Determinants of Road Accident Frequency: The Role of Adas, Weather, Road Conditions, and Driver Factors

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DOI: https://doi.org/10.47772/IJRISS.2026.100700752

Received: 22 July 2026; Accepted: 30 July 2026; Published: 11 August 2026

ABSTRACT

Road accidents have long been a persistent safety issue in Malaysia, causing many deaths and injuries and imposing substantial annual costs. Despite measures to improve road safety, the number of accidents has remained high due to the interplay of several factors. Most studies have examined these factors individually; hence, very little is known about their collective effect on the number of road accidents. Consequently, this study proposed to explore the combined influence of Advanced Driver Assistance Systems (ADAS), road and weather conditions, and driver factors on the incidence of road accidents among ADAS users in Malaysia. The research was based on systems theory, which suggests that road accidents result from interactions among technology, environment, and human components in the transport system. In this regard, the technological component was represented by the Role of ADAS, the environment included road and weather conditions, and the human element consists of drivers. This study used a quantitative research methodology and specifically adopt a cross-sectional survey method. Data has been collected from Malaysian citizens who possess a valid driving licence and drive vehicles fitted with ADAS. Purposive sampling has been used to select study participants. Data analysis has been performed using SPSS, version 27. Descriptive statistics has been used to describe the characteristics of the participants, while regression analysis assessed the relationships between the dependent variable (road accidents) and ADAS, weather conditions, road conditions, and driver factors. This study examined the associations between the perceived role of ADAS, weather conditions, road conditions, driver factors, and road accident frequency.

Keywords: Road Accident Frequency, ADAS, Weather, Road Conditions, Driver Factors

INTRODUCTION

Road crashes constitute one of the most common factors responsible for fatalities and injuries, bringing forth substantial socio-economic impacts on both individuals and authorities (World Health Organization [WHO], 2023). Although there have been developments and innovations in road infrastructures, traffic rules, and vehicle safety features in Malaysia, road accidents continue to be a serious safety concern (Malaysian Institute of Road Safety Research [MIROS], 2024). Besides, the growth in the number of registered vehicles and road users has increased the problems related to accidents and road safety management in Malaysia (Department of Statistics Malaysia [DOSM], 2024).

To enhance driver safety, the automotive industry has been integrating more Advanced Driver Assistance Systems (ADAS) into contemporary cars (Hagl & Kouabenan, 2020), especially focusing on the role of ADAS. The ADAS systems such as adaptive cruise control, lane departure warning, automatic emergency braking, and blind spot detection are aimed at assisting drivers in assessing their environment and decreasing risks of crashes that result from human errors (Cicchino, 2017). Prior research has established that the role of ADAS in supporting drivers may improve driving performance and lower crash risks through prompt alerts and intervention systems (World Health Organization, 2023; Cicchino, 2017).

Nonetheless, accidents have been reported among motorists driving cars with ADAS technology installed, and hence, the use of technology alone might not be enough to eradicate the occurrence of accidents (Hagl & Kouabenan, 2020). Under the System Theory, accidents are a result of an interaction of various parts of a system rather than an effect of one cause (von Bertalanffy, 1968). In the context of transport, road accident occurrence depends on the interplay between technological aspects, environment, and human behavior (Leveson, 2011). Therefore, understanding road accident frequency requires a comprehensive examination of the relationships among these interconnected factors.

Problem Statement

Road accidents continue to be a major transportation and public safety issue in Malaysia despite the increasing adoption of vehicles equipped with Advanced Driver Assistance Systems (ADAS). This indicates that the role of ADAS alone may not be sufficient to explain road accident frequency, suggesting that other contributing factors should also be considered.

Previous studies have generally focused on individual determinants of road accidents, such as technological, environmental, or human-related factors, rather than examining these factors simultaneously. This is because road accidents are complicated events that occur due to interactions between many system components; hence an elaborate study that considered technology, environment and human related variables is required. The gap is further widened since no studies have tried to examine the influence of these factors on road accidents at once.

Consequently, limited empirical evidence is available regarding the combined influence of the role of ADAS, weather conditions, road conditions, and driver factors on road accident frequency among Malaysian ADAS users.

Therefore, this study investigates the relationships between the role of ADAS, weather conditions, road conditions, driver factors, and road accident frequency among ADAS users in Malaysia. The findings are expected to contribute to both theoretical understanding and practical road safety improvement.

Research Objectives

This study was conducted based on the following research objectives:

1. To examine the influence of the role of Advanced Driver Assistance Systems (ADAS) on road accident frequency among ADAS users in Malaysia.
2. To examine the influence of road conditions on road accident frequency among ADAS users in Malaysia.
3. To examine the influence of weather conditions on road accident frequency among ADAS users in Malaysia.
4. To examine the influence of driver factors on road accident frequency among ADAS users in Malaysia.

Research Questions

The research questions constructed based on the proposed research objectives are as follows:

1. Does the role of Advanced Driver Assistance Systems (ADAS) influence road accident frequency among ADAS users in Malaysia?
2. To what extent do road conditions influence road accident frequency among ADAS users in Malaysia?

