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A Correlation Study on Human Factors Value among AEB Equipped Vehicle Users: Experience and Satisfaction

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ABSTRACT – *The Autonomous Emergency Braking (AEB) system in a car has had great potential to prevent traffic accidents since its introduction in the past years. It is one of the safety systems embedded in the vehicle that can oversee the impending forward crash, which automatically brakes the car when sensing a collision threat. This safety system is available in specific vehicle models that can be opted for by vehicle users. Thus, the functionality of this system can be studied in terms of human acceptance and satisfaction.* ***Objectives:*** *This paper intends to investigate the relationship between the car models equipped with the AEB system and the perceived value construct under study.* ***Methodology:*** *A cross-sectional study was conducted among AEB system users' that experienced the AEB operation. Using the data, descriptive and correlation analyses were used to investigate the relationship between the construct under study.* ***Result:*** *There is a significant relationship between perceived value and vehicle models.* ***Conclusion:*** *This paper aid car manufacturers to fulfil the users' needs and satisfaction regarding AEB function and benefits. New technologies can be tested for human satisfaction and acceptance of the systems operations in a vehicle. Future research regarding human and technology acceptance can be conducted extensively.*

KEYWORDS: Autonomous Emergency Braking (AEB), braking system, human factors, technology acceptance

1. INTRODUCTION

Road safety has evolved over the years to ensure road users' safe well-being regardless of the variety of road users such as a cyclist, motorists, pedestrians, car occupants, and many others. Moreover, establishing road transportation as one of the safest ways of commuting is one of the concerns in road safety research. Despite that, an estimated 1.35 million casualties due to road accidents are reported yearly (WHO, 2018). World Health Organization (2018) also revealed that injuries related to road accidents are one of the primary causes of death, more than any type of fatal communicable disease such as HIV/AIDS, tuberculosis, or respiratory-related disease. Moreover, other studies also claimed that casualties related to road accidents increased every year (Roslin et al., 2020). While in Malaysia, about 6,000 fatalities are reported due to road accidents annually (Abu Kassim et al., 2016). Thus, developing and improving a safety system for vehicles is one of the efforts to mitigate accident occurrence. With the development of the safety system in vehicles many years ago, it is hoped that road-related injuries and fatalities can be significantly decreased.

Generally, there are two types of safety systems in the vehicle, which are active and passive safety systems (Hu et al., 2015). Active safety systems emphasize the prevention and mitigation of accident occurrence, for instance, the Autonomous Emergency Braking (AEB) and Blind Spot Detection (BSD) system. On the other hand, passive safety systems will be "activated" during the occurrence of the accident by minimizing potential injuries and damage, such as seatbelts and airbags. Both systems are involved in providing life-saving action to the vehicle occupants as well as contributing to road safety comprehensively. In addition, development in the automotive industry in terms of transportation safety to had led to various Advanced Driver Assistance Systems (ADAS) in vehicles. Car manufacturers developed various types of ADAS to counter human error during driving (Ziebinski et al., 2017). For example, inattention and distracted driving can cause a major accident. Thus, ADAS potentially improve driving performance, decrease the occurrence of collisions, and enhance the driver's comfort (Rahman et al., 2017). Some advantages related to ADAS include yield control over the vehicle during dangerous situations and increasing the driver's performance. Moreover, the primary role of ADAS in terms of context-awareness of the vehicle system, which can anticipate and proactively respond to various traffic conditions (Antony & Whenish, 2021), hence, maximizing and optimizing the functional system to driver's usage and driving behavior (Hasenjager & Wersing, 2018).

Table 1 shows the AEB system in a vehicle with the respective manufacturer. The use and functionality of AEB in vehicles had been proven to mitigate collision and accident occurrence among the vehicle's users. Regardless, this technology can also make possible improvements in terms of operations and effectiveness based on the vehicle users' perceptions. Considering the AEB system is only equipped in recently manufactured vehicles, especially in Malaysia, the acceptance and satisfaction of the end-user towards AEB functions and operation is important to the manufacturers to fulfill the end-users demand. Nevertheless, some vehicle manufacturers only equipped AEB in a certain model that can be opted by the users. Thus, vehicle occupants might perceive the AEB system either as fitting their needs or just another car system that is supplementary to the vehicle. It is also important to identify if AEB systems provide safety advantages, drivers' acceptance, and factors influencing technology acceptance. This must be recognized through extensive research because the technology might oppose the vehicles' traditional ways of operating (Rahman et al., 2017). Moreover, despite the safety support system in the vehicle, in terms of AEB functions, potential forward crashes are only detected at certain speeds and circumstances (Tan et al., 2020; Baharuddin et al., 2019). Indeed, some in-vehicle safety systems can only be activated to function, giving the drivers the authority to choose whether to use them. Therefore, the safety systems equipped in vehicles ultimately cannot substitute the driver's awareness and attention which they must remain liable to the safe driving behavior.

