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TRAFFIC SAFETY MANAGEMENT ON PALEMBANG-INDRALAYA TOLL ROAD

Muhammad Alfarizi, Nur IzieAdiana Abidin*

Department of Structure and Materials, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

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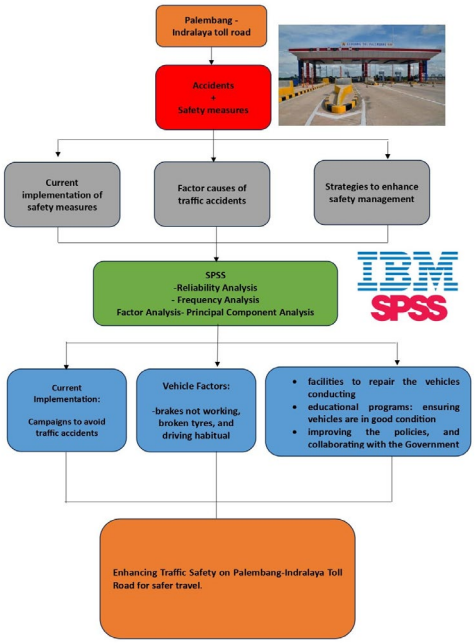
*Corresponding author
izieadiana@utm.my

Graphical abstract



Abstract

Effective traffic safety management is essential for minimizing accidents and ensuring the safety and comfort of toll road users. Despite implementing safety management measures on the Palembang-Indralaya Toll Road in Indonesia, persistent barriers continue to contribute to accidents. This paper aims to study the Traffic Safety Management on the Palembang-Indralaya Toll Road, by identifying the factors that caused an accident, the current implementation method and propose strategies to enhance the safety management in the toll road. All the information was responded to by the toll road management known as PT Hutama Karya through an online questionnaire survey. Statistical Package for the Social Science (SPSS) is used to conduct the Reliability Analysis, Frequency Analysis, and Factor Analysis of the data received from respondents. Palembang Indralaya has initiated public campaigns aimed at preventing the occurrence of traffic accidents. The predominant factor contributing to accidents is vehicle-related issues, including brake failures, broken tires, and habitual driving. Several strategies have been proposed to enhance safety management at Palembang-Indralaya, including the expansion of vehicle repair facilities, implementation of educational programs to promote vehicle maintenance practices, policy enhancements, and collaboration with the government. The multifaceted approach proposed in this study is to holistically enhance safety measures and contribute to a safer and more secure travel experience on the Palembang-Indralaya Toll Road.

Keywords: Toll Road, Traffic Accident, Safety management, Barriers, Strategies

Abstrak

Pengurusan keselamatan trafik yang berkesan adalah penting untuk mengurangkan kemalangan dan memastikan keselamatan serta keselesaan pengguna lebuhraya tol. Walaupun langkah-langkah pengurusan keselamatan telah dilaksanakan di Lebuhraya Tol Palembang-Indralaya di Indonesia, halangan yang berterusan masih menyumbang kepada kemalangan. Kertas ini bertujuan untuk mengkaji Pengurusan Keselamatan Trafik di Lebuhraya Tol Palembang-Indralaya, dengan mengenalpasti faktor-faktor yang menyebabkan kemalangan, kaedah pelaksanaan semasa, dan mencadangkan strategi untuk meningkatkan pengurusan keselamatan di lebuhraya tol tersebut. Semua maklum balas diperoleh daripada pengurusan lebuhraya yang dikenali sebagai PT Hutama Karya melalui kaji selidik soal selidik dalam talian. *Statistical Package of Social Science (SPSS)* digunakan untuk menjalankan Analisis Kebolehpercayaan, Analisis Frekuensi, dan Analisis Faktor terhadap data yang diterima daripada responden. Palembang-Indralaya telah melancarkan kempen awam bertujuan untuk mencegah kemalangan trafik. Faktor utama yang menyumbang kepada kemalangan adalah isu berkaitan kenderaan, termasuk kegagalan brek, tayar pecah, dan sikap pemanduan. Beberapa strategi telah dicadangkan untuk meningkatkan pengurusan keselamatan di Palembang-Indralaya, termasuk penambahan fasiliti membaiki kenderaan, pelaksanaan program pendidikan untuk mempromosikan amalan penyelenggaraan kenderaan, penambahbaikan dasar, dan kerjasama dengan kerajaan. Pendekatan pelbagai yang dicadangkan dalam kajian ini adalah untuk meningkatkan langkah-langkah keselamatan secara holistik dan

menyumbang kepada pengalaman perjalanan yang lebih selamat dan terjamin di Lebuhraya Tol Palembang-Indralaya.

Kata kunci: Jalan Tol, Pengurusan keselamatan, Halangan, Strategi

1.0 INTRODUCTION

Traffic accidents are a problem that occurs globally in all parts of the world. Factors causing accidents include human, vehicle, infrastructure, and environmental [1, 2, 3]. According to Liu et al. [4], based on annual traffic accident report data, there were 346 serious accidents from 2004 to 2015 caused by human factors. Besides, the cause of fatal traffic accidents is about 7.8% of cases caused by vehicle factors, with 71.7% of vehicle cases experiencing tyre bursts [1]. It has also been reported that many drivers are to blame for the occurrence of accidents on the toll road between 2018 and 2020. Cars, road network characteristics (such as geometric design, pavement surfaces, and street furniture), and the environment all have a role in traffic accidents [5].

Toll roads have a different traffic safety management system than urban or rural highways since they are designed to handle considerable traffic [5]. In Indonesia, the toll road serves as a link between locations to reduce traffic congestion, particularly in large cities. Since the toll road is designed to be a freeway with a high level of comfort and safety, Indonesian toll roads still experience a high rate of accidents [6, 7]. The records show that in a case study at Semarang Toll Road, the accident was caused by the driver being sleepy, driving too fast, a shortage of rest stops and petrol stations, and using electronic devices while driving. Others emphasized the behavioural and psychological aspects of the driver. However, the most common traffic accidents occur due to drivers speeding and driving in the wrong lane [8]. Although some regulations related to safety drive were structured, human beings often obey the rules provided [6, 9]. Furthermore, there are also vehicle factors that cause traffic accidents, such as vehicle lights failing to illuminate and brakes failing to function properly [10]. Besides human and vehicle factors, Yaacob et al. [11] found that environmental factors caused 26% of the incidence of traffic accidents. The environmental factor was weather conditions, such as foggy and rainy. Weather conditions significantly impact vehicle performance, driver visibility, driver behaviour, travel demand, traffic flow characteristics, and traffic safety [7].