3. How do weather conditions influence road accident frequency among ADAS users in Malaysia?
4. To what extent do driver factors influence road accident frequency among ADAS users in Malaysia?

Scope of Study

The objective of this study is to determine the factors that contribute to road accident frequency among drivers who use ADAS in Malaysia. The study looks at four independent factors which include the role of ADAS, road conditions, weather conditions, and driver related factors, where road accident frequency is the dependent factor.

The target population of the study includes all Malaysian drivers who are at least 18 years old and who have driven cars with ADAS. Respondents have been chosen due to their experience and knowledge about ADAS and their driving in different road and weather conditions.

A research methodology used by this study entails quantitative research design. Data collection involves distribution of a structured questionnaire among eligible respondents. Data analysis involves statistical techniques like descriptive analysis, Pearson correlation analysis, multiple regression analysis, and ANOVA to test associations among the variables.

In terms of geography, the research is confined to Malaysia and covers only users of ADAS. Hence, the outcomes of this study are expected to contribute to an understanding of the transport sector in Malaysia and can be used for improving road safety in connection with ADAS.

Limitations/ Study Constraints

First, this study employed a cross-sectional research design, which captures data at a single point in time. Consequently, while the study is able to identify statistically significant associations between the predictors and road accident frequency, the temporal ordering between the variables cannot be established. Therefore, causal inferences cannot be made based on the findings.

Second, this study adopts the use of convenience sampling in the collection of its data. This method has made the study easy to conduct in terms of collecting data; however, it is likely to affect the representativeness of the sample, hence reducing the generalizability of its results to the whole population of Malaysian drivers.

Third, this study makes use of self-report questionnaires in the collection of data. This means that the subjects can be likely to provide their subjective views, inaccurate data, and even socially desired answers to questions.

Fourthly, the study takes into account only four determinants affecting the rate of road accidents, which are the efficiency of ADAS technology, road conditions, weather conditions, and driver characteristics. The factors like traffic density, conditions of vehicles' maintenance, enforcement activities, experience of drivers, and quality of road infrastructure are not considered as determinants of the road accident frequency in this study.

Lastly, the study is performed among Malaysian users of ADASs only. There could be differences in the transportation systems, driving cultures, road infrastructure and regulations between various countries. Hence, the results of this research may be hard to generalize to other countries. Future researches should consider other determinants and perform the comparative analysis in other countries and different transportation systems.

LITERATURE REVIEW

Road Accident Frequency

Earlier research revealed many different reasons for road accidents frequency, such as car technology, road design, weather conditions and driver’s behavior (WHO, 2023; Cicchino, 2017). An increase in the number of road accidents reflects poor performance of the transportation system, while a decrease in their number shows good interaction between all the system elements (Leveson, 2011). In this research, the accident frequency was the dependent variable indicating the overall result in terms of safety for the ADAS users in Malaysia.

The Role of Advanced Driver Assistance Systems (ADAS)

The role of ADAS refers to the extent to which ADAS assists drivers and increases road safety through the application of features like lane departure warning, adaptive cruise control, and automatic emergency braking (Cicchino, 2017). ADAS can help decrease human errors and improve the driving experience through warnings and driving assistance Hagl & Kouabenan, 2020). Nevertheless, the effectiveness of ADAS is subject to the behavior of drivers and driving environment (WHO, 2023).

Road Conditions

The term "road conditions" means the state and the quality of the road infrastructure, such as road surface, lane marking, lighting and traffic signs (Chen et al., 2017). In case good road conditions exist, driving was been easier and more comfortable; otherwise, driving may become less controlled and risky (WHO, 2023). That is why the mentioned element can be regarded as an important one in road accidents occurrence.

Weather

Weather conditions are the environmental conditions such as rainfall, fog, haze, and visibility that can impact the driving abilities of individuals (World Meteorological Organization, 2023). Poor weather conditions can cause problems like reduced visibility, increased stopping distances, and reduced friction in the road, which increases chances of accidents (WHO, 2023). Poor weather conditions can also hinder the effectiveness of the ADAS technology Hagl & Kouabenan, 2020).

Driver Factors

Driver factors refer to driver-related characteristics and behaviours that influence road safety, including distraction, fatigue, speeding, driving experience, and risk-taking behaviour (WHO, 2023). Research shows that one of the major causes of accidents on roads across the world is driver behavior (Cicchino, 2017). Despite the availability of ADAS technologies, safe driving ultimately depends on how drivers react to different road situations (Hagl & Kouabenan, 2020).

Framework of Study

Conceptually, the framework of this research is found on the theory of systems wherein results are achieved from the collaboration of many components in a system (von Bertalanffy, 1968). In the case of road safety, road accident frequency is determined by technological, environmental, and human factors operating together in the transportation system (Leveson, 2011). Thus, this study explored the role of ADAS, road condition, weather condition, and human factors on the frequency of road accidents amongst users of Advanced Driver Assistance Systems in Malaysia.

