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# Examining the relationship between road service quality and road traffic accidents: a case study on an expressway in Malaysia

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**Abstract:** Malaysia's economic prosperity is overshadowed by a concerning rate of 19 daily road fatalities. This study aimed to investigate road users' perceptions of road service quality (RSQ) and its association with road traffic accidents (RTAs) on an expressway in Malaysia. A questionnaire-based approach collected data from respondents comprising bikers, motorists, bus operators, and truck drivers. Descriptive analysis indicated that, except for motorcyclists, most road user groups rated the overall RSQ of the expressway as poor. Statistical analysis revealed significant variations in perceptions of road surface among road user categories. Pearson correlation analysis demonstrated strong positive relationships between road surface, road drainage, road maintenance, and RTAs. No significant relationships were found between road furniture, rest areas, and RTAs. Multiple regression analysis revealed that road maintenance, road surface, and road drainage accounted for 7.6% of the variance in RTAs, highlighting their importance as predictors. The Relative Importance Index analysis identified ten influential factors on RTAs, including permanent wave, poor workmanship, water pounding, road settlement, repeated construction, invisible road markings, insufficient traffic signs, potholes and bumps, insufficient street lighting, and oily road surfaces. These findings provide policymakers with valuable insights to enhance road safety regulations and develop effective strategies for improving RSQ and reducing RTAs.

**Keywords:** Malaysia, road service quality (RSQ), road traffic accidents (RTA), user perception

## 1 Introduction

Road networks are often referred to as the 'lifeline' for national economic growth (Berg et al., 2015), as they facilitate the free flow of products, services, and people, contributing to the development of economically stagnant areas (Mohmand et al., 2017). Additionally, roads play a crucial role in connecting various modes of transportation, including airports, train stations, and ports, thereby enhancing accessibility and promoting national integration in Malaysia, a multi-racial developing country (Othman et al., 2016; Anor et al., 2012). However, the reliability of roads in Malaysia, from the perspective of the public, is hindered by the high occurrence of road traffic accidents (RTAs) and related fatalities and injuries (Hamid et al., 2023). In fact, RTAs rank as the country's fourth highest cause of death overall, with the number of fatal and nonfatal accidents on the rise (Pillary et al., 2022). RTAs have emerged as a significant public health concern and an obstacle to national prosperity, both in emerging and wealthy nations (Samsuddin & Masirin, 2016). Therefore, it is imperative to provide a safe and efficient road network with a high level of service, as RTAs have a detrimental impact on public health and the economy (Tehrani et al., 2015).

RTAs are responsible for a significant number of deaths and injuries worldwide each year (WHO, 2015). In Malaysia, the Ministry of Transport reports an average of 19 deaths per day due to RTAs (2014). Despite efforts to enhance roadway safety, the rate of RTAs continues to increase (ASEAN, 2016). Therefore, comprehending the root causes of RTAs is crucial for developing effective preventative measures. Despite previous research on RTAs, there has been a notable lack of focus on roadway factors (Bhatti et al., 2010; Chen, 2010; Amedorme & Nsoh, 2014; Belwal et al., 2015; Mohanty & Gupta, 2015; Kelarestaghi et al., 2017; Adanu & Jones, 2017; Bokaba et al., 2022). Understanding how different aspects of roads influence RTA rates is crucial for effective preventative initiatives (Infante et al., 2023). While previous studies have primarily concentrated on human factors, highway factors have been overlooked. Besides, research has shown that various road management systems, including safety management systems, may complement one another (Cafiso et al., 2021; Putrajaya, 2006). Thus, this research aims to contribute to the existing body of knowledge by investigating the connection between RSQ and RTAs from the perspective of drivers. The study investigates drivers' perceptions of RSQ, its correlation with RTAs, and its ability to predict RTAs. Research questions, thus, are: *(1)* What is the perception of drivers regarding RSQ, including road surface, drainage, furniture, rest areas, and maintenance? *(2)* Is there a correlation between the level of RSQ and the occurrence of RTAs? *(3)* Can RTAs be predicted based on the RSQ?

By analyzing drivers' perspectives on RSQ in Malaysia, this study aims to enhance our understanding of the causes of RTAs and guide industry professionals and legislators towards effective solutions. Evaluating the quality of road services through the lens of road users is essential, as they are critical stakeholders in any road system (Zeithaml et al., 1990). The results of this investigation will be valuable to policymakers, industry practitioners, and researchers seeking to implement better road safety measures. Furthermore, the findings of this study have the potential to deepen our knowledge of RTAs in Malaysia and other developing nations, enabling more effective efforts to address this significant public health concern. Ultimately, this research aims to shed light on the factors contributing to RTAs in Malaysia and aid in the development of effective preventative policies.

## 2 Literature review

### 2.1 Role of road infrastructure in economic development: empirical evidence and global perspectives

Investment in road infrastructure has long been recognized as a crucial driver of economic expansion due to its ability to strengthen economic chains, accelerate development, and support regional growth objectives (Crescenzi et al., 2016; Magazzino & Mele, 2021). Improved economic growth, increased productivity, job creation, and enhanced well-being for local residents are positive outcomes of road infrastructure investments (Porter, 2014; Hlotywa & Ndaguba, 2017; Sun et al., 2018). Consquently, the total length of paved roadways in a country is often used as a measure of its development level (Aldagheiri, 2009). Leung (2006) demonstrates the multiple ways in which investments in road infrastructure contribute to economic growth and societal well-being, as depicted in Figure 1.

The relationship between road infrastructure and economic change is influenced by various factors, including the competitive structure of regional markets, technological and institutional shifts in transport, communications, and production systems, as well as the overall condition of the transport network (Lakshmanan & Chatterjee, 205). Table 1 categorizes the impacts of transport infrastructure upgrades based on time (short-term, long-term) and space (local, regional, global) as classified by Lakshmanan & Chatterjee (205).

According to HE (2016), investing in roads can have positive effects on the economy through direct and indirect means. Direct effects include investment in capital, while indirect effects result from savings in transportation costs. Four primary techniques contribute to these effects:

1. Capitalizing on opportunities to enhance performance, stimulate agglomeration economies, increase competitiveness, and maximize the