TABLE 1: Car manufacturer and respective AEB system in the vehicle

Manufacturer	**AEB Systems**
Honda	Collision Mitigation Braking System (CMBS)
Perodua	Advance Safety Assist (A.S.A)
Proton	AEB + Forward Collision Warning
Nissan	Driver Assistance Systems: Collision-Avoidance System
Hyundai	Hyundai Smart Sense: Forward Collision-Avoidance Assist
Toyota	Toyota Safety Sense (TSS): Pre-collision System

The technology acceptance and user satisfaction on the safety system developed in vehicles, especially on the AEB, is proposed using a conceptual model in the current study. Figure 1 illustrates the conceptual model outline in the study. This conceptual framework was developed from two consecutive theories/models, which are Social Exchange Theory (SET) (Homans, 1958), and the Expectation-Confirmation Model (ECM) (Oliver, 1980). The theory of SET explained the exchange of activity, which is tangible or intangible regardless of any social form or material, or nonmaterial goods exchanged between individuals (Emerson, 1976; Lambe et al., 2001). Meanwhile, ECM details the performance and expectations perceived by the user, which lead to satisfaction after the post-purchase (experienced) stage and eventually causes the intention to repurchase (Hsu & Lin, 2015). The perceptions can be adjusted over time based on the new information, especially on the system the user experienced. As the user gains more experience from using the system, the expectations increase towards the system. Afterward, whenever the performance of the system is confirmed and meets the users' expectations, satisfaction with the application will be achieved. This leads to the technology continuance intention.

Based on Figure 1, in terms of AEB-equipped vehicles, AEB's primary function and benefits are to provide safety for the vehicle occupants. This preliminary impression leads to a trust factor in the safety features provided among the potential buyer during the pre-purchase stage. Later, the user trust changed into expectations because they were convinced of the systems. Therefore, the AEB performance and functions are expected to be tailored with information from the manufacturers. Subsequently, the buyer purchases the AEB-equipped vehicle. During the post-purchase stage, the buyer (which is now the user) or the AEB-equipped vehicle user is confirmed with the AEB system operation after the vehicle's driving experience for a while. Henceforth, from the confirmation of the driving experience of the AEB-equipped vehicle, satisfaction with the system's effectiveness and functionality is established. The satisfaction towards the AEB system is studied further to explore the association with five perceived value factors (perceived performance, perceived usefulness, perceived ease of use, complacent behavior, value for money) that lead to continuance intention to use the vehicle with the AEB system. According to Bhattacherjee (2001), further extensive research is required regarding the ECM to enhance understanding of the expectation and confirmation of technology and eventually cause the continuance of technology usage behavior on the user.