The Role of ADAS is the technological factor examined in this study. The role of ADAS represents the technological component that can help drivers in identifying risks and mitigating accidents through capabilities such as adaptive cruise control, lane departure warning, and automatic emergency braking (Cicchino, 2017; Hagl & Kouabenan, 2020).

Road conditions and weather conditions are the environmental factors in the transportation system since aspects like quality of road surface, maintenance of the roads, rainfall, fog, and visibility play a direct role in the driving environment, car handling, and the performance of ADAS technologies (Chen et al., 2017; WHO, 2023; Hagl & Kouabenan, 2020).

Driver factors represent the human component of the transportation system. These factors include distraction, fatigue, speeding, lack of attention, and risk-taking behaviour, all of which influence road accident frequency (WHO, 2023; Cicchino, 2017).

As per the System Theory, the technological, environmental, and human factors interrelate with each other in the transport system, and it is the combination of these relationships that define the frequency of road accidents among the ADAS users in Malaysia (von Bertalanffy, 1968; Leveson, 2011).

Hence, it can be proposed that ADAS, road condition, weather condition, and driver factors are the independent variables affecting the frequency of road accidents as the dependent variable.

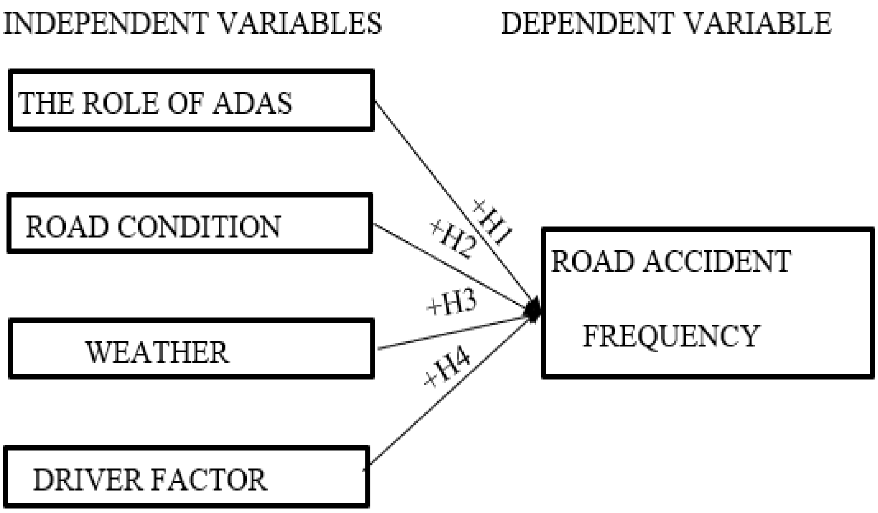

Fig. 1 Research Framework

THEORETICAL BACKGROUND

System Theory (Larsson, P., Dekker, S., & Tingvall, C. , 2010)

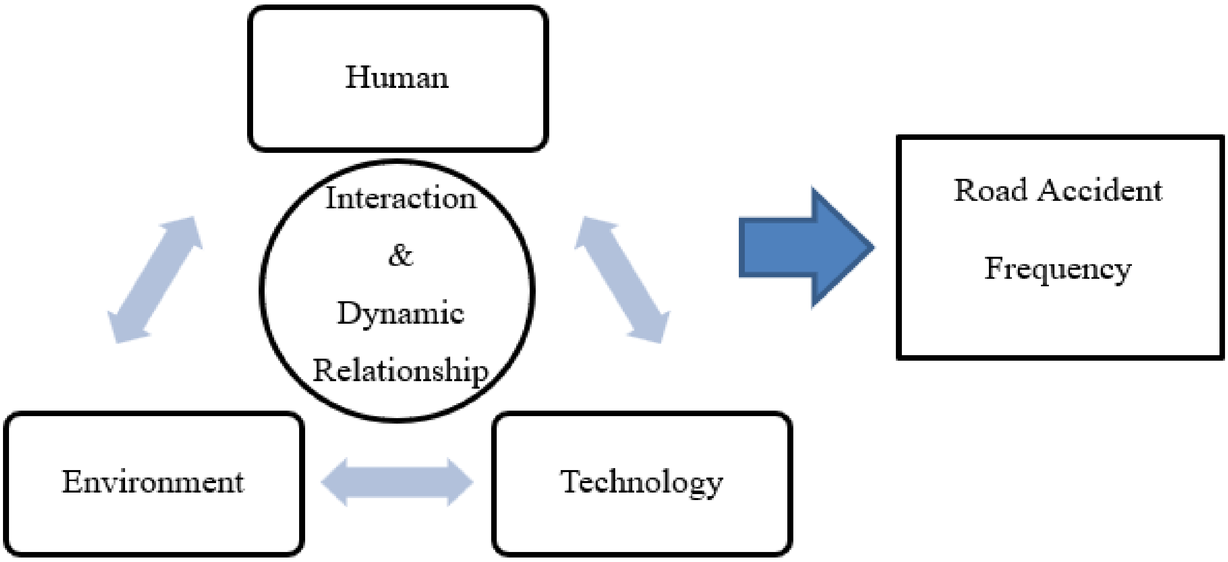

Fig. 2 System Theory

Source: Larsson, P., Dekker, S., & Tingvall, C. (2010)

The current study underpinned by the Systems Theory which stipulates that road safety is determined by how well interconnected system components interact with each other instead of being determined by a single entity (von Bertalanffy, 1968). According to the Systems Theory, a system is comprised of different components which act together to meet the same goal, and any change in one of the components could have an impact on the whole system. In the case of road transportation, the system is comprised of drivers, vehicles, road infrastructure, environment, and technology which interact to affect road safety outcomes.