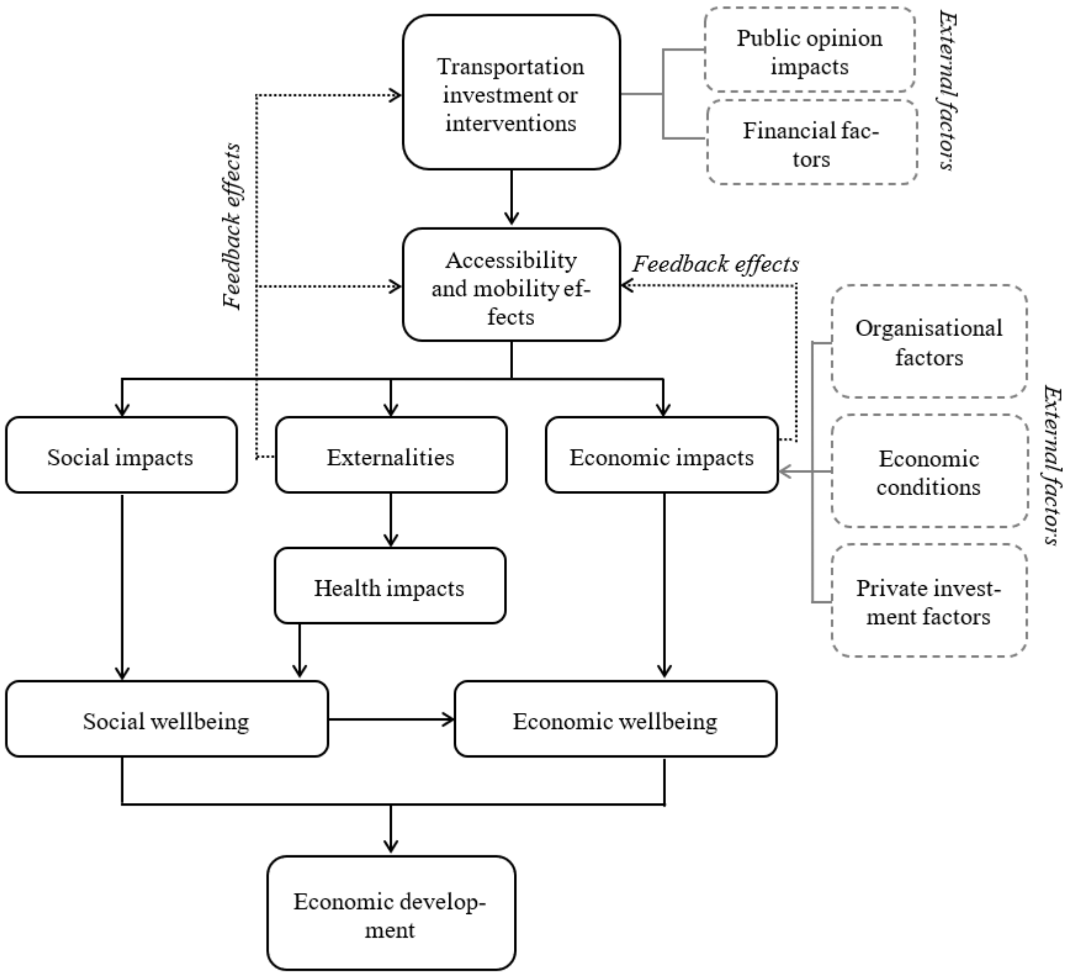


**Figure 1** Transportation and economic growth (Leung, 2006)

benefits of international trade and investment

2. Boosting exchange rates between countries
3. Encouraging domestic and international investment by businesses and builders alike
4. Reducing unemployment rates and increasing job availability.

Transportation investments have been shown to have a positive economic impact, particularly in underdeveloped nations. Hlotywa & Ndaguba (2017) analyzed the relationship between road transport investment and Gross Domestic Product (GDP) growth in South Africa using panel data from 1990 to 2014. They found a positive correlation between road transport investment and economic growth in South Africa, with the explanatory variables accounting for approximately 86.7% of the variance in economic growth. Similarly, Shabani & Safaie (2018) examined the impact of Iran's road and rail networks on the country's provincial economies. Their research revealed that investments in road and railway infrastructure not only directly boosted provincial economies but also had indirect positive effects on neighboring provinces, indicating the presence of spatial spill-over effects.

The effects of improving road infrastructure on GDP and competitiveness within the European Union (EU) were studied by Ivanova & Masarova (2013) in Slovakia. Their time series and correlation study demonstrated that increased spending on roads and attracting Foreign Direct Investment (FDI) both contributed to higher GDP and improved competitiveness. Additionally, Peter et al. (2015) investigated the impact of road transportation on GDP growth in Nigeria. Through econometric analysis of primary and secondary data, they found a long-term connection between road transport infrastructure and economic growth. Similarly, Saidi (2016) examined the influence of road transport on economic development and FDI attraction in Tunisia.

**Table 1** Impacts of investments in transportation (Lakshmanan & Chatterjee, 205)

| Attributes | Short-term | Long-term | Very long-term |
|---|---|---|---|
| Types and forms of effects | Reduced congestion<br>Shorter travel times and lower vehicle operating costs<br>Rising demand and output<br>Logistical reorganization<br>Inventory cost reduction<br>Local and regional growth | Larger markets for products, labours, and services<br>Export expansion<br>Entry and exit of firms<br>Regional/national integration<br>Structural and developmental effects | Promotion of globalization processes<br>Global distribution and production<br>Global flows of goods, services, capital and knowledge |
| Underlying processes and contextual factors | Increased competition<br>Supply and demand forces | Monopolies may emerge<br>Economic of scale<br>Agglomeration<br>Cumulative causation<br>Endogenous growth | Confluence of technical and organisational or institutional changes in transport, communication, and production sectors |
| Description and measurement of effects | Benefit-cost analysis | New economic geography theory<br>Notion of gains from trade<br>Computable general equilibrium models | Economic history analysis |

Econometric modeling revealed that roads contribute to attracting FDI, which, in turn, fosters long-term economic growth.

The studies cited above underscore the importance of roads in promoting economic growth. They provide evidence of the positive effects of investing in road transport infrastructure on productivity, trade, investment, and GDP expansion. These findings support the argument that national investment in road infrastructure is crucial for enhancing regional connectivity and boosting national economies.

### 2.2 RTAs in Malaysia: current situation

Despite the important contribution of road infrastructure development to the nation's growth, the rapid development of road infrastructure has led to a rising number of fatalities and injuries caused by road traffic accidents (RTAs). According to Pembuain et al. (2020), the number of RTAs would be increased as the infrastructure risk increases unless it was designed and constructed to accommodate all aspects of safety for its users. Today, RTAs issue representing a major challenge to public health and national growth worldwide especially in developing countries, and Malaysia is one of those countries.

Various road safety policies and plans have been forwarded to account for the significant reduction in RTAs. However, it seems does not prove to be successful in reducing RTAs, as the number of RTAs is still alarming, although a number of policies have been implemented. Like many other developing countries, the situation of RTAs in Malaysia is not much different. Figure 2 illustrates the historical data of RTAs and road deaths in Malaysia spans from 2015 to 2022. It can be seen that the number of RTAs has increased from 489 606 in 2015 to 521 466 in 2016, recording 6 706 people deaths in 2015 before accelerating to reach all time high of 7 152 people deaths in 2016. The number of RTAs increased steadily to 533 875 in 2017, 548 875 in 2018, and finally peaked to reach all time high of 567 516 in 2019. Within this period, however, the number of deaths has shown a decreasing trend, with figures dropping to 6 740 in 2017, 6 284 in 2018, and further dropped to 6 167 in 2019. In 2020 and 2021, the number of RTAs has decreased to 418 237 and 370 286, respectively. Following the decreasing of the number of RTAs, the number of deaths has also decreased to 4 634 in 2020 and reached a lower peak of 4 539 in 2021.