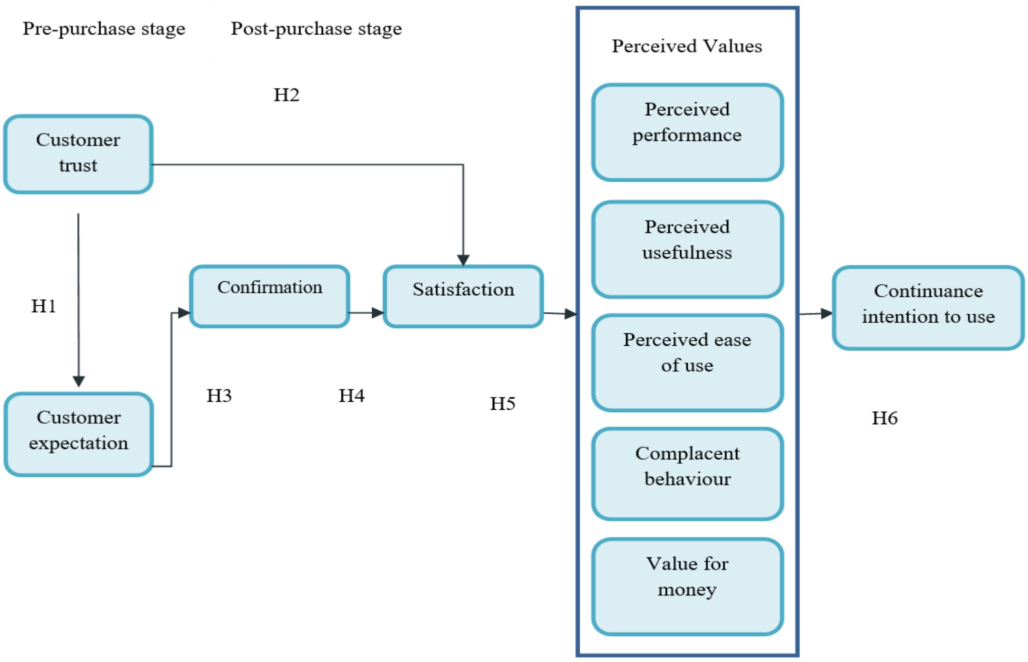

FIGURE 1: Conceptual framework of the study

2. METHODOLOGY

This study used a quantitative method to gain data on vehicle occupants on AEB. A set of questionnaires was designed and adopted based on the collective related literature and study needs. All the items were adapted and adopted from the Social SET and the ECM. Based on Table 2, the questionnaire was found to be reliable to use in the study with the 10-factor constructs. Overall, Cronbach's Alpha value is 0.938, indicating that the developed questionnaire is consistent internally. The ten factors construct was finalized after conducting a content validity test on the instrument. The factors are customer trust (CT), customer expectation (CE), confirmation (C), satisfaction (S), perceived performance (PP), perceived usefulness (PU), ease of use (EU), complacency (CC), value for money (VM), and intention to use (IU). There is a total of 61 items to measure the factors under study. The questionnaire consists of three sections:

- (i) Demographic information of the respondent,
- (ii) Consent form, and
- (iii) Ten factors construct.

The development of the questionnaire was discussed in Mohd Ishanuddin et al. (2021a) and its validity was also tested (Mohd Ishanuddin et al., 2021b), showing that the developed questionnaire is valid to be further used. The questionnaire was distributed through an online platform that targeted the specific car models equipped with AEB on social media. A short explanation of the study objective was stated at the beginning of the questionnaire. A total of 273 respondents with the AEB-equipped vehicle were collected. Based on the statistical analysis, the data was found to be not normally distributed. Hence, a non-parametric test was used to analyze the data. Then, all the data obtained were analyzed using descriptive and inferential analyses. The initial result to see the distribution of the respondents' agreement towards the study construct can be found in the authors' earlier manuscript (Mohd Ishanuddin et al., 2022).

TABLE 2: Reliability analysis

	Mean	Std. Deviation
Customer Trust (CT)	4.2125	0.50
Customer Expectation (CE)	4.2271	0.55
Confirmation (C)	4.1190	0.64
Satisfaction (S)	4.2007	0.72
Perceived Performance (PP)	4.1033	0.61
Perceived Usefulness (PU)	4.2762	0.72
Ease of Use (EU)	4.2448	0.72
Complacency (CC)	3.9495	0.67
Value for Money (VM)	3.8498	0.70
Continuance Intention to Use (IU)	4.2135	0.70

3. RESULTS AND DISCUSSION

After data collection was conducted, all the data were analyzed and discussed using statistical analysis. The demographic information was presented descriptively while ten constructs under study were analyzed using bivariate analysis.