An Indonesian City, Palembang, is developing, and the toll road will inevitably expand, which is expected to accommodate the projected daily traffic growth between Palembang City and Indralaya on the southwest side of Palembang City. With this toll road, the volume of vehicles will be divided and support regional economic growth and accessibility to and from Indralaya and Palembang [12]. PT Hutama Karya [13] stated that the daily traffic on the Palembang-Indralaya Toll Road was between 10,000-12,000 vehicles between January and March 2020, with traffic accidents in 16 cases. Then, during the pandemic, the Indonesian Government enacted and enforced restrictions called Large-Scale Social Restrictions and Enforcement of Community Activity Restrictions, which limited all activities during COVID-19. This impacted the modest amount of daily traffic on the Palembang-Indralaya toll road from April 2020 to November 2021. As a result, the number of vehicles using the toll road is around 4000-6000 per month. However, in December 2021, the government allowed normal activities, which had an impact on gradually returning to normal on the amount of traffic on the Palembang-Indralaya toll road. After the pandemic, from December 2021 to February 2022, the level of existing traffic began to stabilise at more than 6000 vehicles monthly using the toll road with 11 cases of accidents.

Human and vehicle factors are found to significantly affect traffic accidents on the Palembang—Indralaya Toll Road, where 55% are due to broken tyres, 27% are due to less anticipation of safety, and 18% are due to sleepiness [13]. Therefore, PT Hutama Karya, as an operator, realises the importance of implementing safety management on the toll roads to improve accidents. Besides, based on an extensive review, information about traffic safety management on toll roads in Indonesia is still limited. This study focuses on the traffic safety management of the Palembang-Indralaya Toll Road by identifying the factors that caused an accident, the current implementation method, and proposing strategies to enhance safety management. This is relevant to the government and the road authority in the development of strategies to reduce accidents, deaths, and severe injuries on a toll road.

2.0 LITERATURE REVIEW

2.1 Questionnaire-Based Investigations on Toll Road Traffic Safety

Situmorang et al. [14] employed a descriptive quantitative approach in their exploration of the Relationship between Safety and Components of the Toll Road Service. The research utilised questionnaire data collection techniques.

In a study focusing on traffic signs and safety, 200 questionnaires were distributed to participants. The questionnaire comprised two sections: the initial part aimed to gather characteristic data about the respondents, while the second, designed as a multiple-choice section, was completed to assess motorcyclists' comprehension of traffic sign meanings [15].

Suwarto et al. [16] conducted a toll road maintenance study, employing secondary and primary data collection methods. Primary data was acquired through the distribution of questionnaires to respondents who were closely located and serving as research subjects. The questionnaire encompassed inquiries about adherence to road maintenance implementation.

Adib & Shiddiqi [17] conducted a study utilizing a literature review and primary data sourced from a toll road safety questionnaire conducted in 2021. The collected data comprised 16 questions covering various aspects such as traffic

characteristics, accident numbers, vehicle class composition, causal factors investigation, accident reduction efforts, and mechanisms for handling accidents.

2.2 Safety Management of Toll Road

Traffic safety management on toll roads is complex and different from rural or urban roads [5]. The efficiency of the safety management process depends on the available information required for selecting and implementing a successful traffic safety strategy, which will lead to the improvement of the decision-making process [18]. Magfirona et al. [5] highlighted a significant gap in research regarding the traffic safety management of toll roads, emphasizing a lack of dedicated definitions for safety management in this specific context. However, Elvik and Naevesta [19] have addressed this gap by providing a comprehensive definition of traffic safety management. Their definition revolves around a safety system aimed at preventing fatal and serious injuries across all categories of road users. This approach embraces a holistic perspective on the road system, recognizing the inevitability of human errors and striving to minimise the impact of energy on the human body to levels deemed tolerable. A toll road is built with a consideration of the safety, security, and convenience of road users. The security factor can be realized with the release of a design area of criminal acts. Safety factors can be realized by the standard highway design required, including road geometric design, road furniture design, and road pavement design [20]. Based on the Act of the Republic of Indonesia number 38, in 2004, road safety was about road surface condition and geometric condition [21]. and Act of the Republic of Indonesia number 22 year 2009 regarding Traffic and Road Transportation said that traffic and road transportation safety is a condition wherein every person is escaping from accident risk while travelling [22]. Transportation service is closely related to the safety aspect of people and goods. With the guaranteed aspect of safe transport, the rights of transport users are protected, and there are no unpredictable costs that society incurs [23]. The availability of Norms, Standards, Guidelines, and Manuals related to the operation of toll roads are important references for good service infrastructure quality and toll road facilities [20].

In Palembang-Indralaya Toll Road, the current implementation of safety management is divided into infrastructure, services, and maintenance. Figure 1 shows the current infrastructures and facilities on the Palembang-Indralaya Toll Road that contribute significantly to safety management in minimising the likelihood of accidents, which includes 4 overpasses, 2 interchanges, seven bridges, 250-unit single ornament lighting lamps, 594-unit double ornament lighting lamps, 16 multi-stations, 9 single substations, 40 CCTV, 8 Variable Message Sign (VMS) cantilever 5x3 m [13]. Other than that, a Rumble Strip has been installed on the Palembang-Indralaya Toll Road in areas that are thought to be prone to sleepiness, offering a jet spray system for clearing concrete barriers and sediments. In addition, two CCTV units per kilometre, the installation of Guardrail along the road, the installation of Crash Cushions, the installation of lighting along the toll road and the addition of a Variable Message Sign (VMS) to facilitate the delivery of information to road users.

Traffic signs are elements of infrastructure used on roads, and they can be letters, numbers, symbols, words, or a combination of these that function as regulations, rules, warnings, or guides for road users [15]. Based on the Decree of the Minister of Transportation No.61 Article 1 concerning Traffic Signs, 1993, traffic signs are in the form of symbols, letters, numbers, sentences, and a combination of them as warnings, prohibitions, orders, or directions for road users [24]. Based on this explanation, traffic signs should be able to provide visual information such as driving in the right lane, avoiding obstacles, and knowing traffic conditions so that driver safety is safe and avoids accidents [25]. Thus, there is also signage information provided at the Palembang-Indralaya toll road located at the entrance gate, in the middle of the toll road, and at the exit gate as shown in Figure 2 [13]. The common warning on signage at practically entrance gates and before entering the toll road is 'don't be sleepy' and 'pay attention while driving'.