Despite a notable decrease in both RTAs and deaths in 2020 and 2021, the figures do not accurately represent the current situation in Malaysia. It was due to a global phenomenon, and the primary reason for its occurrence was the Movement Control Order (MCO) which was enacted by a number of countries as a reaction to the COVID-19 pandemic (OECD, 2020). It can be observed when the number of RTAs has increased significantly by 47.3% from a total of 370 286 in 2021 to 545 588 in 2022. The number of deaths has also recorded an increasing of 34.0% from a total of 4 539 in 2021 to 6 080 in 2022. Hence, the current situation concerning the RTAs in Malaysia remains unacceptable and requires for an improvement. It could not be denied that the existing road safety efforts may have mitigated the situation from getting worse when considered in the context of the increasing global population and rapid motorization that has taken place over the same period (WHO, 2023), nevertheless more efforts need to be made.

On the basis of the current circumstances, it is important to point out that the Malaysian aspirations of halving deaths from RTAs by the year 2030, as outlined in the Malaysia Road Safety Plan 2022–2030 (Putrajaya, 2022), will not be accomplished unless effective mitigation measures are developed. As a consequence to this, the agenda of the Decade of Action for Road Safety 2021–2030 with a target of halving at least 50% of deaths and injuries from RTAs by 2030 (WHO, 2021), is unlikely to be achieved. This gives rise to the following question: have the formulated policies and plans related to road safety in Malaysia taken into consideration all of the causation factors of RTAs?

### 2.3 Road safety plans and initiatives in Malaysia: strategies, implementation, and results

The government of Malaysia has implemented road safety strategies and programs to reduce the number of road traffic deaths (Putrajaya, 2006, 2014). The Malaysian Road Safety Plan 2006–2010, outlined by the Putrajaya (2006), aimed to implement road safety plans, set new targets, provide education in schools, conduct media campaigns, establish road safety audit units and departments, and implement blackspot treatment programs. However, the targets for 2010 were not achieved, as the overall number of RTAs and fatalities from 1997 to 2016 exceeded the set targets. This indicates a need for more effective implementation of the measures outlined in the Malaysian Road Safety Plan 2006–2010.

In response to international initiatives to improve road safety, the Government of Malaysia established the Road Safety Plan of Malaysia 2014–2020. The Ministry of Transport Malaysia developed a five-point plan to reduce the number of road traffic accident-related fatalities, setting both long-term and short-term goals (Ultimate Outcomes and Midterm Outcomes) (Putrajaya, 2014). Although progress has been made, the goals of the Road Safety Plan of Malaysia 2014–2020 have not been fully achieved. Recent data indicates that the number of fatalities in RTAs did not decrease as expected between 2015 and 2019, despite a temporary slowdown in trends starting in 2016. The overall number of RTAs continued to rise. While the 2020 COVID-19 outbreak resulted in a significant reduction in RTAs due to the movement restriction order imposed by the government, further research into the root causes of RTAs in Malaysia is warranted.

RTAs have multifaceted causes, with human error, particularly reckless driving, being a major contributor. Driver-related factors such as speeding, lack of attention, and unsafe driving maneuvers are often responsible for accidents (Abdelfatah, 2015). Additionally, the condition of the roads, their design quality, and maintenance play a significant role (Naveen & Kumar, 2016). Vehicle-related issues, such as mechanical problems, also contribute to a substantial number of accidents (Jaiswal & Bhatore, 2016). It is important to consider the interactions between individuals, roads, and vehicles when addressing RTAs, as neglecting any of these factors can hinder accident prevention efforts. Further research is needed to identify the root causes of RTAs in Malaysia and develop effective solutions to improve road safety.

The systems theory of accident causation provides a useful framework for understanding the factors contributing to accidents. According to Firenze (1978), accidents occur when human beings, technology, and the natural world interact, with risks determined by the interplay of these factors. Errors are viewed as breakdowns of the entire system, encompassing hidden flaws and vulnerabilities (Van Elslande & Fouquet, 2007). Molinero et al. (2009) emphasize the significance of human error within the framework of rules and regulations, highlighting that RTAs are systemic failures resulting from the need for drivers to navigate machines and a constantly evolving environment. Understanding RTAs through the lens of the systems theory of accident causation is vital, as it acknowledges the roles played by humans, technology, and the surrounding environment.

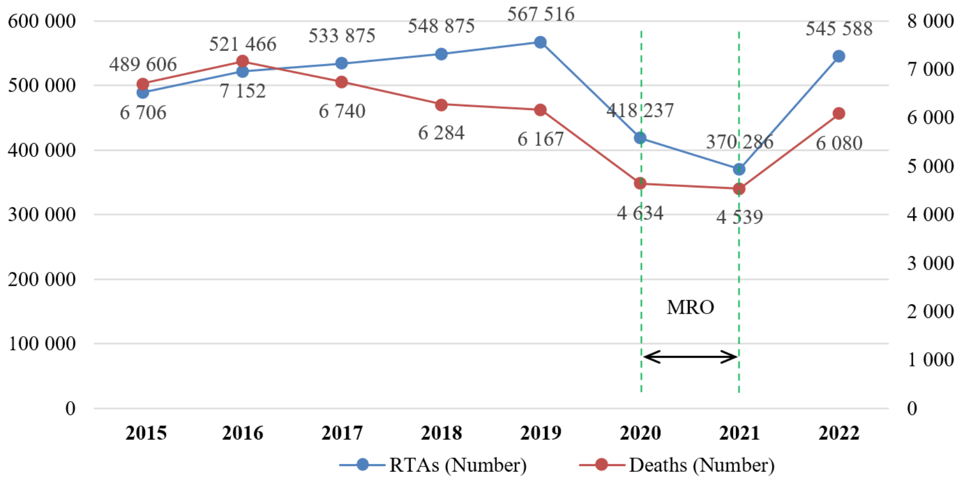


**Figure 2** Number of RTAs and deaths from 2015 to 2022 (DoSM, 2023)

### 2.4 Malaysian studies on RTAs

Considerable research has been conducted on the causes of RTAs in Malaysia. Abdullah & Zamri (2010) examined the relationship between RTAs and population, registered vehicles, and road length. Their findings revealed a significant association between RTAs and these variables, with registered vehicles exhibiting the highest correlation. Najib et al. (2012) utilized the Analytic Hierarchy Process to identify the primary contributors to RTAs in Malaysia. Their research identified several causes, including speeding, inattentive driving, poor road conditions, roadside obstacles, and inadequate vehicle maintenance. Junus et al. (2017) explored how economic, climatic, and calendar characteristics varied across regions in Malaysia and influenced RTAs. The results demonstrated that the consequences of RTAs vary by location due to local factors. Darma et al. (2017) investigated how road-related issues contribute to fatalities resulting from automobile accidents, highlighting the role of poorly lit streets, steep shoulder drop-offs, and potholes.