3.1 Demographic Information

Table 3 shows the demographic information of the respondent who participated in this study. The respondents that participated in this study were a total of 273 vehicle drivers from two countries, which are Malaysia and Indonesia. The demographic data that were collected included the gender of the respondents, age group, level of education, and working and driving experience. An additional question on current vehicle satisfaction and AEB experience during driving was added to select and confirm AEB vehicle users and non-AEB vehicle users. Out of 273 respondents, most of them were males (75.8%). In terms of age, most of them were 17-25 years old (42.5%), followed by the 36-45 years old age group (23.1%). Of all respondents, 54.6% are bachelor's degree holders, followed by those with certificate education (22.7%). As for the working years, most of the respondents had worked less than five years (45.8%), and there are 112 (41%) respondents who had 11 years and above of working experience. Further, to gain information on driving experience among the respondents, a question regarding driving experience was asked. Most of the respondents had one to five years of driving experience (39.6%), and only 9.5% of the respondent were having 16-20 years of driving experience.

Although the data collection was conducted among drivers with AEB-equipped vehicles, the respondents were refined into those with AEB operation experience and those without AEB operation experience. The data revealed that from all the total respondents, there are more drivers with AEB operation experienced regardless of country. There are 142 (52%) respondents with AEB operation experience compared to the drivers without AEB operation experience with 131 (48%) respondents. Figure 2 illustrates the vehicle satisfaction among the respondents and the distribution of the respondents for Malaysian and Indonesian drivers. The results show that more than half of the respondents are satisfied and very satisfied with their current vehicle (83.9%, combined). Somehow, only 1.5% of the respondent are dissatisfied and very dissatisfied with their current vehicle. However, this data does not detail the questions regarding the features or systems (or problems) of the vehicle that they feel dissatisfied about. In total, Indonesian drivers slightly outnumbered Malaysian drivers as the study's respondents, i.e., 57.1% versus 42.9%.

TABLE 3: Socio-demographic information of the respondents

		Frequency	Percent (%)
Gender	Male	207	75.8
	Female	66	24.2
Age	17 - 25 years	116	42.5
	26 - 35 years	53	19.4
	36 - 45 years	63	23.1
	46 - 65 years	41	15.0
Educational level	Diploma	28	10.3
	Master	25	9.2
	Bachelor's	149	54.6
	PhD	9	3.3
	Certificate	62	22.7
Working years	0 - 5 years	125	45.8
	11 - years and above	112	41.0
	6 - 10 years	36	13.2
Driving experience	1 - 5 years	108	39.6
	11 - 15 years	33	12.1
	16 - 20 years	26	9.5
	20 - years and above	66	24.2
	6 - 10 years	40	14.7
AEB operation experience	No	131	48.0
	Yes	142	52.0

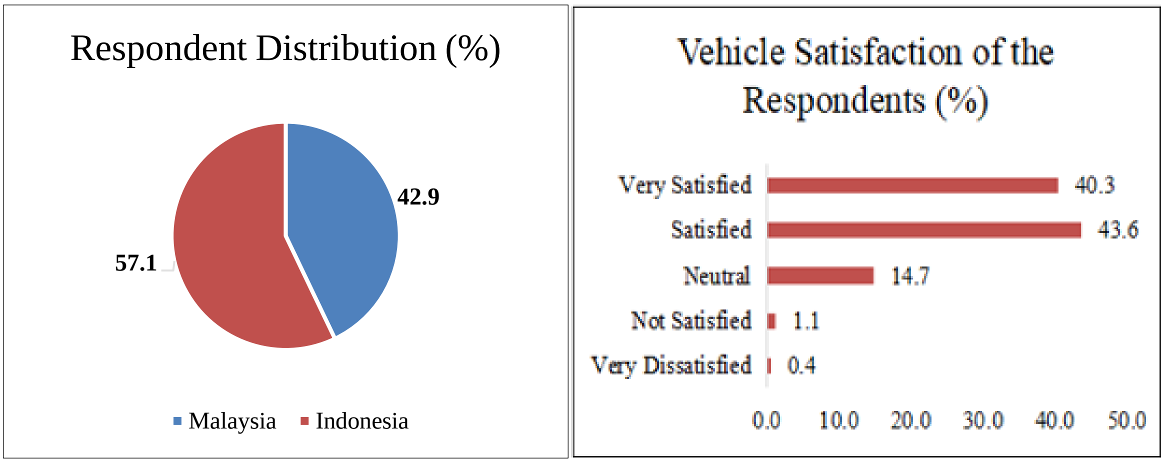

FIGURE 2: General satisfaction towards the current vehicle and respondent distribution