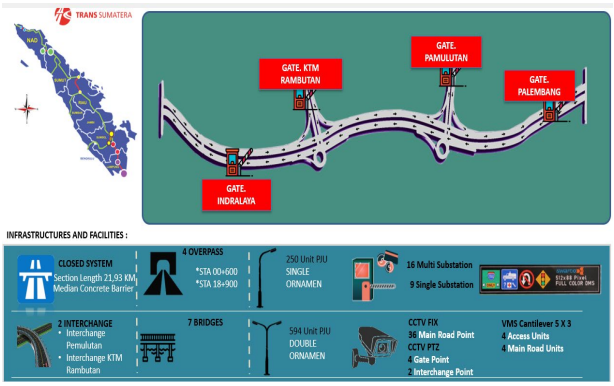


Figure 1 Infrastructures and Facilities on Palembang-Indralaya Toll Road
Source: PT Hutama Karya

Figure 2 Barriers and VMS on Palembang-Indralaya Toll Road
Source: PT Hutama Karya

Other than infrastructure, service operations are an essential part of the successful management of toll road operations as they support the quality of product provision and customer service. According to Rao [26], services operations cover a broad range of tasks and procedures in the areas of operations and maintenance, traffic safety, customer service, technology management, public relations and marketing, financial services and commercialisation, human resources, and asset management. Government Regulation No. 392/2005 added the substance regarding service units for help/rescue and relief services [27]. According to PT Hutama Karya [13], the operation service staff consists of 136 persons and is divided into several parts. Then, the police department consisted of 10 persons, and the paramedic staff consisted of 4 persons. Besides, there is also the role of operators responsible for conducting public

campaigns on social media and the Health and Safety team to check and give information to drivers.

Elements of maintenance are also essential for maintaining a safe, effective transportation system as well as protecting the nation's multibillion-dollar investment in its road system [28(16)]. Maintenance includes tasks such as monitoring the condition of the road and any related facilities as well as doing maintenance, repair, and rehabilitation [29]. The Palembang-Indralaya toll road's subgrade is made up of very soft soil, with an N-SPT value of 10 and a soft soil depth of 16.95 m. Due to the subgrade's low bearing capacity and low permeability, it must be improved using the preloading method to boost the subgrade's carrying capacity. The bearing capacity of the subgrade is a pivotal element influencing the stability and safety of the road. If the subgrade possesses inadequate bearing capacity, it can result in settlement problems, giving rise to irregular road surfaces, potholes, and conditions that may pose hazards for drivers. Therefore, road maintenance on the Palembang-Indralaya Toll Road is repaired quickly using a cold mix and patching. In the case that damage is discovered, repairs are made immediately. Additionally, audits and regular maintenance usually appear every six months [13].

2.3 Factor Causes of Traffic Accidents

The factors that cause accidents are not only influenced by one specific cause but are a result of many interacting factors. Most of the classification of accident cases merely focuses on errors and actions that lead to some conflict [30]. Therefore, there are categorisations of factors made by previous research such as Lin et al. [2], which mentioned that accidents are caused by the vehicle, road, and environmental conditions. While Mphekgwana [3] also agreed that the factors of accidents are vehicle, road, and environment, with the addition of human factors, Colagnerade [29] added that it is well-known the causes of traffic accidents rely on the interrelated factors of humans, vehicles, the environment, and the road infrastructure. Further, it is estimated that 80% of traffic accidents are mainly caused by human error, 20% are due to vehicles, and the remainder are attributable to the road and environment. Therefore, this research will categorise the factors that cause accidents into human, vehicle, road, and environment, which will be useful in finding the causes of toll-road accidents in Palembang-Indralaya. Table 1 shows a literature summary of previous research on the factors causing traffic accidents, which led to the categorization of this paper as human, vehicle, road, and environment.

Table 1 Summary of previous research on the factors that cause traffic accidents.

Author	Human	Vehicle	Road	Environment
[2]		*	*	*
[3]	*	*	*	*
[7]				*
[10]		*		
[29]			*	
[30]	*			
[31]	*			
[32]	*		*	
[33]		*	*	
[34]			*	
[35]			*	

2.3.1 Human Factors

Most safety studies show that the human factor is the most common cause of accidents [30]. The number of traffic accidents is mostly determined by how a driver habitually drives and the style of the driver chooses to drive [31]. The driving behaviour of every driver differs and is generally defined and shaped by many factors, including human personality traits, time of day, and place of driving. Furthermore, drivers are forced to take particular drugs due to age or physical sickness, which might impair their cognition and cause complications while driving. Some medicines can impair drivers' ability to respond to auditory and visual inputs; other disorders limit their ability to do so, resulting in tragic accidents [32]. Besides, the factors of young human drivers such as lack of skills, inexperience, and risk taker behaviour are the main contributing factors to road collisions, while the older human drivers are due to visual, mobility impairments, and cognitive impairments. Additionally, there are also other several aspects of humans such as carelessly changing lanes without using a signal, being unable to follow the recommended distance between cars, blind spots, and wrongly estimating the velocities of other vehicles [31].

2.3.2 Vehicle Factors

The most common causes of vehicle factors are broken tyres, brakes not working well, metal melts resulting in broken vehicle parts, worn-out equipment that is not replaced, and various other causes [10]. Additionally, Dwi [33] also supported that the factors of the vehicle causing the accidents are broken brakes and the vehicle's lights do not turn on. Broken brakes are frequently caused by a lack of monitoring and maintenance. Then, broken tyres are normally caused by sharp stones, nails, or items puncturing the tyre. The vehicle’s light signals are usually caused when the directional indicator light does not turn on when turning, causing the vehicle behind it to be unaware that the vehicle in front of it will turn.

2.3.3 Road Factors

The Road is a crucial mode of transportation, but it is one of the factors that cause traffic crashes on toll roads [34]. Serious accidents could happen due to any road surface or structure defect [32]. Dwi [33] mentioned that accidents caused by road factors are due to road conditions, potholes, slippery roads, unsmooth road surfaces due to unpaved roads, roads with rock, and asphalt roads that have been damaged. Potholes are normally caused by an inadequate coating system where the drivers attempt to avoid them but eventually turn into an accident. While, slippery roads are generally caused by rainwater, and accidents happen when smooth surfaces meet the slippery road, and there is no friction between tyres and the road. According to the National Highway Traffic Safety Administration, other common road factors that contribute to accidents include poor road design, insufficient or poorly maintained signage, road construction, and weather conditions [35].