Understanding the mindset and behavior of drivers is crucial for addressing RTAs. Redhwan & Karim (2010) investigated the knowledge, attitudes, and behaviors of Malaysian college students regarding RTAs. They identified speeding, lack of awareness of road laws, and violation of road rules as primary causes of accidents. Ismail et al. (2015) developed a model to assess driver engagement in RTAs based on criteria such as frequent overtaking, tailgating, and high speeds. Mohamad et al. (2017) examined the role of young drivers in speeding, highlighting the influence of factors such as experience, driving time, circumstances, and road conditions. Sultan et al. (2016) studied young motorcyclists in Malaysia, emphasizing impatience, carelessness, and risky driving behaviors as significant factors.

The studies mentioned above contribute to our understanding of the causes of RTAs in Malaysia. They highlight the importance of road and environmental factors, as well as vehicle-related issues, while emphasizing the role of human behavior. It is evident that RTAs rarely have a single cause but rather result from the complex interaction of multiple factors. By comprehending the intricate relationships among individuals, machines, and their surroundings, efforts can be directed towards reducing accidents and mitigating environmental hazards. Nevertheless, to the best of the authors knowledge, the assessment of the correlation between RSQ and RTAs appears to have been overlooked.

### 2.5 Development of measurement constructs: assessing RSQ and RTAs

For assessing the RSQ and RTAs, the measurement constructs utilized in this study were developed by drawing upon relevant sources. The following literature provides insights into approaches for evaluating the quality of road services and the occurrence of RTAs. The Quality Assessment System for Completed Road Work, developed and published by the Construction Industry Board Malaysia in 2011 (CIDB, 2011), offers a third-party technique for assessing the quality of recently completed road projects. The standard comprises five elements of road works service quality: road surface, slope and retaining structure, drainage, bridges and other structures, and traffic and road furniture. Table 2 provides an overview of the defect groups assessment used to standardize the quality of road construction projects.

Tortum et al. (2012) developed a model that identified road failure as a major cause of accidents in Turkey. The model highlighted road pits, wheel traces, soft shoulders, loose material, permanent waves, lack of road signs, and road settlement as contributors to road failure. Chang et al. (2015) created the 'Assessment Framework of RSQ from the Point of View of Road Users' in Taiwan. The framework encompasses safety, surface, construction, management, and facilities and landscaping as the five pillars of road quality service. This framework allows for an assessment of which aspects of RSQ are most important to different demographics of drivers. Table 3 presents the Users' Perceptions of the Quality of Road Services Assessment Framework.

**Table 3** Road service quality (RSQ) (Chang et al., 2015)

| Dimension | Measurement |
|---|---|
| 1. Road safety | Unsafe conditions due to manhole covers<br>Slipping due to traffic marking<br>Insufficient street lighting<br>Road sign safety |
| 2. Road surface | Potholes and bumps on pavements<br>Subgrade slippage<br>Damaged manhole covers<br>Drainage failure<br>Defective gutters |
| 3. Road construction | Insufficient information on construction works<br>Notice of construction duration<br>Poor backfilling after construction<br>Repeated construction |
| 4. Road management | Curtailed or narrow lanes<br>Encroachment on right of way<br>Insufficient parking space<br>Large traffic volume |
| 5. Road facilities and landscaping | Disorder/dirty roads<br>Untidy roadside landscaping<br>Poor installation of street lighting<br>Landscape image |

Zuna et al. (2016) developed the Toll RSQ model in Indonesia using an artificial neural network methodology. The model combines the SERVQUAL and Minimum Service Standards frameworks to analyze customer satisfaction with toll road services. Table 4 summarizes the dimensions and features of the Toll RSQ model.

**Table 4** Measurements and characteristics of Toll RSQ (Zuna et al., 2016)

| Dimension | Attribute |
|---|---|
| 1. Information | Accuracy of information<br>Information board and signage |
| 2. Accessibility | Toll gates<br>Performance of toll gates officer<br>Hospitality of toll gates officer<br>Honesty of toll gates officer |
| 3. Reliability | Smoothness of road surface<br>Road lighting |
| 4. Mobility | No traffic congestion |
| 5. Safety and security | Driving safety<br>Security from crime |
| 6. Rest area | Rest area facilities |
| 7. Responsiveness | Accident handling<br>Road maintenance<br>Call centre<br>Fast response of emergency unit |

To measure the state of roads in India, researchers Pilaka et al. (2017) created the road service indices. There are eighteen different indications of service built into the indices' four road service standards, as illustrated in Table 5.

Pilaka et al. (2017) created road service indices to measure the condition of roads in India. The indices include four road service standards with eighteen different indicators. Table 5 illustrates the service indicators and standards incorporated in the road service indices.

While these models provide valuable insights, they may not directly align with measuring drivers' satisfaction with improvements made to the East Coast Expressway Phase 2 (ECE2) from their perspective. Some elements, such as 'slope and retaining structure' and 'bridge and other structures' require technical knowledge and physical on-site inspections for accurate assessments. However, drivers can provide valuable input regarding road surface, drainage, traffic volume, and road furnishings. The measurement constructs developed for this study (Table 6) were based on expert opinion

**Table 2** Groups of defects evaluating the standard (CIDB, 2011)

| Component | Element | Defect groups |
|---|---|---|
| Road surface | Carriageway, shoulder and verge, median | Riding quality<br>Safety<br>Aesthetic |
| Slope and retaining structure | Slope, retaining structure, slope drainage, above ground services, slope furniture | Crack and damage<br>Joint, filler, and gaps<br>Functionality<br>Finishing<br>Installation |
| Drainage | Drain, drain cover, sump, pipe, box culvert | Crack and damage<br>Joint and gap<br>Functionality<br>Finishing |
| Bridge and other structures | Above ground bridge (road bridge, pedestrian and motorcycle bridges)<br>Special structures (underpass/vehicular box culverts, tunnel) | Crack and damage<br>Joint and gap<br>Functionality<br>Visibility<br>Finishing<br>Installation |
| Traffic and road furniture | Marking, traffic calming devices, traffic sign, electrical devices, pedestrian facilities, kerb, traffic barrier, delineators | Crack and damage<br>Functionality<br>Visibility<br>Finishing<br>Installation |

**Table 5** Indicators of roadway service (Pilaka et al., 2017)

| Road service parameter | Service indicator |
|---|---|
| 1. Quality of road | Smoothness<br>Roadway markings<br>Shoulder condition |
| 2. Safety of road | Pedestrian crossing facilities<br>Signs and signals<br>Lighting at the junctions |
| 3. Security and emergency services of the road | Highway police patrolling<br>Ambulance for accidents victims<br>Crane facility for vehicle breakdown<br>Telephone booth for emergency call |
| 4. Road user amenities | Restaurants<br>Canteens<br>Petrol pumps<br>Auto service centers<br>Medical aid<br>Parking lots<br>Public toilets<br>Rest house for drivers and travellers |

and existing literature.

Previous studies on RTAs have primarily focused on objective measurements derived from secondary data. However, subjective measurements have also been used to assess drivers' feelings of safety and the likelihood of accidents on the road. This study incorporates subjective measurements, including RTA occurrence rates, response times, accident management efficiency, and drivers' overall perceptions of expressway safety.