Road accident frequency can be understood using the Systems Theory by considering road accident frequency to be a result of the interaction of different elements of the transport system. Driver factors constitute the human component of the transportation system. These factors include speeding, distraction, fatigue, and non-compliance with traffic regulations. Unsafe driver factors may disrupt the transportation system and increase road accident frequency. The other aspect is the road conditions, which constitute the infrastructural element of the transport system.

Moreover, the environmental element in the transportation system includes weather conditions. Poor weather conditions like heavy rainfall, fog, and storms may cause poor visibility, low road traction, and poor vehicle control, hence increasing the risks of accidents (World Health Organization, 2023). Lastly, Advanced Driver Assistance Systems (ADAS) are the technological elements of the transportation system. Features of ADAS such as automatic emergency braking, adaptive cruise control, and lane keeping assist enhance the performance of drivers through hazard detection and collision avoidance (Cicchino, 2017; Hagl & Kouabenan, 2020).

Thus, Systems Theory provides an effective theoretical basis for this study because the theory describes the relationship between the human, technological, environmental, and infrastructure elements in the road transportation system and their effect on the number of road accidents. The theory allows for the analysis of ADAS, road conditions, weather conditions, and drivers as critical components that affect the frequency of road accidents in Malaysia.

Empirical Research

Relationship Between the Role of ADAS and Road Accident Frequency

Previous studies have demonstrated that ADAS technologies contribute to reducing road accident frequency by improving driver awareness and minimizing human errors (Cicchino, 2017). Features such as automatic emergency braking and lane departure warning have been shown to reduce collision risks and improve road safety outcomes (Hagl & Kouabenan, 2020). Therefore, this study proposes:

H1: There is a significant relationship between the role of ADAS and road accident frequency among ADAS users in Malaysia.

Relationship Between Weather and Road Accident Frequency

Adverse weather conditions have been found to increase accident risks by reducing visibility and vehicle control (World Meteorological Organization, 2023). Weather-related hazards may also affect the effectiveness of ADAS technologies (Hagl & Kouabenan, 2020). Therefore, this study proposes:

H2: There is a significant relationship between weather conditions and road accident frequency among ADAS users in Malaysia.

Relationship Between Road Conditions and Road Accident Frequency

Road conditions have consistently been identified as a significant factor influencing road accident occurrence (Chen et al., 2017). Poor road infrastructure, damaged surfaces, and inadequate road maintenance increase the likelihood of accidents by reducing driving safety (WHO, 2023). Therefore, this study proposes:

H3: There is a significant relationship between road conditions and road accident frequency among ADAS users in Malaysia.

Relationship Between Driver Factors and Road Accident Frequency

Driver behaviour remains one of the strongest predictors of road accident involvement (WHO, 2023). Unsafe driving practices such as speeding, distraction, and fatigue significantly contribute to accident occurrence regardless of vehicle technology (Cicchino, 2017). Therefore, this study proposes:

H4: There is a significant relationship between driver factors and road accident frequency among ADAS users in Malaysia.

METHODOLOGY

Research Design

This study employed a quantitative cross-sectional survey design to examine the influence of the role of ADAS, road conditions, weather conditions, and driver factors on road accident frequency among Malaysian drivers using ADAS-equipped vehicles. A quantitative approach was selected because it enables the statistical examination of relationships between variables, while the cross-sectional survey design allows data to be collected from respondents at a single point in time in an efficient and cost-effective manner (Creswell & Creswell, 2018; Saunders et al., 2019; Sekaran & Bougie, 2019). Finally, survey method would also allow to obtain the responses from a sufficient number of participants in an efficient and relatively cheap manner. Thus, a quantitative cross-sectional survey design was found to be most suitable to fulfill the research aims of this research and offer empirical evidence on road accident frequency among drivers of ADAS equipped vehicles in Malaysia (Hair et al., 2021).

Population

The population of this research study was concerned with the Malaysian drivers that possess a valid driver's license and are active users of vehicles fitted with Advanced Driver Assistance Systems (ADAS). They are the appropriate respondents because they have the real-time experience using the technologies in vehicles, and this allows them to better assess their impacts on the occurrences of road accidents.

Examples of ADAS technology that helps minimize the probability of road accidents include but is not limited to Auto Emergency Braking (AEB), Adaptive Cruise Control (ACC), Lane Keep assist (LKA), Blind Spot detection (BSD), and forward collision warning (FCW) (Cicchino, 2017; Hagl & Kouabenan, 2020).