2.3.4 Environment Factors

Environmental factors will have a role in traffic accidents due to fog and rain. Rainy weather is a common cause of accidents since

the road conditions become wet and slick when it rains [7]. Inadequate road conditions can lead to decreased driver comfort, affecting the vehicle's control ability [7]. The effect of accident severity of single vehicles due to the environment can be investigated from rainfall intensity, temperature, wind speed, wind direction, water film depth, the distance between cars at the time of the crash, and stopping sight distance [3].

2.4 Strategies to Enhance Safety Management

Various strategies can enhance the implementation of safety management on toll roads, including human, financial, government, and infrastructure. Table 2 shows the summary of the categorization based on a critical review conducted on previous research.

Table 2 Summary of Strategies to Enhance Safety Management

Author	Human	Financial	Government	Infrastructure
[5]				*
[8]		*		
[18]			*	
[32]	*			
[36]	*			*
[37]	*			
[38]		*		
[39]		*		
[40]			*	
[41]			*	

2.4.1 Human

Driver awareness is very important when driving their vehicle; preparations such as being in good health, not taking drugs, or getting drunk must be considered before using their vehicle. According to [32], the effect of drug consumption showed that the drivers who injected insulin had more chance of accident occurrence, but the difference was not significant. Therefore, regular road safety conversations should also be held in various community forums to raise public awareness of the issue. Massive public awareness campaigns can be carried out in national and local newspapers, television, radio, or social media. The awareness encourages drivers to drive slowly and carefully to avoid road crashes and wear seatbelts. The horrific effects of the disaster were broadcast on the radio and television, and people were urged to prevent traffic accidents [36]. In Malaysia, road safety promotion is implemented at federal and state levels mainly through media campaigns, advertisements, and the education syllabus in Schools, based on the strategies formulated in the current Road Safety Plan of Malaysia (RSPM) and Zero Fatality Vision [37].

2.4.2 Financial

As safety management requires higher investment costs, incentives are much needed for the operator to overcome the financial constraint in terms of maintaining road facilities well. Road privatization may offer additional benefits in addition to supplementing public funding. For example, the lack of competition in the public sector may limit the public sector's incentives to perform efficiently [38]. In addition, the greater level of collaboration between the Government would change the Government's perspective towards safety management on the toll road. Governments should better understand their critical role in toll road safety management, such as providing proper financial support. The Government supports improving traffic safety, and private-public partnerships appear to be one of the most significant contributors to the success of such initiatives [8]. Furthermore, establishing toll pricing is one of the Risk Management Plans that must be carried out. In [39], road pricing allows for estimating and implementing tolls for short- and long-term planning purposes. Existing empirical evidence suggests that road pricing reduces vehicle demand and externalities, making it possible to attain socially optimal equilibriums or, at the very least, equilibriums that are close to the social optimum.

2.4.3 Government

The policies should clearly state and attach a commitment from the top management regarding the goals to be accomplished. The governments and road authorities need to identify affordable solutions. According to Fuentes et al. [40], the analysis considers infrastructure financing policies (exogenous constraints in the optimization model), such as full government financing, zero financing (toll revenues fund 100% of the costs), or partial financing (a mix of government resources and toll revenues). The model's objective is to maximize social welfare, assuming that the daily demand is constant. As a result, user options are limited by the amount of time they have to travel and this decision is factored into the optimization problem using a stochastic discrete choice model.

The legislation establishes a framework for regulating and controlling health and safety. Legislation with Public-Private Partnerships should be strengthened and appropriately implemented. In addition, management must strictly adhere to the rules and regulations, with appropriate penalties meted out to those who break them [41]. If speed-related legislation is adopted, there will be a major influence on lowering fatalities and injuries. The value of safety equipment like motorcycle helmets, seat belts, and child restraints is similarly proportional to the level of risk [18].

2.4.4 Infrastructure

The safety of road users, particularly during maintenance and construction work, is one of the most critical elements to consider on a road construction site. For safe driving, the placement of better signage on the roadways and billboards will help alert the users [36]. Furthermore, road infrastructure safety management procedures help find cost-effective safety-oriented solutions during all road infrastructure life cycle stages. Besides, Road safety audits are part of a traffic prevention strategy that improves the condition of buildings, complementary buildings, and road support facilities through a comprehensive, systematic, and independent road inspection concept [5].

3.0 METHODOLOGY

A comprehensive literature review was carried out to identify the factors that caused accidents, current application methods, barriers, and strategies of implementation by operator management of toll roads to increase safety management on the Palembang-Indralaya Toll Road. This extensive literature review has somehow concluded with the identification of eighteen (18) factors that caused accidents, eight (8) types of the current implementation, and seven (17) strategies in the implementation of safety management on a toll road.

Before collecting the actual data, a preliminary survey was conducted to determine the questions' time, cost and feasibility. Respondents were also required to add any information that would enhance the questionnaire. The preliminary survey engages with stakeholders, such as toll road operators, safety officers, and relevant authorities. These stakeholders can offer insights into their perspectives, concerns, and experiences related to traffic safety on the toll road. The researcher was required to make necessary amendments based on the suggestions and opinions given by the respondents. Additionally, a reliability analysis was conducted to ensure the consistency and dependability of the survey questions. This process helps ensure that the data collected is reliable and can be confidently used to draw meaningful conclusions in the study. Afterwards, the actual data collection process is conducted, where the data is collected from the online questionnaire survey. Four sections were involved in this questionnaire: demographic information, the current implementation method of safety management on a toll road, factors that caused accidents on the toll road of Palembang-Indralaya, and finally, proposed strategies to improve safety management on toll roads. The questions are formed using the Likert scale, and the respondents will be required to rate each question according to the agreement level with a scale point between '1' and '5'. The targeted respondents are the Traffic Management and Maintenance Manager, HSE Officer, Patrol Supervisor, Service Operation, and Paramedic from PT Hutama Karya.

