

FACTORS INFLUENCING TOLL LANE PAYMENT MODE

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Abstract

The efficient operation of a toll-lane system is one of the key aspects of promoting sustainable mobility. Successful implementation of initiatives in a toll-lane system can occur if the response from users is highly encouraging. The efficiency of the toll-lane systems is highly dependent on the type of payment method available at the toll plaza. Thus, the objectives of this study are to identify (i) the preferred mode of payment among toll-lane users in the Klang Valley, (ii) the factors that influence the mode of toll-lane payment, and (iii) the queue time at a toll plaza for each mode of toll-lane payment. This study uses a questionnaire to collect various types of information necessary to meet the study objectives. Results reveal that radio frequency identification detection (RFID) is the most preferred payment mode among road users. Also, the findings indicated that factors such as convenience, the number of lanes available for the toll-lane payment mode, benefits, and availability influence the preference for toll-lane payment modes. This study provides valuable insights for transportation authorities' efforts to optimise toll-lane operations and improve the road user experience.

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1.0 INTRODUCTION

Growing populations and urbanisation exacerbate the strain on transportation systems and infrastructure (Bari *et al.*, 2023). The increase in this trend has impacted the traffic flow on open roads. This situation has compelled road users to rely on toll highways, which are more efficient for free-flow travel. A toll highway is a type of road that requires payment for each passage. The toll highway has high mobility, but it is less accessible than local roads, which have more accessibility than mobility. Toll highways have become a preferred option for road users seeking to avoid traffic congestion and reduce travel time. However, toll plazas on toll highways usually act as bottlenecks in the free flow of traffic and cause congestions (Parmar *et al.*, 2013; Saad *et al.*, 2019).

The payment for usage at a toll highway, also known as toll collection, is a type of road pricing that recovers the costs associated with the road's construction and maintenance. The direct method involves collecting tolls directly from automobiles using the toll highway (Kumawat and Chandramore, 2014). There are two distinct methods of collecting tolls: manual toll collection (MTC) and electronic toll collection (ETC). MTC is a system that requires road users to either present a ticket or pay cash directly to the tollgate operator when passing through the toll plaza. On the other hand, ETC is a method that allows road users to make toll payments using sensors and transponders. Malaysia initiated the development of the ETC system in 1994 and completed its nationwide implementation

by July 2004 (Yusoff *et al.*, 2006). The commonly used ETC collections in Malaysia are Touch N Go (TnG), SmartTAG, and radio frequency identification (RFID). The ETC method also implemented credit and debit cards as a payment option in July 2023 (Azizan, 2023).

Toll plazas frequently encounter significant traffic congestion and extended waits during periods of high demand, such as the morning and evening peak hours. Several factors contribute to the congestion, including the bottleneck effect upstream and downstream of the toll plaza. Drivers competed for service upstream, but sometimes the various lane configurations and different tolling systems confused them (Iseki and Demisch, 2012; Parmar *et al.*, 2013; Saad *et al.*, 2019; Karim *et al.*, 2020; Jiang *et al.*, 2021; Aksoy *et al.*, 2024). Following the completion of payments, constrained road space and overlapping driving decisions may significantly vary the initial motion states of vehicles downstream, leading to frequent speed and lane changes beyond the toll plaza (Abuzwidah, 2019; Saad *et al.*, 2019). This will disrupt traffic flow and diminish traffic capacity, thereby increasing accident risks (Li *et al.*, 2016; Abuzwidah and Abdel-Aty, 2018; Jiang *et al.*, 2021).

Conversely, numerous studies indicated that traffic accidents were common at toll plazas (Mohamed *et al.*, 2001; McKinnon, 2013; Abuzwidah and Abdel-Aty, 2015; Abuzwidah and Abdel-Aty, 2018; Saad *et al.*, 2019; Xing *et al.*, 2019; Xing *et al.*, 2020; Jiang *et al.*, 2021). Between 1994 and 1997, 32%

of traffic accidents on toll highways transpired near the primary toll plazas in Central Florida (Mohamed *et al.*, 2001). McKinnon (2013) disclosed that rear-end and sideswipe collisions frequently occurred in Massachusetts toll plazas from 2010 to 2012.