Table 4 demonstrates the information on the respondents driving experience with AEB operation. There are 148 drivers with below 10 years of driving experience. Meanwhile, there are 125 drivers with more than 10 years of driving experience. This result indicates that, out of the total respondents, the frequency of drivers with less than 10 years of driving experience is larger than those with more than 10 years of driving experience. Moreover, the frequency of the respondent that experienced the AEB system operation to stop the vehicle during the critical situation is 142 drivers. Meanwhile, there are 131 drivers without experience with the AEB operation system. This data implies that there are more drivers with AEB experience in this study compared to those without AEB experience. Despite the AEB implementation in the vehicles in both countries being considered new for these past few years, more drivers are experienced with AEB operations. Regardless of whether all the respondents that participated are those who are own AEB-equipped vehicles, it cannot guarantee that the driver will encounter the activated AEB system. Essentially, drivers below 10 years of driving experience were found to be having less experience with AEB systems. Conversely, drivers with more driving experience encounter the AEB system operation more than those with less driving experience. This result may be explained by the fact that the longer the driving experience, the higher the exposure to possible risks or potential accidents that can be happened on the road. Thus, it implied the result that drivers with more driving years encounter more AEB experience. More experienced drivers were supposed to have better driving skills, which is contrary to the result obtained.

TABLE 4: Respondents were driving experienced with experienced AEB operation

Driving Experience	(D12) Experienced AEB Operation		Total
	No (N = 131)	**Yes** (N = 142)	
Below 10 years	84	64	148
10 years and above	47	78	125

3.2 Descriptive Analysis of the Factors

The ten constructs under study were also analyzed and presented descriptively. The scale ranges from "1" (strongly disagree) to "5" (strongly agree) to measure the central tendency of the responses by the participating respondents. Thus, the higher mean value indicates a strong agreement with the construct items. At the same time, a lower mean value demonstrates disagreement towards the construct under study. Table 5 shows the result of the descriptive analysis using mean and standard deviation. CT factor was revealed to have a mean value and SD (4.21, 0.49). The result presented the user's agreement towards the CT construct during the pre-purchase stage. This also suggests that the users believe that AEB-equipped vehicle is trustworthy to prevent and mitigate potential crashes. Further, the CE construct had a mean of 4.23 (SD = 0.55). This data indicated that the users agreed with AEB functionality and effectiveness expectations. During the pre-purchase stage, certain expectations and impression of the system is established. Then, certain fundamental information on the AEB can affect the users' decision to use or purchase a vehicle with AEB or not. Following that, the C construct had a mean value and SD (4.12, 0.64), which also indicates the agreement of the user towards the AEB system. The users affirm the AEB system operation to prevent and mitigate potential crashes during the post-purchase stage. The user also practically experienced the system operation after driving the vehicle. In addition, the S construct had a mean (4.20) and SD (0.72).

This evidence might be explained by the fact that the respondents agree that they are satisfied with the AEB system operation as they experienced the system just after a short while. Another possible justification is the effectiveness of the AEB system to prevent forward impending crashes and injuries that possibly lead to satisfaction among AEB-equipped vehicle users. The next construct is PP construct, yield means and SD 4.10 and 0.61 respectively. This construct is one of the five perceived value factors. The analysis suggested that the AEB vehicle user agrees that the AEB-equipped vehicle enhances driving performance that significantly reduces accidents. Therefore, the performance of the AEB -equipped vehicle is affirmed further by its ability to ensure the users' safety during driving. Finally, PU represents the perceived usefulness construct had a mean (4.28) and SD (0.71). The data obtained suggested that the respondents agree with the usefulness of AEB system operation to ensure safe driving conditions other than sensing potential critical incidents. The PU construct also affirmed the validation of the AEB usefulness that led to user satisfaction in the post-purchase stage. The next construct is EU with mean and SD (4.24, 0.71). The results' possible justification includes, the drivers somehow agreeing that the system operation of AEB is easy to use.