By investigating the connections between RSQ and RTAs, this study aims to address the under-recognized and under-studied relationship between road factors and RTAs. While previous road safety policies have primarily focused on human factors, it is evident that a comprehensive approach considering all potential causes of RTAs and their interactions is necessary to effectively address the alarmingly high rate of accidents (Konlan & Hayford, 2022). The literature emphasizes the importance of road conditions, environmental factors, and vehicle variables in causing RTAs. A significant proportion of reported accidents can be attributed to combinations of road, human, and vehicle factors. Therefore, road safety measures should

**Table 6** Measurement constructs

| | Dimension | Component | Variable |
|---|---|---|---|
| 1. | Road surface | Carriageway | Potholes and bumps on carriageway<br>Permanent wave<br>Road settlement<br>Water pounding<br>Improper cross fall<br>Oily road surfaces |
| | | Shoulder | Soft shoulders<br>Insufficient shoulder space<br>Untidy shoulder<br>Level gap between shoulder and road surface |
| 2. | Road drainage | Drain and sump | Too close to the shoulder<br>Damaged manhole covers<br>Not functioning |
| 3. | Road furniture | Marking | Dirty road marking<br>Invisible road marking |
| | | Traffic sign | Unclear traffic signs |
| | | Street lighting | Insufficient street lighting<br>Poor installation of street lighting |
| | | Guardrail | Defective guardrail<br>Too close to carriageway<br>Inconsistently aligned to carriageway |
| 4. | Rest area | Rest area location | Uncomfortable for rest |
| | | | Inappropriate location<br>Too far between one another |
| 5. | Road maintenance | Maintenance works | Fast repair of defects<br>Insufficient traffic signs<br>Poor workmanships<br>Repeated construction |

encompass all potential causes and their interactions. Effective road safety measures can only be developed by addressing the underlying causes of RTAs, as highlighted by the World Health Organization (WHO, 2015).

## 3 Methodology

With the knowledge gained from the literature review section, this section outlines the methodology employed in this study to address the research objectives. It is organized into four sub-sections, each focusing on a specific aspect.

### 3.1 Research design

The research design is guided by a conceptual framework that illustrates the interconnected nature of RSQ and RTAs. The proposed conceptual framework, Figure 3, shows how various factors, such as road conditions, drainage systems, furnishings, rest stops, and upkeep, contribute to the overall quality of road services. The study aims to determine the relationship between RSQ and RTAs and quantify this connection. The research design aligns with postpositivism, as it seeks to isolate and evaluate the factors that contribute to the results. A quantitative approach is employed to gather empirical data and analyze the relationship between RSQ and RTAs.

### 3.2 Research location

The was conducted on the East Coast Expressway Phase 2 (ECE2), one of the newly completed road infrastructure projects in Malaysia. The ECE2 is 184 kilometres long, dual-direction, four-lane was built at a cost of RM4.1 billion. The expressway has attracted public concern and government attention due to the substantial number of RTAs occurred shortly after it opened to the public. Within six months (July 2015 to December 2015) after opened to the public, it was recorded 963 cases of RTAs with a death of 26 peoples, 53 peoples suffered from serious injuries, and another 173 victims' minor injuries. The cases have resulted in overall increasing of number of RTAs in Malaysia for the year 2015 (Putrajaya, 2016). The RTAs most frequently occurred along the KM200 to KM400. Table 7 summarized the number of RTAs, deaths, and injuries occurred on the ECE2 from 2016 to 2021.

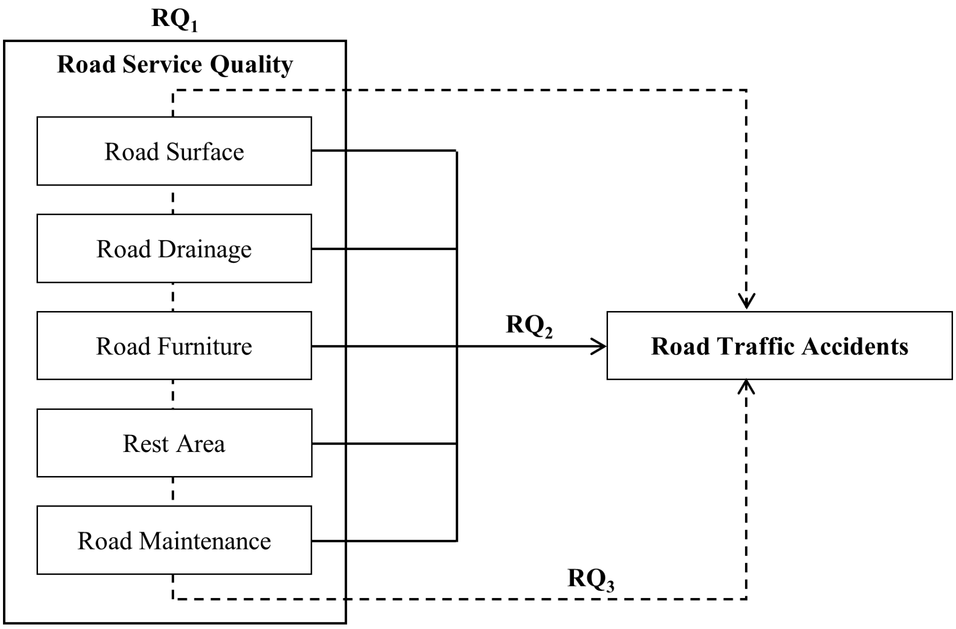


**Figure 3** Conceptual framework

**Table 7** Number of RTAs, deaths, and injuries on the ECE2 (2016–2021) (Putrajaya, 2023)

| | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|
| RTA | 955 | 737 | 772 | 721 | 579 | 522 |
| Deaths | 16 | 20 | 17 | 20 | 10 | 9 |
| Serious injuries | 48 | 56 | 58 | 82 | 36 | 32 |
| Minor injuries | 176 | 125 | 165 | 133 | 96 | 65 |

Throughout the mitigation efforts that have been done, the number of RTAs in 2016 has decreased to 955 cases with 20 deaths, 56 serious injuries, and 125 minor injuries, and further decreased to 737 cases with 26 deaths, 53 serious injuries, and 173 minor injuries in 2017. However, the number of RTAs was increased to 772 cases, with 17 deaths, 58 serious injuries, and 165 minor injuries before decreased to 721 cases in 2019 with 20 deaths, 82 serious injuries, and 133 minor injuries. In 2020 and 2021 where the Movement Control Order (MCO) has been enforced saw the number of RTAs has decreased to 579 and 522 cases, respectively. As a result, the number of deaths has decreased to 10 in 2020 and nine in 2021. Consequently, the number of serious injuries has also decreased to 36 in 2020 and 32 in 2021. Furthermore, the number of minor injuries recorded a decreasing to 96 in 2020 and further decreased to 65 in 2021.

Since RTAs occurred in unacceptable rate considering the length, and traffic volume compared to other highways, the ECE2 is an interesting case research. Moreover, the physical conditions of the highway are expected to be of acceptable quality due to its newly opened. For example, the quality of road surface in term of wear and tear result from normal wear or aging should be not the issued.