The data obtained were analyzed using the software Statistical Package for the Social Science (SPSS) to conduct the Reliability Analysis initially. In this paper, since all questions are assessed by using the Likert scale with five points, Cronbach's alpha coefficient test, α, was used to measure the internal consistency under the adopted scale of the data measurement. Besides, Cronbach's alpha was also used to assess the reliability of the data for further analyses. According to Nawi et al. [42]], Cronbach's alpha coefficient ranges from 0 to +1. An acceptable value of Cronbach's alpha is 0.7, while 0.8 indicates good internal consistency, and 0.9 is excellent. Then, a frequency analysis was conducted to analyze the demographic information, and a factor analysis was used as a method to prioritise the data for the current implementation, factor causes of accidents, and strategies to enhance safety management. The Principal Component Analysis (PCA) with Varimax rotation was used as a rotational and extraction method. According to Costello and Osborne [43], PCA helps to produce an empirical summary of data, while Varimax simplifies the data, enabling it to be read and reported easily since it will maximise the item from high loading to low loading. There are several protocols to conduct PCA, such as the Kaiser-Meyer-Olkin index (KMO ≥0.50) and Bartlett's test of sphericity ($p < 0.05$). Lastly, Factor Loading (FL) will be selected in which, according to Pallant [44], the item with 0.50 and higher will be retained. A conclusion is drawn to synthesize key findings and provide comprehensive insights into safety management in Palembang Indralaya. Figure 3 illustrates the comprehensive research process undertaken in this study.

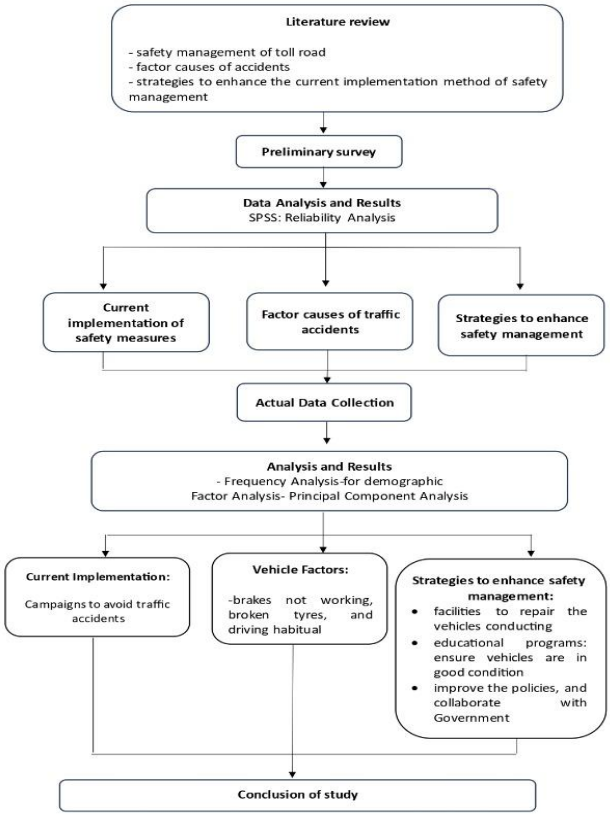


Figure 3 Research Process

4.0 RESULTS AND DISCUSSION

4.1 Demographic Information

The online survey form was opened for one (1) month, and a total of forty (40) response data were successfully collected within this period, representing the total staff in PT Hutama Karya. The 40 stakeholders identified represent a stratified sample of subject matter experts actively engaged in toll road operation management. This group encompasses toll booth operators, safety officers, and other managerial staff. The selection process for these experts is guided by recommendations from PT Hutama Karya, ensuring that the chosen individuals possess pertinent expertise and insights in line with the study's objectives.

The result of the demographic information of respondents' designation and years of working experience is shown in Figure 4 and Figure 5. Most respondents, representing 30% of the total sample, are from Service Operations, 20% are HSE Officers and Patrol Supervisors, 18% are paramedics, 10% responses are from Traffic Management and Maintenance Management, and 3% of responses are from Managers. For the respondents' years of experience working, the calculated proportion shows that 42% of respondents worked for 1-5 years. Then, 41% of respondents

had work 6-10 years of experience, while 17% had 11-15 years of work experience.

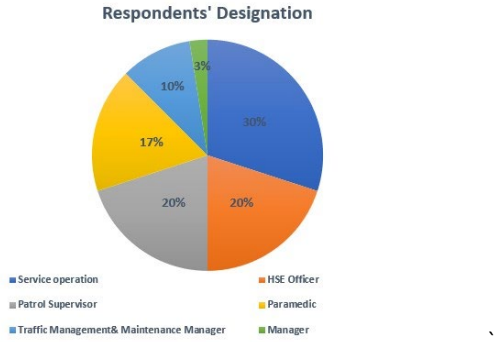


Figure 4 Designation of respondents'

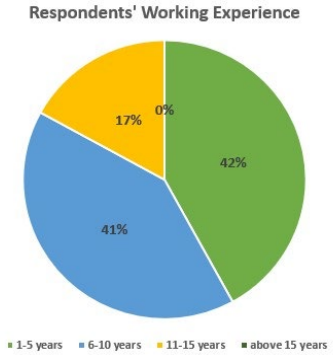


Figure 5 Respondents' Working Experience

4.2 Reliability Analysis

The results of the reliability statistics analysis are shown in Table 3. Each section's Cronbach's Alpha value was achieved to be greater than 0.7, which indicates that the data collected for this study is acceptable and has a higher level of reliability in the internal consistency. The Cronbach's Alpha coefficient value shows a high reliability of 0.900 for the current implementation of method of safety management, 0.748 for factor causes of accidents and 0.952 for strategies to enhance safety management. Then, the corrected item-total correlation values of 0.460, 0.580, and 0.530 all exceed the threshold of 0.300, implying that each item is sufficiently contributing to the overall reliability and internal consistency of the scale.

Table 3 Reliability Statistics

Section	Reliability Analysis		
	Cronbach Alpha's	Corrected Item – Total Correlation	N of Items
Current implementation method of safety management	0.900	0.460	8
Factor causes of accidents	0.748	0.580	18
Strategies to enhance safety management	0.952	0.530	17

4.3 Current Implementation Method Of Safety Management On Palembang-Indralaya Toll Road

The PCA results offer valuable insights into the current safety management methods implemented on the Palembang-Indralaya Toll Road. The KMO measure was 0.75, indicating a suitable level of correlations among the variables, suggesting that the dataset was appropriate for factor analysis. The Bartlett's Test had achieved a significance level (Sig) of $p < 0.001$, indicating that the data was suitable for PCA. The analysis showed that the principal components explained a cumulative variance of 72%. This sufficiently represents the main underlying patterns of the dataset.