In Malaysia, drivers predominantly contributed to congestion upstream of the toll plaza, particularly during peak hours, by inadvertently selecting incorrect ETC toll payment lanes. Another factor contributing to the congestion upstream is the potential lack of sufficient credit on users' devices to enable toll payment (MStar, 2024). Furthermore, either the sensors and transponders fail to detect the road users' devices, or they encounter difficulties during the installation and placement of the RFID tags (Malaysia Kini, 2022; Tee, 2022; Yeo, 2022; Khadir, 2023). Road users who fail to successfully pay the toll often reverse or switch lanes to use an alternative payment method (Mstar, 2024). Consequently, significant congestion has occurred, particularly during peak hours, occasionally resulting in accidents at the toll plaza (Leong, 2022; Yeo, 2022; Sinar Daily, 2023).

Thus, this study aims to address issues related to congestion and accidents at toll plazas by examining the influence of toll lane payment configuration layouts on toll operations, specifically the number of lanes offered for different payment modes and the positioning of different payment modes on toll plazas. Thus, the first objective of this study was to identify the preferred mode of payment among toll-lane users in the Klang Valley. This is to determine and compare the preferred mode of payment among Malaysians when they pass the toll plaza. The second objective of the study was to identify the factors that influence the mode of toll-lane payment among road users. Understanding the preferences of road users is crucial for the toll operation provider to offer a sufficient variety of toll lane payment options, thereby reducing the likelihood of congestion and accidents at the toll plaza. Furthermore, the third objective involves determining the average waiting time at a toll plaza for each toll-lane payment mode. Obtaining this information would be useful to suggest the number of toll-lane payment configurations that should be in operation during peak periods. On the other hand, the collected data could suggest the arrangement of different types of toll payment modes.

We structure the remaining sections of the paper as follows: Section 2 contains a comprehensive analysis of existing literature, whereas Section 3 outlines the specific methodology used in the study. Section 4 encompasses the results and discussions, while Section 5 presents the conclusions.

2.0 LITERATURE REVIEW

The road pricing scheme refers to the collection of direct costs for the use of toll highways, including taxes based on distance or time, as well as urban congestion pricing (Milenković *et al.*, 2018). Factors, such as the type of vehicle and the distance travelled, frequently determine the collection of this toll. Toll collections could be MTC or ETC. The MTC method involves collecting tolls using cash, credit card, or debit card, and directly paying them to the toll plaza operator while the automobile passes through the facility. Usually, MTC requires the road users to stop entirely upon reaching the toll plaza to complete the toll payment.

There are several ETC methods. For example, the ETC system in Indonesia employs a smart card (Joewono *et al.*, 2017), often referred to as a chip card or integrated circuit card, which is a compact card containing an embedded integrated circuit. This toll payment system is a collaborative venture between the card-issuing bank and the toll road operator. In 1998, Singapore introduced the toll collection mechanism known as electronic road pricing (ERP). The ERP system employs information and communication technology to oversee and regulate road usage (Parayil and Yeo, 2005). This road user bypasses the toll booth without having to halt or slow down the vehicle. To pass through the ERP gantries, the road user simply needs to exhibit a gadget on the car dashboard.

The first toll highway in Malaysia was the North-South Expressway, spanning 20 km and linking Tanjung Malim and Slim River, which was opened on March 16, 1966. The system operated on a closed-toll basis, using MTC. Users would obtain a ticket upon entering the toll road and settle the tolls upon exiting. Consequently, Peninsula Malaysia has seen the construction of an increasing number of toll highways to enhance its transportation infrastructure. Additionally, there is an open toll system for collecting tolls, in which road users are required to pay a toll when they reach the toll plaza (Kumawat and Chandramore, 2014). The Malaysian government introduced the ETC system in 1994. By July 2004, Malaysia had fully established the ETC system (Yusoff *et al.*, 2006). By August 14, 2017, all toll plazas in Malaysia had transitioned to exclusively accepting ETC. In Malaysia, there are multiple ETC payment methods available, such as TnG, SmartTAG, and RFID. Since 2023, ETC has authorised credit and debit card acceptance.