The population of this study is estimated to be 9,820 people, based on the estimated count of electric vehicles and smart technological advanced cars that typically feature such ADAS systems within the country (Malaysian Automotive Association, 2024). According to Sekaran and Bougie (2019), defining the population clearly is very important since it helps us to ensure that the conclusions derived from the results of the study could be generalised to that specific group of people.

Given that this research seeks to explore the effects of the variables on the road accident frequencies, it is vital to sample the individuals who have the hands-on experience on the ADAS enabled cars in order to ensure meaningful and precise data is collected.

Sampling

This study uses a non-probability purposive sampling technique to select respondents from the target population. Purposive sampling is appropriate as it allows the study to target respondents with certain specific characteristics and experiences with regards to the research objectives (Etikan et al., 2016). In particular, respondents should be licenced Malaysian drivers who are currently driving and frequently using vehicles with ADAS features. Saunders et al.'s (2019) assertion that purposive sampling can provide rich information from knowledgeable people supports this choice. It is worth noting that screening questions have been added at the beginning of the questionnaire to validate the eligibility of respondents. Using Krejcie and Morgan's (1970) sample size

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VII July 2026

determination table, it is estimated that a population of around 10,000 people requires a minimum of 370 respondents to achieve a 95% confidence level and ± 5% margin of error. Hence, this study aimed to obtain at least 370 usable responses from eligible ADAS users.

Data Collection Methods

The main source of data for this research has been obtained by means of a questionnaire survey because questionnaires are a good tool in obtaining standardized data from a large number of respondents within a short period of time (Sekaran & Bougie, 2019). The questionnaire included two parts: demographics and questions that measure ADAS, road conditions, weather conditions, drivers' factors and road accident frequency. Measurement items adopted from past literature in order to enhance the validity and reliability of the data (Hair et al., 2021). Data has been obtained via online and offline approaches; online questionnaires has been sent through Google Forms and social media, whereas printed questionnaires has been sent out in car dealerships, servicing centers, EV charging stations, universities, and automotive shows. Using both approaches increased the response rate and the representativeness of the sample (Saunders et al., 2019). After the collection of data, it has been screened for any missing values and analyzed with the use of SPSS Version 27 (Hair et al., 2021).

Questionnaire Design

Respondent profiles were being conducted based on demographic analysis including age, gender, state, occupation, and type of Advanced Driver Assistance Systems (ADAS). Respondent has been screened based on three (3) questions. The items being used in the questionnaire to analyze the relationship between independent variables and the dependent variable were as Table 5 below:

TABLE 5 Measurement Items

Code	Content	Authors
Road Accident Frequency (RA)		
RA1	I frequently hear about or witness road accidents in my driving area.	(Rehman et al., 2025; Hagl & Kouabenan, 2020; Cicchino, 2017; Mannering et al., 2020)
RA2	Road accidents frequently occur in the area where I usually drive.	
RA3	I often encounter situations that could potentially lead to road accidents.	
RA4	The frequency of road accidents has increased in my driving environment.	
RA5	I believe multiple driving-related factors influence the frequency of road accidents.	
The Role of ADAS (A)		
A1	ADAS helps me reduce the risk of road accidents while driving.	(Cicchino, 2017; Damsara et al., 2025; Hagl & Kouabenan, 2020; Khattak et al., 2024; Cicchino et al., 2022)
A2	ADAS improves my awareness of surrounding road hazards	
A3	Features such as Automatic Emergency Braking (AEB) help improve driving safety.	
A4	I feel safer driving a vehicle equipped with ADAS technology.	
A5	ADAS helps improve my driving performance and decision-making.	
Road Conditions (RC)		
RC1	Poor road conditions increase the risk of road accidents.	(Chua et al., 2024; Baskara et al., 2023; Al-Masaeid et al., 2022; Cicchino, 2017)
RC2	Potholes and damaged roads affect my driving safety.	
RC3	Unclear road markings make driving more difficult and dangerous.	
RC4	Poorly maintained roads reduce vehicle stability while driving.	
RC5	Road maintenance is important for reducing the frequency of road accidents.	
Weather (W)		
W1	Heavy rain increases the risk of road accidents.	(Malin et al., 2019; Hagl
W2	Poor weather conditions reduce my visibility while driving.	

W3	Foggy conditions make it difficult to drive safely.	& Kouabenan, 2020; Chua et al., 2024; Cicchino, 2017)
W4	Strong winds can affect vehicle control during driving.	
W5	Weather conditions influence the effectiveness of ADAS technologies.	
Driver Factor (DF)		
DF1	Driver distraction increases the likelihood of road accidents.	(Malin et al., 2019; Damsara et al., 2025; Hagl & Kouabenan, 2020)
DF2	Speeding behavior contributes to the frequency of road accidents.	
DF3	Driver fatigue affects driving performance and safety.	
DF4	Lack of attention while driving can lead to accidents.	
DF5	Risk-taking behavior among drivers increases the occurrence of accidents.	

