Figure 4: The hierarchy framework in prioritizing customer requirements

4.4 Discussion on AEB, Motorcycle Safety, and ASEAN NCAP Roadmap

The AEB is one of the safety assist technologies (SAT) which is scored 25% of the car safety rating in ASEAN NCAP Roadmap 2017-2020. ASEAN NCAP is recommending to regulatory authorities to make the AEB compulsory in vehicles (Abu Kassim, 2017). Based on this survey, 80% of respondents were interested in owning vehicles with AEB technology. However, only 40% of the respondents were willing to pay extra of not more than MYR 5,000 (equivalent to USD 1,300) for this safety feature. According to the overall priority factors in Figure 4, the top factor that influenced public interest in owning a vehicle with AEB is the reduced severity of injuries and crashes. According to fatality distribution by transportation mode, motorcycle fatalities were the highest at 60% compared to that of cars' at 22 % and pedestrians' 9% (Abdul Manan & Várhelyi, 2012). Therefore, one of the focus of the ASEAN NCAP Roadmap 2017-2020 was to reduce motorcycle accidents. Based on the Royal Police of Malaysia (RMP/PDRM) annual report of 2009, the largest group of motorcycle fatalities were caused by the 'Angular or Side' collision type (RMP, 2010). The AEB system is focused on preventing head-on collisions. Therefore, the AEB system cannot be a suitable method to reduce motorcycle accidents.

5.0 CONCLUSION

In summary, the AHP framework was used to determine the importance rating of public opinion using the AHP method. The priority factor of the public interest matrix in owning vehicle with AEB system was carried out. The consistency ratio obtained from this study was acceptable, with a value of below 10%. This study demonstrated that the three priority factors that influence public interest in owning a vehicle with the AEB system which was the reduction of the severity in injuries and crashes (SF-2), the safety consequences of equipment or system failure (SF-1) and the reduction of driver load (DB-2).

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