Considering the results from factor loading as shown in Figure 6, among eight (8) current implementation methods, the public campaign ranked as the top method with an FL of 0.777. Public campaigns can be carried out on social media as the simplest method to give reminders to prevent accidents [45]. A public campaign is a proactive endeavour to raise awareness and educate people on potential hazards and how to prevent them. Signage information is the second-highest implementation method, with an FL of 0.732. Toll road guidance signage typically uses text, visuals, or a combination of the two. The information on the signage's design and layout has an impact on how effectively drivers can gather information [46]. Signage on the Palembang-Indralaya toll road provides information on potential hazards using simple language and images and is easily visible from a distance. Meanwhile, well-implemented rest areas and safety facilities were achieved with the same FL of 0.722. Currently, the rest area of Palembang-Indralaya Toll Road is provided with several checkpoints with facilities to allow users to rest from their trips. The services that have been provided include a café, parking area, bathroom, prayer room, tyre repair, and ambulance. In terms of safety facilities, Palembang-Indralaya toll road has provided users with an emergency parking bay and escape shelter. Meanwhile, the infrastructure and service for users is the next implemented safety management, achieving the same FL of 0.696. Users need services that are worth what they pay. Thus, performance goals have been set for adopting innovative services, including user safety, incident management, road maintenance, and electronic tolling for overall commuters' satisfaction [28]. Regarding road maintenance and maintenance services, respondents agree that it has been well provided, with FL achieving 0.680 and 0.673. According to PT Hutama Karya [13], road maintenance on the Palembang-Indralaya Toll Road is repaired quickly using a cold mix and patching. Additionally, audits and regular maintenance usually appear every six months.

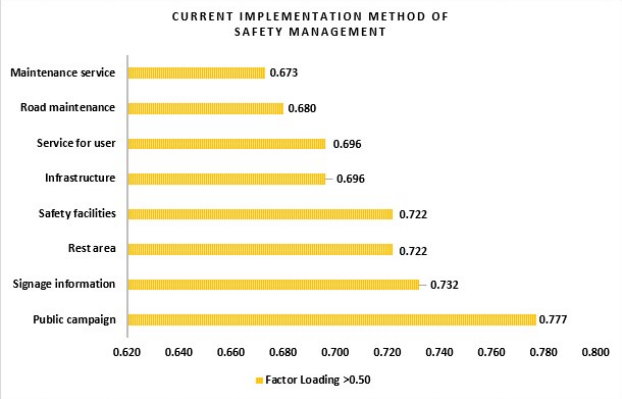


Figure 6 Current Implementation Method of Safety Management

4.4 Factor causes of accidents in Palembang-Indralaya Toll Road

Given the KMO value of 0.72 and the significant results from Bartlett's Test ($p < 0.001$), the dataset was suitable for PCA. The total explained variance of 68% suggests that these factors encapsulate the core reasons behind the accidents on the Palembang-Indralaya Toll Road.

The results for the factors that caused accidents on the Palembang-Indralaya Toll Road are illustrated in Figure 7. Meanwhile, Figure 8 shows the most common factors that caused accidents, which are categorized based on vehicle, human, road, and environment. Vehicle Factors were the highest factor that caused accidents, with a FL of 0.773. These findings align with a growing body of research emphasizing vehicle factors' importance in accident causation. Mohamed et al. [47] highlighted that the factors that cause accidents vary in different contexts, where vehicle-related factors play a significant role in road traffic accidents. For example, India identifies their country's primary cause of accidents as mechanical vehicle failures. In Tanzania, road traffic accidents are mainly caused by vehicle age, poor service conditions and vehicle maintenance. Therefore, it is recommended to have specific measures to overcome the causes of vehicles. In addition, it is also crucial to recognise that accidents often result from the complex interaction between human and vehicle-related elements. Future research could also explore how these factors intersect and influence the accidents. A study also explored by Ventaktesh Raja et al. [48], on road traffic accidents, where participants observed either autonomous vehicles or human-driven vehicles. The initial investigation revealed that in five out of six scenarios with identical antecedents and outcomes to those involving human drivers, autonomous vehicles were more likely to be assigned blame and less likely to be trusted.

Most of the respondents indicated that accidents under vehicle factors are brakes not working, followed by a broken tyre, with a factor loading of 0.710 and 0.706, respectively. This is supported by [3], which states that the top two most significant causes of vehicle crashes on the road are worn-out tyres and brakes. The next cause of accidents is due to broken vehicle parts, vehicle light conditions, and worn-out vehicle equipment, with an FL of 0.683, 0.634, and 0.620, respectively. Broken vehicle parts, such as suspension systems and steering components, can lead to impaired performance and handling, longer stopping, and increased collision risk. Inadequate lighting, such as dimmable or non-functional, will impair the driver's ability to see confusing drivers on the roads, which increases the likelihood of accidents.

Human Factors were ranked as the second factor that caused accidents on the Palembang- Indralaya Toll Road with an FL of 0.764. The highest cause of accidents by human factor is driving habit with an FL of 0.708, followed by human behaviour. Driving habits, according to Sheykhfard and Haghihi [49], are related to how familiar the drivers are when driving under special conditions such as in the rain, at night, in peak hours, on unfamiliar roads, and lastly, the response towards road signs and traffic signals. Apart from habit, Chu et al. [30] mentioned that violations and errors were both labelled as bad behaviours, which has been justified in the main of traffic safety. Errors are unexpected behaviours that are classified as slips or lapses based on the error's potential consequences. Then, human personality traits are the third agreed factor with an FL of 0602. This is because driving skills are influenced by the attitudes and personalities of the driver since different drivers have different driving styles 18.

Next is physical sickness with FL 0.581. According to Bucsuhazy et al. [28], physical sickness is much more related to older people or to ageing conditions that affect cognitive and psychomotor function and changes in involutional. While age is the last factor that contributes to accidents with FL 0.574. According to Gomes-Franco and Rivera-Izquierdo [50] [36], it has been widely highlighted that younger and older drivers have a high risk of causing traffic accidents due to risky driving behaviour and age-related loss of capabilities.