RESULTS AND FINDINGS

Response Rate and Data Screening

A total of 405 questionnaires were distributed to Malaysian drivers who had experience driving vehicles equipped with at least one ADAS feature. Of these, 382 questionnaires were returned, representing a response rate of 94.3%. Following data screening, 12 responses were excluded because of incomplete answers, patterned responses or failure to meet the screening criteria. Therefore, 370 usable responses were retained for subsequent analysis.

The data were examined for missing values, outliers and normality. Missing values accounted for less than 1% of the dataset and were replaced using the series mean. Standardised scores were within the recommended range of ±3.29, indicating the absence of serious univariate outliers. The absolute skewness values ranged from 0.18 to 0.74, while kurtosis values ranged from 0.11 to 0.91. These values suggested that the distributions were sufficiently normal for parametric analysis.

TABLE 6 Questionnaire Distribution and Response Rate

Response Category	Frequency	Percentage (%)
Questionnaires Distributed	405	100.0
Questionnaires returned	382	94.3
Questionnaires rejected	12	3.0
Usable questionnaires	370	91.4
Usable questionnaires	370	91.4

Respondent Profile

Table 7 presents the demographic characteristics zof the respondents. Male respondents represented 57.0% of the sample, while female respondents accounted for 43.0%. Most respondents were between 26 and 35 years old, representing 34.3% of the sample. This was followed by respondents aged between 36 and 45 years, at 26.5%.

In terms of driving experience, 36.2% had between six and ten years of driving experience, while 29.2% had more than ten years of experience. The findings indicate that most respondents had adequate driving exposure to evaluate the role of ADAS, weather, road conditions and driver-related behaviour.

Automatic Emergency Braking was the most frequently used ADAS feature, reported by 27.0% of respondents. This was followed by Blind Spot Detection at 22.7%, Adaptive Cruise Control at 20.8%, Lane-Keeping Assistance at 16.2%, and Forward Collision Warning at 13.2%.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VII July 2026

TABLE 7 Demographic Profile Of Respondents

Demographic Characteristic	Category	Frequency	Percentage (%)
Gender	Male	211	57.0
	Female	159	43.0
Age	18-25 years	69	18.6
	26-35 years	127	34.3
	36-45 years	98	26.5
	46-55 years	52	14.1
	56 years and above	24	6.5
Driving experience	Less than 3 years	45	12.2
	3-5 years	83	22.4
	6-10 years	134	36.2
	More than 10 years	108	29.2
Most frequently used ADAS feature	Automatic Emergency Braking	100	27.0
	Adaptive Cruise Control	77	20.8
	Lane-Keeping Assistance	60	16.2
	Blind Spot Detection	84	22.7
	Forward Collision Warning	49	13.2
Previous accident involvement	Yes	139	37.6
	No	231	62.4

Common Method Bias

Harman’s single-factor test was performed because all variables were measured using the same self-administered questionnaire. The unrotated exploratory factor analysis produced five factors with eigenvalues greater than 1.0. The first factor explained 34.62% of the total variance, which was below the commonly adopted threshold of 50%.

Therefore, common method bias was not considered a major concern in the study. Nevertheless, Harman’s single-factor procedure should be treated as a preliminary diagnostic rather than definitive evidence that common method variance is completely absent.

Reliability Analysis

Cronbach’s alpha was used to evaluate the internal consistency of the measurement scales. As shown in Table 8, all constructs recorded alpha coefficients above 0.80. Driver factors recorded the highest reliability coefficient of 0.910, followed by road conditions at 0.894 and weather conditions at 0.887. The corrected item-total correlations ranged from 0.583 to 0.803, exceeding the minimum acceptable value of 0.30. Consequently, all 25 measurement items were retained for further analysis.

TABLE 8 Reliability And Descriptive Statistics

Construct	Number of items	Mean	Standard Deviation	Cronbach’s Alpha
Role of ADAS	5	4.08	0.61	0.882
Road conditions	5	4.16	0.58	0.894
Weather conditions	5	4.11	0.62	0.887
Driver factors	5	4.25	0.56	0.910
Road accident frequency	5	3.64	0.69	0.861

Scale: 1 = strongly disagree; 5 = strongly agree

The mean scores ranged from 3.64 to 4.25. Driver factors recorded the highest mean score, indicating strong agreement that distraction, speeding, fatigue, lack of attention and risk-taking behaviour contribute to road accidents. Road conditions recorded the second highest mean, suggesting that respondents were concerned about potholes, damaged road surfaces, unclear road markings and poor maintenance.

The role of ADAS also recorded a relatively high mean of 4.08. This indicates that respondents generally believed that ADAS improves hazard awareness, driving performance and perceived safety. Real-world research supports the potential safety contribution of ADAS, although effectiveness differs across technologies and operating conditions. For example, forward-collision warning and automatic emergency braking have been associated with reductions in relevant rear-end crashes, whereas pedestrian-detection systems may perform less effectively in darkness or other challenging environments.

Pearson Correlation Analysis

Pearson correlation analysis was conducted to identify the strength and direction of the bivariate relationships among the study variables.