The capacity analysis directly determines the quantity of toll lanes, which is the primary design factor for a toll plaza (Bari *et al.*, 2022). The toll booth configuration for each toll plaza varies depending on its location and purpose. Typically, the number of channels for each payment mode varies considerably. Several factors affect toll payment mode, including variable payment, accident prediction, quality of service, tollbooth operator conduct, and the inclination to own an ETC device (Bari *et al.*, 2023). Since not all modes of payment are available at toll plazas, consumers may have different choices and reasons for choosing the type of payment mode they prefer to use. Occasionally, malfunctions in certain payment modes can impact the overall performance of the toll plaza operation. For example, PLUS Malaysia Berhad, one of the toll highway operators, formally apologised for the malfunction of its RFID technology at multiple toll plazas in early January 2024 (Tee, 2022).

Moreover, the primary driver of willingness-to-pay is self-interest, which involves assessing the balance between the benefits and costs in relation to individual income and frequency of usage (Yusuf *et al.*, 2014). The user's willingness to accept all payment methods is a function of their ownership of the mode of payment. This is because not all highway users want to have access to every mode of payment. This is due to the perception that each approach may be redundant, as faucets are not always used or applicable in all scenarios. Additionally, queue formation at toll booths is an important issue in the toll road system (Joewono *et al.*, 2017). This occurs due to the

transaction time required to pass through the toll booth. Each mode of payment has its own transaction time. For instance, a cash lane takes 15 seconds, TnG takes six seconds, and SmartTAG only takes three seconds. When a vehicle enters the toll area, it should carefully consider all the available circumstances and choose an option that minimises the duration of the queue (Bari *et al.*, 2022). Travel time is considered an element of a journey's perceived quality. Highway toll plazas are structures located on the highway that require automobiles to slow down or come to a full stop to make a payment for the services offered by the plaza operator (Knorr *et al.*, 2014). An automated toll collection system may verify vehicles enrolled in a toll payment program by matching a unique code affixed to the windscreen of each vehicle with the database kept in the processor (Lima *et al.*, 2019). So, toll highway users are more likely to choose modes that will reduce their travel time and queue when driving through the toll booth.

3.0 METHODOLOGY

In this study, factors influencing toll-lane payment modes were identified by the questionnaire surveying method. We divided the data collection into two types: online questionnaire surveys for the pilot study and face-to-face interviews for the data collection stage. Figure 1 displays the flow chart of the research methodology.

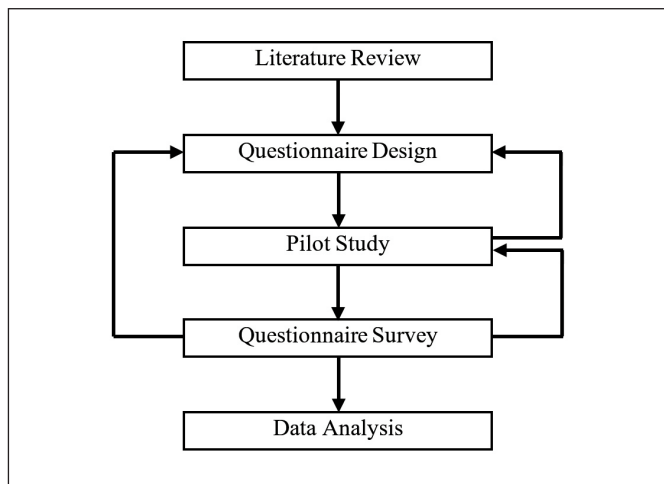


Figure 1: Flow chart of the research methodology

The study commences with a comprehensive literature review, which entails gathering preparatory information from many sources, such as journal articles, books, newspapers, and other relevant publications. After completing the literature review, we designed a questionnaire to gather the essential data for this study. The questionnaire covers several factors that are likely to affect the toll-lane payment. The questionnaire consisted of 27 questions divided into 8 sections, including a screening. We conducted a pilot study using Google Forms for one week in early January 2024. 43 participants provided responses during this period, and we used 28 of them to improve the questionnaire.

We eliminated and incorporated some questions into the questionnaire to improve its quality after the first pilot study. The enhanced version of the questionnaire comprises five

different sections, totalling 24 questions. We conducted the second pilot study using Google Forms for one week in late January 2024. The study received a total of 38 responses, with 16 of them later confirmed as valid. We conducted face-to-face interviews with 100 people working within Universiti Pertahanan Nasional Malaysia (UPNM) in February and March 2024, following the second pilot study.