Moreover, the system is only activated when a potential forward crash is about to happen. Besides, the system does not get in the way of driving concentration; indeed, the system aids in safe driving behavior. Another result to be reported is the CC construct which had a mean of 3.94 and an SD of 0.67. This construct is one of the constructs that was interpreted as moderately agreed by the respondents other than the VM construct. The possible explanation for the outcome is that the AEB-equipped vehicle user certainly feels that they are somewhat complacent to the AEB system operations since the system is always will be activated during a potential critical occurrence. The VM construct also had a mean value of 3.85 (0.69) which indicated the respondents' responses moderately agree with the construct items. One of the items used to measure this construct includes the AEB-equipped vehicle, which is economical about the functionality of the AEB system that prevents the accident from occurring. In the event of accidents, losing money is bound to happen. Indirectly, financial wise is using AEB-equipped vehicles. Finally, the last construct to be discussed is IU construct with a mean of 4.21 (SD = 0.69). The outcome suggested that the drivers of the AEB-equipped vehicle agree to continue to use the vehicle. AEB is a system that cannot be removed from the existing car. Thus, considering that fact, the intention to continue using the vehicle in the future could also be indicated that the users are satisfied with the system's effectiveness and even consider choosing a future vehicle equipped with the safety system. Overall, all constructs indicated as agree apart from CC and VM construct, which are interpreted as moderately agree with the responses towards the items construct.

TABLE 5: The descriptive analysis of the construct under study

	Mean	Std. Dev. (SD)
Customer Trust (CT)	4.21	0.49
Customer Expectation (CE)	4.23	0.55
Confirmation (C)	4.12	0.64
Satisfaction (S)	4.20	0.72
Perceived Performance (PP)	4.10	0.61
Perceived Usefulness (PU)	4.28	0.71
Ease of Use (EU)	4.24	0.71
Complacency (CC)	3.94	0.67
Value for Money (VM)	3.85	0.69
Intention to Use (IU)	4.21	0.69

3.3 Correlation Analysis between the Factors Under Study

Table 7 shows the significant association between the 10 factors under study. It was found that all factors are significantly associated at the significance level of 0.01. S construct had the strongest correlation with the PP factor with r = 0.799, whilst it had a weak correlation with CC with r = 0.363. This result indicated that user satisfaction with the AEB system or AEB-equipped vehicle is highly associated with the excellent performance of the AEB operation system after the post-purchase stage. However, the user's satisfaction with the AEB system or AEB-equipped vehicle is poorly related to neglectful behavior. Logically, performance-related can predict positive outcomes such as satisfaction but not negative driving behavior

Similarly, CT had the strongest correlation with the PP at r = 0.688. These results suggested that the trust factor in the pre-purchase stage proved a firm conviction on the AEB systems. After experiencing the system firsthand, the users' trust develops more in the system's operation. Otherwise, customer trust demonstrated a weak positive correlation with complacent behavior with r = 0.371. This may be explained by the fact that the trust established on the AEB systems enables the users to feel comfortable and dependable towards the system's functional ability to ensure the safety of occupants' well-being from potential crashes. This association also proved that trust factors somehow did influence complacency behavior in the system. Next, the CE construct had a somewhat high correlation coefficient with C construct with r = 0.717. The association possibly indicates that the expectation during the pre-purchase stage on the AEB system functionality and ability leads to confirmation during the post-purchase stage. Thus, proving the relationship between these constructs.

Besides that, confirmation of the AEB-related effectiveness or functionality also had a strong correlation with PP construct at r = 0.762. The strong correlation demonstrated the strong confirmation of the AEB performance after using the AEB-equipped vehicle. Meanwhile, confirmation of AEB system operation and CC construct somehow had a moderate correlation coefficient with r = 0.447. The findings explained the feeling of confirmation on the AEB system experienced leads to a comfortable and dependable feeling when driving the vehicle. Then, PP and PU had a strong correlation coefficient value with r = 0.831. The result can be interpreted as the performance and effectiveness of the AEB system in the vehicle being affirmed to be helpful to prevent accidents. Therefore, the findings strongly proved that AEB performance-related is highly useful to ensure the safety of the occupants during driving. Further, PU and EU constructs had a strong correlation coefficient with r = 0.733. Yet, the PU construct had a moderate correlation with the CC construct with a correlation coefficient of r = 0.499. The analysis explained the usefulness goes hand in hand with the ease of use of the AEB system, thus explaining the strong association between these two constructs. However, the usefulness of the AEB system in the vehicle can develop complacent behavior among the drivers. Moreover, the EU construct and IU construct had a strong correlation coefficient with r = 0.716. Nevertheless, the EU construct had a moderate correlation with CC at r = 0.413. A possible explanation is that the impression of the effortless or easy-to-use AEB system leads to the intention to continue using the system operation yet, the comfortable and easy feeling can also cause complacent behavior to the drivers. Lastly, VM and IU constructs had a moderate correlation with r = 0.569. The results demonstrated that the AEB-equipped vehicle price range is economical considering the ability to prevent crashes that can cause losing money, somehow leading the user to continue using the AEB-equipped vehicle. Table 6 shows the degree of correlations varying from negligible to very strong correlation. Note that the stronger the correlation, the higher the value of the correlation coefficient closer to 1.