### 3.3 Data collection

The data was collected from road users who stopped at Rest and Service Areas (RSAs) located each two at Perasing, Paka, and Ajil. These RSAs accommodated road users driving from Kuantan to Kuala Terengganu, as well as from Kuala Terengganu to Kuantan and located along the KM200 to KM400 of the expressway. This approach allowed for convenient access to a diverse range of road users and facilitated the collection of representative data. The self-administered questionnaire with delivery and collection type is used as the primary data collection instrument, consisting of three parts: general information, ECE2 service quality, and overall service quality perception. Prior presentation (Zahidy et al., 2019) of exploratory factor analysis of the variables served as the foundation for this study's survey. The questionnaire items are measured on a five-point Likert scale to capture respondents' experiences and opinions. An abbreviated copy of the final questionnaire is provided in Appendix A . A convenience quota sampling method is utilized to gather data from primary groups of road users include motorcyclists, car drivers, bus drivers, and truck drivers. The research study considered recommendations on sample size in correlation studies. Salkind (2017) advises a minimum of 30 individuals per group for investigating group differences, while Bujang & Baharum (2017) suggest a minimum of $n \geq 29$ to detect a reasonably high correlation coefficient. Since there was no comprehensive list of road users available, a convenience quota sampling method was employed during the sampling process.

Prior to the main survey, however, a pilot study with 24 participants is conducted to refine the questionnaire, assess its face validity, and ensure understandability. The content validity of the questionnaire is established through expert reviews, while construct validity is inferred from existing literature. The reliability of the questionnaire is measured using Cronbach's alpha coefficient. Data screening is performed to validate input, fill in missing values, test for normality, identify outliers, and verify linearity.

### 3.4 Analysis of data

The data analysis is conducted using SPSS Version 26.0. Descriptive statistics are employed to assess how respondents rate different aspects of the ECE2's road quality. One-way analysis of variance (ANOVA) is used to determine if there are statistically significant differences in mean ratings among different groups of drivers. Correlation analysis is conducted to examine the relationship between RSQ variables (road surface, drainage, furnishings, rest areas, and road maintenance) and RTAs. Multiple regression analysis is employed to calculate the coefficient of determination (R2) and assess the relative importance of the RSQ variables in predicting RTAs. The Relative Importance Index (RII) is utilized to rank RSQ elements based on their likelihood and impact on RTAs:

$$RII = \frac{\sum W}{(A * N)} \tag{1}$$

where:

$W$ is the weight given to each factor of independent variables by the respondents from 1, 2, 3, 4, and 5 based on the five-point Likert scales (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree);

$A$ is the highest weight (i.e. 5 in this case);
$N$ is the total number of respondents.

The methodology ensures that valid and reliable data is collected and analyzed using appropriate statistical techniques. By employing a combination of quantitative methods, the study aims to provide insights into the relationship between RSQ and RTAs on the ECE2.

## 4 Results

The measurement tool used in this study was evaluated for reliability using Cronbach's alpha coefficient analysis. The results indicate that all items achieved Cronbach's alpha coefficients greater than 0.7, indicating high reliability. Among the dimensions of RSQ, road furniture exhibited the highest reliability (0.887), while road maintenance demonstrated the lowest (0.739). The constructs of road furniture, road surface, road traffic accident, and road drainage showed high levels of reliability with coefficients of 0.887, 0.834, 0.829, and 0.810, respectively. The reliability of rest area and road maintenance was considered acceptable with coefficients of 0.765 and 0.739, respectively. Additionally, the inclusion of all variables contributed to the reliability, as slight changes in Cronbach's alpha were observed upon removing any variable.

The validity of the measurement instrument was assessed through content validity and construct validity. Content validity was achieved by conducting a comprehensive literature review and involving academicians, industry professionals, and participants in a preliminary investigation. Their input was used to improve the questionnaire, ensuring that the items were unambiguous, relevant, and precise. Construct validity was established using principal component factor analysis with varimax rotation. The Kaiser-Meyer-Olkin measure of sampling adequacy was found to be 0.68, indicating satisfactory intercorrelations among the items. The Bartlett's test of sphericity confirmed the suitability of the data for further analysis. The factor analysis revealed that the eigenvalues accounted for 69.9% of the variance, surpassing the suggested threshold of 60% for adequate explanation of variance.

To answer research question 1, a descriptive analysis was conducted to assess the perception of different groups of respondents regarding the overall service quality of the ECE2. The results, presented in Table 8, indicate that perceptions varied among the different road user groups. For motorcyclists, 42.3% perceived the overall RSQ as good, while 14% viewed it as poor. Among motorists, 43.9% perceived poor RSQ, and 22.0% considered it good. Among bus operators, 56.1% perceived poor RSQ, and 19.5% perceived it as good. For truck drivers, 45% perceived poor RSQ, and 22.5% perceived it as good. The analysis also conducted a one-way analysis of variance (ANOVA) to determine if there were statistically significant differences in perception between road user groups for each RSQ dimension. The results showed that only road surface exhibited a statistically significant difference in perception between groups ($F = 3.008$, $p < 0.05$), while the other dimensions did not show significant differences.

**Table 8** Overall perception on RSQ

| Respondents | Scale | Frequency (N) | Percentage (%) |
|---|---|---|---|
| Motorcyclists (N = 52) | Very poor | 1 | 1.9 |
| | Poor | 14 | 26.9 |
| | Acceptable | 15 | 28.8 |
| | Good | 22 | 42.3 |
| | Very good | - | - |
| Motorists (N = 41) | Very poor | 1 | 2.4 |
| | Poor | 18 | 43.9 |
| | Acceptable | 13 | 31.7 |
| | Good | 9 | 22.0 |
| | Very good | - | - |
| Bus operators (N = 41) | Very poor | - | - |
| | Poor | 23 | 56.1 |
| | Acceptable | 10 | 24.4 |
| | Good | 8 | 19.5 |
| | Very good | - | - |
| Truck drivers (N = 40) | Very poor | - | - |
| | Poor | 18 | 45.0 |
| | Acceptable | 13 | 32.5 |
| | Good | 9 | 22.5 |
| | Very good | - | - |

To answer research question 2, correlation analysis was conducted to examine the relationship between RSQ dimensions and road traffic accidents (RTAs). The results, shown in Table 9, indicate that road surface, road drainage, and road maintenance exhibit significant positive correlations with RTAs. Road maintenance showed the highest correlation ($r = 0.280$, $p < 0.05$), followed by road surface ($r = 0.226$, $p < 0.05$), and road drainage ($r = 0.159$, $p < 0.05$). Road furniture and rest area, on the other hand, did not show significant correlations with RTAs ($r = 0.129$, $p > 0.05$; $r = 0.111$, $p > 0.05$, respectively). These findings suggest that deficiencies in road maintenance, road surface, and road drainage contribute to a higher risk of RTAs.