Road factor, with an FL of 0.733, ranked as the third factor that caused accidents. Serious accidents could happen due to any road surface or structure defect [29]. The most common accidents caused by road factors were due to potholes and damaged asphalt, with FL of 0.684 and 0.673, respectively. When all other factors are equal, driving on a road with potholes and damaged asphalt increases the probability of a serious accident by 2.59 times compared to driving on a road with animals' presence [3]. Additionally, the slippery road contributed to the third highest cause of accidents, followed by the unpaved road, with each FL being 0.680 and 0.624, respectively. Vehicle crashes on poor or defective road surfaces were more likely to result in death and serious injuries [3].

The environmental factor achieved an FL of 0.688, which is rated as the last factor that caused accidents on the Palembang-Indralaya Toll Road. The most common factor caused by environmental is weather conditions, with an FL of 0.680, followed by thick fog with an FL of 0.661. Bad road weather conditions, such as heavy rain, increase the possibility of accidents. The risk of an accident increases when driving in bad weather because it impairs the driver's sight and the traction of the vehicle [3]. Other than that, haze due to open burning and ground shift also contributed to the causes of accidents in Palembang-Indralaya, with each FL at 0.574 and 0.549, respectively. In Indonesia, open burning is a yearly activity that has greatly reduced the driver's visibility and led to multiple accidents and high rates of casualty. Other than that, the natural disasters in Indonesia also caused unstable ground conditions on roads, occasionally influencing crashes at certain locations [9].

Overall, the analysis of accident factors on the Palembang-Indralaya Toll Road highlights that vehicle-related issues,

particularly worn-out brakes and tyres, are the most significant contributors to accidents. This underscores the critical need for robust vehicle maintenance and inspection practices to ensure roadworthiness.

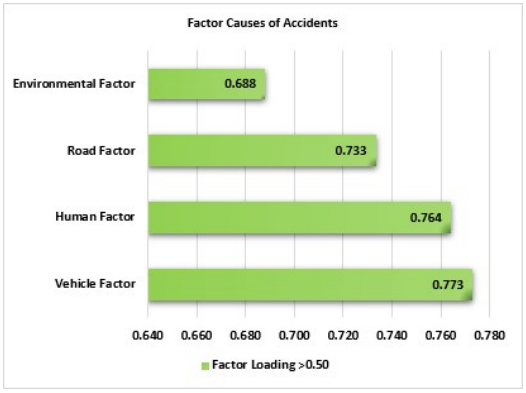


Figure 7 Factor Causes of Accidents

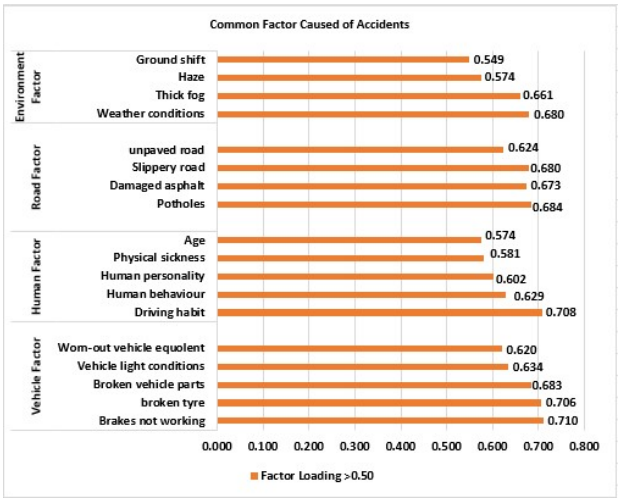


Figure 8 Common Factor Caused of Accidents

4.5 Strategies to Enhance the Current Implementation Method of Safety Management in Palembang-Indralaya Toll Road

In this last section, respondents were asked to choose and rate the strategies to enhance the current implementation method of safety management in Palembang-Indralaya Toll Road that can help overcome the barriers, as illustrated in Figure 9. The significant results from Bartlett's Test ($p < 0.001$) and the KMO measure (0.730) confirm the data's suitability for PCA, validating the analysis. Figure 10 presents the details of the strategies for each infrastructure, human, government, and financial. Among four (4) potential strategies to enhance the current implementation method of safety management, infrastructure strategies were ranked as the top-ranked strategies with a factor loading of 0.745. With these findings, infrastructure strategies should be prioritized for further safety enhancements. The agreed strategies under infrastructure consist of improvement of existing facilities (FL=0.720), road infrastructure procedures (FL=0.715), road safety audit (FL=0.710), and placement of better signage (FL=0.708). Improvement of existing facilities is to ensure that users have access to high-quality road infrastructure as well as other amenities, with an emphasis on strengthening safety measures [28]. Improved road infrastructure facilities also enable users of the area to access fundamental amenities, such as rest areas, service stations, emergency response services and others [51]. Besides, road safety audits are part of a traffic prevention strategy to improve the condition of buildings, complementary buildings, and road support facilities through a comprehensive, systematic, and independent road inspection concept [3]. Vehicle-related factors such as worn-out brakes, broken tyres, and defective vehicle parts are major contributors to accidents. Infrastructure strategies play a crucial role in mitigating these risks. By improving road infrastructure, repairing potholes, and maintaining road surfaces, accidents caused by mechanical failures or poor vehicle handling can be reduced. Infrastructure also includes the installation of better signage, road lighting, and safety barriers, which contribute to minimizing vehicle-related accidents.

Other than that, human strategies, with a FL of 0.734, were ranked as the second strategies to improve. The educational program, awareness, and publicity campaign strategies under human earned an average score with an FL of 0.710, 0.708, and 0,688, respectively. To prevent teenage drivers from engaging in risky driving behaviours like speeding and using a phone while driving, educational programs that empower peer passengers to "speak up" against risky driving may be helpful [34]. Furthermore, awareness and campaigns should be given on the preparation of vehicles, such as ensuring the vehicle is in good condition and not taking drugs or alcohol [36]Accidents due to human factors, including driving habits, behaviour, and errors, can be addressed by these human strategies, which focus on driver education, enforcement of traffic rules, and campaigns to promote safe driving behaviours. These strategies align with the human factors identified in the study, as they aim to reduce risky driving habits and improve adherence to road signs and traffic signals.