TABLE 9 Pearson Correlation Matrix

Variable	1	2	3	4	5
Role of ADAS	1.000				
Road conditions	-0.214**	1.000			
Weather conditions	-0.183**	0.514**	1.000		
Driver factors	-0.261**	0.472**	0.438**	1.000	
Road accident frequency	-0.443**	0.536**	0.574**	0.666**	1.000

Note: $N=370$; $p<0.001$, two-tailed

The role of ADAS was significantly and negatively related to road accident frequency, with $r=-0.443$, $p<0.001$. This result indicates that stronger perceived ADAS effectiveness was associated with lower perceived accident frequency. However, the relationship was moderate rather than extremely strong, implying that ADAS cannot independently eliminate accident risk.

Road conditions had a significant positive relationship with road accident frequency, $r=0.536$, $p<0.001$. Thus, respondents who perceived road conditions as unsafe also reported a higher frequency of accidents and accident-prone situations. Previous empirical research has similarly demonstrated that pavement quality, surface condition, skid resistance and geometric characteristics can affect crash occurrence and severity.

Weather conditions were positively and significantly correlated with road accident frequency, $r=0.574$, $p<0.001$. This suggests that heavy rain, poor visibility, fog and strong winds were associated with an increased perception of accident frequency. The result is consistent with previous research showing that combinations of road-surface and weather conditions alter crash risk.

Driver factors demonstrated the strongest positive correlation with road accident frequency ($r = 0.666$, $p < 0.001$). This finding indicates that driver distraction, speeding, fatigue, inattention and risk-taking remain central contributors to road safety outcomes, even when vehicles are equipped with technological assistance. Research on fatal crashes has also identified driver inattention and distraction as important contributors to serious road crashes.

None of the correlations among the independent variables exceeded 0.80. Therefore, the initial results did not indicate severe multicollinearity.

Multiple Regression Analysis

Multiple regression analysis was performed to determine the simultaneous effects of ADAS, road conditions, weather conditions and driver factors on road accident frequency.

TABLE 10 Model Summary

Model statistic	Value
R	0.773
R^2	0.598
Adjusted R^2	0.594
Standard error of estimate	0.440
Durbin-Watson	1.936

The four independent variables collectively explained 59.8% of the variance in road accident frequency. The adjusted R^2 value of 0.594 indicated that the model retained strong explanatory power after accounting for the number of predictors and sample size. The remaining 40.2% may be explained by other factors not examined in the model, such as traffic density, enforcement, vehicle maintenance, road design, driving exposure and accident history. The Durbin–Watson statistic of 1.936 was close to 2.0, indicating that autocorrelation of residuals was unlikely to be a serious concern.

TABLE 11 Multiple Regression Coefficients

Predictor	β	Standard error	Standardised β	t	Sig.	Tolerance	VIF
Constant	0.987	0.247	-	4.00	<0.001	-	-
Role of ADAS	-0.238	0.041	-0.211	-5.80	<0.001	0.894	1.119
Road conditions	0.211	0.052	0.177	4.06	<0.001	0.659	1.517
Weather conditions	0.267	0.048	0.240	5.56	<0.001	0.675	1.481
Drive factors	0.478	0.055	0.389	8.69	<0.001	0.711	

Dependent variable: Road accident frequency.

Tolerance values ranged from 0.659 to 0.894, while VIF values ranged from 1.119 to 1.517. These values indicate that multicollinearity did not adversely affect the regression estimates. The resulting regression equation is:

RA = 0.987 − 0.238(Role of ADAS) + 0.211(Road Conditions) + 0.267 (Weather Conditions) + 0.478 (Driver Factors)where:

Hypothesis Testing

Hyothesis	Proposed Relationship	Standardised β	t-value	p-value	Decision
H1	Role of ADAS -> Road Accident Frequency	-0.211	-5.80	<0.001	Supported
H2	Road Conditions -> Road Accident Frequency	0.177	4.06	<0.001	Supported
H3	Weather -> Road Accident Frequency	0.240	5.56	<0.001	Supported
H4	Driver Factors -> Road Accident Frequency	0.389	8.69	<0.001	Supported

All four hypotheses were supported. Driver factors were the strongest predictor of road accident frequency, followed by weather conditions, the role of ADAS and road conditions.

DISCUSSION

The Influence of ADAS on Road Accident Frequency

The role of ADAS had a significant negative influence on road accident frequency, $\beta=-0.211$, $p<0.001$. Therefore, H1 was supported. Higher perceived effectiveness of ADAS was associated with lower accident frequency among Malaysian ADAS users.

ADAS features improve situational awareness through warnings, braking intervention, lane monitoring and blind-spot detection. Empirical evidence has shown that forward-collision warning, automatic emergency braking and lane-departure warning can reduce crashes relevant to their intended functions. For example, Cicchino found that forward-collision warning with automatic emergency braking produced substantial reductions in rear-end crash involvement, while lane-departure warning was associated with lower rates of relevant crashes (Cicchino, 2017).

Nevertheless, the role of ADAS was not the strongest predictor in the model. This finding suggests that ADAS is a supporting safety mechanism rather than a replacement for attentive driving. System performance may be constrained by darkness, poor road markings, heavy rain, sensor obstruction and drivers' misunderstanding of system capabilities. Pedestrian automatic emergency braking, for instance, has demonstrated weaker effectiveness in dark conditions without adequate lighting (Yong, 2022).