To answer research question 3, multiple regression analysis was performed to examine the effect of RSQ dimensions on RTAs. The regression coefficients and standardized beta coefficients ($\beta$) were used to determine the unique contribution of each dimension. The results, presented in Table 10, indicate that road surface ($\beta = 0.167$, $p = 0.037$), road drainage ($\beta = 0.109$, $p = 0.039$), and road maintenance ($\beta = 0.186$, $p = 0.005$) were statistically significant predictors of RTAs. Road furniture ($\beta = 0.006$, $p = 0.945$) and rest area ($\beta = 0.026$, $p = 0.664$) did not significantly contribute to the regression model. The regression equation provides a predictive model for RTAs based on the defects in road maintenance, road surface, and road drainage:

$$y = 1.937 + 0.186 \cdot x_1 + 0.167 \cdot x_2 + 0.109 \cdot x_3 \quad (2)$$

where:

$y$ is level of RTAs;
$x_1$ is defects of road maintenance;
$x_2$ is defects of road surface;
$x_3$ is defects of road drainage.

Additionally, RII technique was used to rank the RSQ factors according to their importance in relation to RTAs. The results presented in Table 11 indicate that factors such as permanent wave, water pounding on pavement or shoulder, road settlement, and insufficient street lighting were identified as significant contributors to RTAs. The ranking provides insights into the factors that have the highest impact on RTAs and can guide interventions and improvements to enhance road safety.

The findings of this study highlight the significance of RSQ dimensions, particularly road surface, road drainage, and road maintenance, in predicting and understanding RTAs. The results emphasize the need for targeted interventions to address deficiencies in these areas to improve road safety on the East Coast Expressway.

Last, but not least, Table 12 present a detailed overview of the demographic characteristics of the respondents, providing information about their profiles, such as

**Table 9** Pearson Correlation

| Variables | | RS | RD | RF | RA | RM | RTAs |
|---|---|---|---|---|---|---|---|
| RS | r | 1 | | | | | |
| | p | – | | | | | |
| RD | r | .424** | 1 | | | | |
| | p | .000 | – | | | | |
| RF | r | .359** | .399** | 1 | | | |
| | p | .000 | .000 | – | | | |
| RA | r | .299** | .359** | .252** | 1 | | |
| | p | .002 | .000 | .001 | – | | |
| RM | r | .422** | .082 | .211** | .104 | 1 | |
| | p | .000 | .284 | .005 | .174 | – | |
| RTAs | r | .226** | .159* | .129 | .111 | .280** | 1 |
| | p | .003 | .036 | .090 | .144 | .000 | - |
| Means | | 3.017 | 2.172 | 2.759 | 2.101 | 3.322 | 3.009 |
| SD | | .714 | .987 | .743 | .955 | .909 | .720 |

Road surface (RS); road drainage (RD); road furniture (RF); rest area (RA); road maintenance (RM)
** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

**Table 10** Standard multiple regression of RSQ dimensions on RTAs

| Varialbes | RTAs | RS | RD | RF | RA | RM | B | $\beta$ |
|---|---|---|---|---|---|---|---|---|
| (Constant) | | | | | | | 1.937 | |
| RTAs | | | | | | | | |
| RS | .226 | | | | | | .167* | .192 |
| RD | .159 | .424 | | | | | .109* | .178 |
| RF | .129 | .359 | .399 | | | | .006 | .006 |
| RA | .111 | .229 | .359 | .252 | | | .026 | .034 |
| RM | .280 | .422 | .082 | .211 | .104 | | .186* | .235 |
| Means | 3.009 | 3.017 | 2.172 | 2.759 | 2.101 | 3.322 | | |
| SD | .720 | .714 | .987 | .743 | .955 | .909 | | |

*p < .05
R = .321*; $R^2$ = .103; Adjusted $R^2$ = .076; F(5, 168) = 3.854

gender, age, occupation, and driving experience. This information helps contextualize the responses and understand potential variations based on demographic factors.

Finally, the results of this study demonstrate the reliability and validity of the measurement tool and provide valuable insights into the perception of overall service quality, the relationship between RSQ dimensions and RTAs, and the predictive power of RSQ dimensions in relation to RTAs. The findings contribute to the understanding of factors influencing road safety on the East Coast Expressway and can guide interventions to improve RSQ and reduce the occurrence of RTAs.

## 5 Conclusion

This study examined the relationship between RSQ and RTAs on a selected expressway in a developing country, Malaysia, providing valuable insights into the factors influencing RTAs. The findings highlight the significance of RSQ in predicting and understanding RTAs, shedding light on factors beyond human error and vehicle defects.

The results revealed that the majority of road users perceived the RSQ of the expressway as inadequate,

**Table 11** RII for the effect of RSQ on RTAs

| | Variable | RII (%) | Rating | | Degree of effect |
|---|---|---|---|---|---|
| | | | Group | Overall | |
| **A.** | **Road surface** | | | | |
| 1. | Potholes and bumps on carriageway | 65.5 | 4 | 8 | HE |
| 2. | Permanent wave | 80.8 | 1 | 1 | VHE |
| 3. | Oily road surfaces | 60.0 | 5 | 10 | HE |
| 4. | Road settlement | 73.2 | 3 | 4 | HE |
| 5. | Water pounding on pavement or shoulder | 73.4 | 2 | 3 | HE |
| 6. | Improper cross fall | 53.9 | 6 | 13 | ME |
| 7. | Soft shoulders | 47.7 | 9 | 19 | ME |
| 8. | Insufficient shoulder space | 46.0 | 10 | 21 | ME |
| 9. | Untidy shoulder | 51.4 | 8 | 17 | ME |
| 10. | Level gap between shoulder and road surface | 51.5 | 7 | 16 | ME |
| **B.** | **Road drainage** | | | | |
| 11. | Too close to the shoulder | 44.3 | 1 | 24 | ME |
| 12. | Damaged manhole covers | 42.6 | 3 | 27 | ME |
| 13. | Not functioning | 43.4 | 2 | 25 | ME |
| **C.** | **Road furniture** | | | | |
| 14. | Dirty road marking | 59.3 | 3 | 11 | ME |
| 15. | Invisible road marking | 67.9 | 1 | 6 | HE |
| 16. | Unclear traffic signs | 51.8 | 5 | 15 | ME |
| 17. | Insufficient street lighting | 65.4 | 2 | 9 | HE |
| 18. | Poor installation of street lighting | 56.7 | 4 | 12 | ME |
| 19. | Defective guardrail | 49.3 | 6 | 18 | ME |
| 20. | Guardrail too close to carriageway | 46.7 | 7 | 20 | ME |
| 21. | Guardrail inconsistently aligned to carriageway | 44.4 | 8 | 23 | ME |
| **D.** | **Rest area** | | | | |
| 22. | Uncomfortable for rest | 38.3 | 3 | 28 | LE |
| 23. | Inappropriate location | 43.3 | 2 | 26 | ME |
| 24. | Too far between one another | 44.8 | 1 | 22 | ME |
| **D.** | **Road maintenance** | | | | |
| 25. | Fast repair of defects | 52.6 | 4 | 14 | ME |
| 26. | Insufficient traffic signs | 65.7 | 3 | 7 | HE |
| 27. | Poor workmanships | 76.4 | 1 | 2 | HE |
| 28. | Repeated construction | 70.9 | 2 | 5 | HE |

with the exception of motorcyclists. This distinction can be attributed to the differences in vehicle size and mechanical systems among the road user groups. The correlation analysis confirmed significant positive relationships between road surface, road drainage, road maintenance, and RTAs. Road maintenance emerged as the most significant predictor of RTAs, followed by road surface and road drainage. Additionally, the study identified the ten most influential factors on RTAs, ranging from permanent wave and poor workmanship to inadequate street lighting and slick road surfaces. These findings provide valuable guidance for addressing specific areas that contribute to RTAs and improving road safety.