TABLE 6: Correlation coefficients with respective interpretations

Correlation coefficients (r)	Interpretation
0.00–0.10	Negligible correlation
0.10–0.39	Weak correlation
0.40–0.69	Moderate correlation
0.70–0.89	Strong correlation
0.90–1.00	Very strong correlation

Source: Akoglu, (2018); Schober et al., (2018)

TABLE 7: Correlation analysis of the constructs

	S	CT	CE	C	PP	PU	EU	CC	VM	IU
S	1									
CT	0.679**	1								
CE	0.643**	0.616**	1							
C	0.792**	0.656**	0.717**	1						
PP	0.799**	0.688**	0.657**	0.762**	1					
PU	0.746**	0.653**	0.656**	0.695**	0.831**	1				
EU	0.780**	0.646**	0.630**	0.734**	0.754**	0.733**	1			
CC	0.363**	0.371**	0.416**	0.447**	0.538**	0.499**	0.413**	1		
VM	0.477**	0.430**	0.405**	0.494**	0.593**	0.541**	0.497**	0.576**	1	
IU	0.700**	0.618**	0.571**	0.658**	0.732**	0.691**	0.716**	0.536**	0.569**	1

*** Correlation is significant at the 0.01 level (2-tailed).*

3.4 AEB Operation Satisfaction for both Countries

Table 8 demonstrated the results of bivariate analysis by Spearman's Rho of satisfaction towards AEB for both Malaysian and Indonesian drivers. Based on Table 8, in Malaysia, the overall current vehicle satisfaction factor had a significant association with the satisfaction of the consumer towards the AEB system at a significance level of 0.01. However, the strength of the correlation was found to be a weak positive correlation at r = 0.367. Nevertheless, Indonesian vehicle drivers that experienced the AEB operation while driving are significantly associated with satisfaction towards the AEB system at a significance level of 0.01, with a correlation coefficient r = 0.275. The finding suggests that the drivers developed satisfaction after the vehicle with the AEB system managed to prevent the collision during driving. Hence preventing the accident from occurring. Besides, overall car satisfaction among

Indonesian drivers also had a significant relationship with satisfaction with the AEB system at a significance level of 0.01 (r = 0.214). This also indicated that the implementation of AEB as one of the safety features that equipped the vehicle contributed to customer satisfaction among the AEB-equipped vehicle users.

TABLE 8: Satisfaction towards AEB for Malaysian and Indonesian drivers

		AEB Experienced	Car Satisfaction	AEB Satisfaction
Malaysia	AEB Experienced	1		
	Car Satisfaction	-0.115	1	
	AEB Satisfaction	0.001	0.367**	1
Indonesia	AEB Experienced	1		
	Car Satisfaction	0.089	1	
	AEB Satisfaction	0.275**	0.214**	1

*** Correlation is significant at the 0.01 level (2-tailed).*

4. CONCLUSION

The study focused on vehicle users with AEB-equipped cars. Some notable findings in this study include the AEB-equipped vehicle users agreeing that the system is useful in terms of functionality and that the system's operation is relatively having ease-of-use, which minimizes distractions during driving. The correlation analysis justified that all the constructs under study were significantly associated with each other. Some convincing evidence, the satisfaction of the customer, was found to be highly associated with confirmation, ease-of-use, the performance of the system, and the usefulness of the system. Also, the expectation of the users in the pre-purchase stage was confirmed after they used the system themselves. The drivers also validated and confirmed the performance of AEB in preventing critical incidents from occurring. Besides, performance-related is also highly associated with the usefulness and ease-of-use using the AEB systems.

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