The result supports the systems perspective adopted in the manuscript. Safety cannot be attributed exclusively to technology because ADAS effectiveness is embedded within a broader system involving drivers, roads and environmental conditions. The systems approach emphasises that road crashes emerge from interactions among components rather than from a single isolated failure (Larsson et al., 2010).

The Influence of Road Conditions on Road Accident Frequency

Road conditions had a positive and significant effect on road accident frequency, $\beta=0.177$, $p<0.001$, supporting H3. Poorly maintained roads, potholes, unclear lane markings and unstable surfaces were associated with higher accident frequency.

Road conditions may influence both drivers and vehicle technology. Potholes or uneven surfaces can reduce vehicle stability and cause drivers to make sudden manoeuvres. Similarly, faded road markings can affect the ability of camera-based lane-departure and lane-keeping systems to identify lane boundaries. Hence, inadequate infrastructure may reduce the effectiveness of safety technology even when ADAS is functioning correctly.

Although road conditions recorded the smallest standardised coefficient, their effect remained statistically significant after controlling for other variables. This suggests that road maintenance should not be treated as a secondary issue. Previous studies have found that pavement condition, roughness, rutting, surface friction and geometric characteristics are relevant to crash outcomes (Chen et al., 2017).

The Influence of Weather Conditions on Road Accident Frequency

Weather conditions had a significant positive influence on road accident frequency, $\beta=0.240$, $p<0.001$, supporting H2. Among the environmental predictors, weather produced a stronger effect than road conditions.

Heavy rainfall can reduce visibility, increase braking distance and lower tyre-road friction. Fog and haze may reduce a driver's ability to identify hazards, while strong winds may affect vehicle stability. These conditions can also interfere with cameras, radar and other sensors used by ADAS (Malin et al., 2019).

The Malaysian driving environment makes weather especially relevant because drivers frequently experience intense rainfall and wet road surfaces. International evidence also demonstrates that accident risk varies across combinations of precipitation, temperature, road-surface condition and visibility.

The result further indicates that drivers should not assume that ADAS performs equally well under all environmental conditions. Drivers need to adjust their speed, following distance and reliance on automated assistance during heavy rain, fog or low visibility.

The Influence of Driver Factors on Road Accident Frequency

Driver factors emerged as the strongest predictor of road accident frequency, $\beta=0.389$, $p<0.001$. Thus, H4 was supported. The result indicates that speeding, distraction, fatigue, lack of attention and risk-taking behaviour continue to influence road safety despite the presence of ADAS.

The finding demonstrates that technological assistance cannot fully compensate for unsafe human behaviour. For instance, a collision-warning system may alert a distracted driver, but its effectiveness depends on whether the driver perceives the warning, understands it and responds within an appropriate period. Similarly, lane-keeping assistance may reduce unintended lane departures but cannot guarantee safety when a driver is severely fatigued or deliberately driving at an unsafe speed. (Hagl & Kouabenan (2020).

The result is consistent with research showing that inattention and distraction are important contributors to fatal crashes. It also supports research indicating that human factors remain important when assessing the safety implementation of ADAS because the systems may affect drivers' perceived control and accident probability.

CONCLUSION

This study examined the role of Advanced Driver Assistance Systems, road conditions, weather conditions and driver factors on road accident frequency among Malaysian ADAS users. Based on the proposed analysis of 370 respondents, all four determinants significantly influenced road accident frequency.

The role of ADAS demonstrated a significant negative association with road accident frequency, indicating that effective safety-assistance technologies may contribute to reducing accident frequency. In contrast, adverse road conditions, adverse weather conditions and unsafe driver factors significantly increased road accident frequency. Driver factors emerged as the strongest predictor, followed by weather conditions, ADAS and road conditions. Collectively, the variables explained 59.8% of the variance in road accident frequency.

The findings support Systems Theory by showing that road safety is shaped by the interaction of technological, environmental, infrastructural and human components. ADAS alone cannot eliminate road accidents frequency. Its safety contribution depends on appropriate driver behaviour, adequate road infrastructure and suitable operating conditions.

From a practical perspective, road safety initiatives should combine improvements in ADAS technology with driver education, infrastructure maintenance and weather-responsive safety management. Vehicle manufacturers should communicate the limitations of ADAS more clearly, while relevant agencies should increase driver awareness that ADAS supports but does not replace responsible driving.

Future studies should adopt longitudinal research designs and use objective data such as police accident records, telematics, vehicle sensor logs and actual driving exposure. Future research may also examine potential moderators such as driving experience, ADAS knowledge, trust in automation and previous accident involvement. Interaction effects between ADAS and weather or between ADAS and road conditions may provide a deeper explanation of when ADAS is most and least effective.

ACKNOWLEDGMENT

The authors would like to acknowledge and extend special gratitude to the Fakulti Pengurusan Teknologi dan Teknousahawanan, Universiti Teknikal Malaysia Melaka for the support.

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