By focusing on the causal relationship between RSQ and RTAs, this study challenges the assumption that accidents are solely caused by human error and vehicle defects. It emphasizes the importance of considering RSQ alongside other factors in road safety initiatives

**Table 12** Demographic of respondents (N = 174)

| | | Frequency (N) | Percentage (%) |
|---|---|---|---|
| **Group** | Motorcyclists | 52 | 29.9 |
| | Motorists | 41 | 23.6 |
| | Bus operators | 41 | 23.6 |
| | Truck drivers | 40 | 23.0 |
| **Gender** | Male / Female | 138 / 36 | 79.3 / 20 7 |
| **Age** | Below 20 | 14 | 8.0 |
| | 21–30 | 45 | 25.9 |
| | 31–40 | 56 | 32.2 |
| | 41–50 | 45 | 25.9 |
| | 51 and above | 14 | 8.0 |
| **Education** | Secondary school | 119 | 68.4 |
| | High school | 7 | 4.0 |
| | Diploma | 14 | 8.0 |
| | Bachelor’s degree | 29 | 16.7 |
| | Master’s degree | 5 | 2.9 |
| **Occupation** | Student | 3 | 1.7 |
| | Government | 6 | 3.4 |
| | Private | 58 | 33.3 |
| | Teacher/Lecturer | 7 | 4.0 |
| | Driver | 80 | 46.0 |
| | Businessman | 6 | 3.4 |
| | Self-employed | 14 | 8.0 |
| **Average distance travelled per year** | < 20 000 km | 43 | 24.7 |
| | 20 001–40 000 km | 45 | 25.9 |
| | 40 001–60 000 km | 20 | 11.1 |
| | 60 001–80 000 km | 31 | 17.8 |
| | 80 001–100 000 km | 32 | 18.4 |
| | > 100 000 km | 3 | 1.7 |
| **Frequency travel along ECE2** | Every day | 50 | 28.7 |
| | 1 time/week | 12 | 6.9 |
| | 2–3 times/week | 15 | 8.6 |
| | 4–6 times/week | 59 | 33.9 |
| | 1 time/month | 30 | 17.2 |
| | More than 1 time/month | 8 | 4.6 |
| **Reasons for travelling along ECE2** | School | 2 | 1.1 |
| | Work | 132 | 75.9 |
| | Transportation | 3 | 1.7 |
| | Business | 5 | 2.9 |
| | Holidays | 10 | 5.7 |
| | Return to hometown | 21 | 12.1 |
| | Other | 1 | 0.6 |
| **Experienced in accidents in ECE2** | Yes / No | 18 / 156 | 10.3 / 89 7 |
| **Caused of accident in ECE2** | Human factors | 5 | 2.9 |
| | Road factors | 7 | 4.0 |
| | Vehicle factors | 4 | 2.3 |
| | Environment factors | 2 | 1.1 |

and underscores the need for public participation in shaping transportation systems. The study contributes empirical evidence to the existing literature on road safety and informs the formulation of policies aimed at reducing RTAs.

From an industry perspective, this study highlights the significance of maintaining a design and maintenance culture that ensures roads meet their intended lifespan, thereby reducing accidents and operational costs. Emergency maintenance is also emphasized as a crucial aspect in addressing defects in key road components, minimizing the risks of RTAs for road users. Furthermore, the study suggests enhancing the delivery and implementation methods for road infrastructure projects based on road users' perceptions of poor RSQ.

However, it is important to consider the assumptions and limitations of this study. The representativeness of the respondents from specific road user groups should be taken into account, along with the reliance on self-reported experiences for data accuracy. The findings are specific to the case expressway and may not be universally applicable. Future research can expand on this study by investigating additional expressways and regions, refining measurement constructs, and increasing sample sizes to enhance the external validity of the findings. Conducting research in diverse geographical settings would also contribute to testing the generalizability of the findings.

In conclusion, this study provides valuable insights into the causal relationship between RSQ and RTAs, highlighting the need for comprehensive approaches to road safety that consider RSQ alongside human and vehicle factors. The findings can guide policymakers and industry professionals in enhancing road safety measures, improving infrastructure quality, and ultimately reducing the incidence of RTAs.

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## CRediT contribution statement

**Aniq Asyranie Zahidy:** Conceptualization, Methodology, Writing—original draft, Writing—review & editing. **Muslich Hartadi Sutanto:** Supervision, Validation, Writing—review & editing. **Shahryar Sorooshian:** Writing—review & editing.

## Declaration of competing interests

The authors report no competing interests.

## Availability of data

The detailed report is available on reasonable request to the Information Resource Centre, Universiti Teknologi Petronas, Malaysia.

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## A Extract from questionnaire

Considering your actual experience as a road user of this highway, indicate the extent to which you agree or disagree with the service quality as the following statements:

| Variables | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| **Road surface:** | | | | | |
| Potholes and bumps | | | | | |
| Permanent wave | | | | | |
| Oily road surfaces | | | | | |
| Road settlement | | | | | |
| Water pounding | | | | | |
| Improper cross fall | | | | | |
| Soft shoulders | | | | | |
| Insufficient shoulder space | | | | | |
| Untidy shoulder | | | | | |
| Shoulder and carriageway drop-off | | | | | |
| **Road drainage:** | | | | | |
| Too close to the shoulder | | | | | |
| Damaged manhole covers | | | | | |
| Not functioning | | | | | |
| **Road furniture:** | | | | | |
| Dirty road marking | | | | | |
| Invisible road marking | | | | | |
| Unclear traffic signs | | | | | |
| Insufficient street lighting | | | | | |
| Poor installation of street lighting | | | | | |
| Defective guardrail | | | | | |
| Guardrail too close to carriageway | | | | | |
| Guardrail inconsistently aligned | | | | | |
| **Rest area:** | | | | | |
| Uncomfortable for rest | | | | | |
| Inappropriate location | | | | | |
| Too far between one another | | | | | |
| **Road maintenance:** | | | | | |
| Fast repair of defects | | | | | |
| Insufficient traffic signs | | | | | |
| Poor workmanships | | | | | |
| Repeated construction | | | | | |
| **Road traffic accident:** | | | | | |
| Frequently occurred | | | | | |
| Occurred in unacceptable rate | | | | | |
| Fast response of emergency unit | | | | | |
| Effective of accident handling | | | | | |
| Safe for driving | | | | | |