Government strategies were ranked in the third position with a FL of 0.628. The strategies consisting of improving policies, providing affordable resources, and effective legislation had an FL of 0.610, 0.604, and 0.598. The government should develop comprehensive National Road Safety Plans that have specific goals and targets to reduce accidents over a defined period. The essence of policy may include speed limit enforcements and proper safety road design that minimize a potential collision. In terms of affordable resource strategies, according to Wang *et al.* [52], depending if the government requires a particular level of service quality, funding and incentive methods can increase the quality of asset services compared to the situation where there is a lack of incentive for quality. Any incentive plan may result in a higher toll payment, but the private party will guarantee better performance than under a contract with no incentives. Lastly, effective legislation may be provided by the Government that consists of traffic laws and legislation, penalties, enforcement mechanisms for unsafe behaviour, and a graduated license system. Government involvement is able to directly address the road factors contributing to accidents, which is essential to ensure road safety regulations are implemented effectively. Road factors such as potholes, damaged asphalt, and slippery roads require government oversight to ensure proper maintenance and safety standards.

Financial strategies ranked fourth important strategy with an FL of 0.525; collaborating with the Government (FL= 0.514), risk management plan (FL=0.505), and providing financial incentives (FL=0.504) are among the agreed strategies. Engaging with relevant stakeholders, such as government agencies, is crucial to collecting comprehensive data to understand their perspectives, concerns, and goals for toll road safety. Additionally, the related company may benchmark with the government to consistently meet safety standards. Besides, creating risk management to improve toll road safety can be conducted by identifying the potential risk, assessing the impact of risk and the likelihood, and outlining the strategies to mitigate and manage the risk. Lastly, implementing financial incentives can be an effective strategy to encourage the relevant stakeholders to prioritise safety enhancement on the toll road. Financial strategies can be at the forefront of efforts to mitigate environmental factors that contribute to accidents, such as adverse weather conditions and thick fog. These strategies entail dedicating resources to road maintenance, safety inspections, and emergency response systems. Investing in weather-resistant road materials, enhanced drainage systems, and better lighting can substantially reduce the risks posed by environmental conditions.

In conclusion, the infrastructure strategy is the most influential factor for enhancing safety on the Palembang-Indralaya Toll Road. This strategy focuses on improving road conditions through enhanced road infrastructure, road safety audits, and better signage, which significantly reduces accidents caused by poor road maintenance or unsafe road features. By addressing these key elements, infrastructure strategies create a safer driving environment and form the foundation of an effective safety management system.

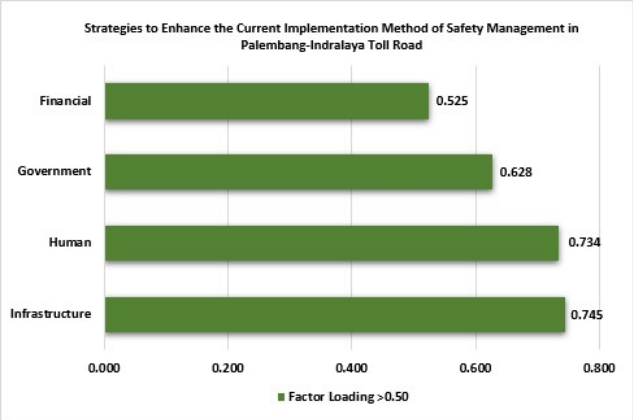


Figure 9 Strategies to Enhance the Current Implementation Method of Safety Management in Palembang-Indralaya Toll Road

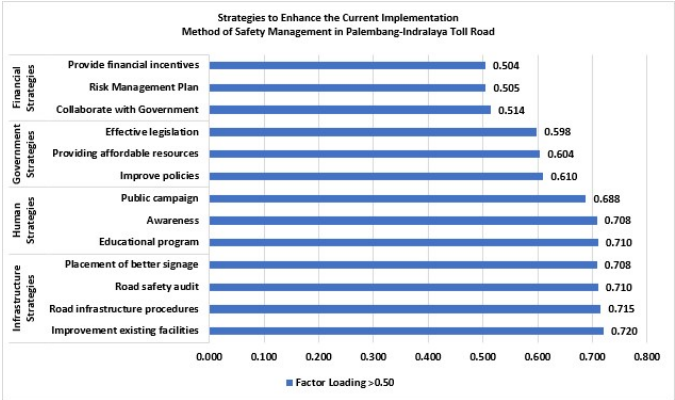


Figure 10 Strategies to Enhance the Current Implementation Method of Safety Management in Palembang-Indralaya Toll Road

5.0 CONCLUSION

In conclusion, this study has centred its efforts on examining the safety management practices employed on the Palembang-Indralaya Toll Road. In the analysis of current implementation methods for safety management on the Palembang-Indralaya Toll Road, public campaigns emerged as the highest priority with a factor loading of 0.777. This indicates that raising public awareness through various campaigns, especially social media, is key in promoting safer driving practices. This study also explored the factors causing accidents on the Palembang-Indralaya Toll Road. Vehicle-related factors were identified as the most significant contributors to accidents, with a factor loading of 0.773. Common issues included brakes not working properly, broken tyres, and other mechanical failures. This highlights the need for regular vehicle maintenance and inspections to ensure roadworthiness.

Afterwards, this study found that among the safety management practices on the Palembang-Indralaya Toll Road, infrastructure strategies emerged as the most influential, with a factor loading of 0.745. Specifically, the key components within this category include improving the existing facilities, improved road infrastructure procedures, road safety audits and better signage. This finding is crucial for road authorities and policymakers aiming to enhance road safety.

In addition to the key findings, it is essential to acknowledge the limitations of this research. One limitation is that the study focused on a single toll road, which might not fully capture the diversity of road safety issues in other regions or different types of toll roads. Additionally, the data collection was limited to a specific timeframe, potentially affecting the generalizability of the results.

Given these limitations, future research should aim to expand the scope by including multiple toll roads across different regions. This broader approach would provide a more comprehensive understanding of safety management practices and their effectiveness. Moreover, future studies should consider a longitudinal approach to capture changes over time and understand how safety management practices evolve.

In conclusion, the findings and insights derived from this investigation hold significant relevance for both governmental bodies and road authorities. The study aims to contribute valuable information to aid in formulating strategies geared

towards mitigating accidents, minimising fatalities, and reducing severe injuries on toll roads. Through a comprehensive analysis of safety management, the research endeavours to provide actionable recommendations that align with the overarching goal of enhancing the safety and well-being of toll road users.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

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