The survey questionnaire comprised four sections. The first section comprised an eligibility screening to ascertain the respondents' qualifications for participation in the survey. The eligibility screening surveyed only respondents who commuted to work on a toll highway at least four days per week over the past year. The second section of the survey gathered data from respondents regarding their preferred toll payment method and the rationale behind their choice. The third section of the questionnaires collected information on the services offered at the toll plaza. This included the promptness of service upon arrival, the frequency of immediate service, and, in the event of a delay, the length of the queue during weekday mornings and evenings when commuting to and from work. We also investigated their experiences using the toll highway over the weekend. The final section of the questionnaire examined the demographics of the respondents.

After data verification and validation, the analysis used a total of 100 responses from the face-to-face interview. We conducted data analysis using the Statistical Package for Social Science (SPSS) and Microsoft Excel.

4.0 RESULTS AND DISCUSSIONS

Table 1 presents a summary of the respondents' demographic characteristics. Most respondents were aged 26-40 years old (48%), male (62%), government employee (56%), and with monthly income between RM 2,500 and RM 4,999 (51%).

Regarding the preferred mode of toll-lane payment amongst the respondents (as shown in Figure 2), 39% of respondents indicated that they preferred using RFID as their means of

Table 1: Descriptive statistics

Variable	Description	N (%)	
Responses	Total Number of Responses	100	
Gender	Gender of the respondents	Male	62 %
		Female	48 %
Age	Age of respondents	< 25 years old	8 %
		26-40 years old	54 %
		> 40 years old	38 %
Occupation	Occupation of respondents	Government employee	56 %
		Private sector employee	33 %
		Self-employed	10 %
		Retiree	1 %
Income	Monthly income of respondents	< RM 2,500	11 %
		RM 2,500 – 4,999	51 %
		RM 5,000 – 7,499	29 %
		RM 7,500 – 9,999	6 %
		> RM 10,000	3 %

toll payment. RFID is a superior option compared to other modes. Road users prefer RFID due to its user-friendliness, convenience, dependability, simplicity, and speed. Additionally, it eliminates the need for road users to stop their vehicles at the toll plaza, thereby preventing lengthy queues. In the United States, the use of RFID in ETC is a highly efficient and effective method to address the issue of traffic queues at toll booths (Ulatowski, 2007). Kim (2008) asserts that an embedded RFID tag in an automobile allows the driver to pass through the toll booth without stopping. This is possible because the RFID reader scans the data quickly, completing the entire payment procedure in approximately 5 seconds.

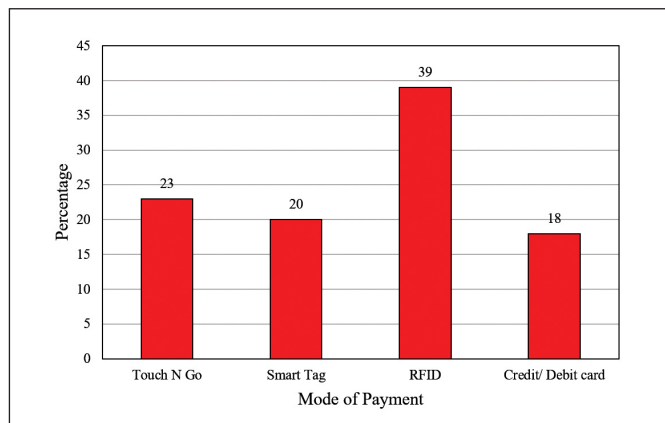


Figure 2: Preferred toll lane mode of payment

TnG ranks as the second most preferred method for paying tolls, accounting for a substantial 23% of the total. This is due to the extensive use of TnG in all forms of ground transportation in Malaysia. TnG can be easily accessed by using an identity card. The current TnG card introductions incorporate near-field communication (NFC), making it easier for road users to top up TnG cards via smartphone-based mobile applications (Dias *et al.*, 2014). Conversely, there are more payment options offered at the toll plaza.

Consequently, the third preferred mode is SmartTAG, accounting for 20% of the total. SmartTAG employs RFID technology, necessitating the prefixing of the TnG card to the device. The SmartTag is efficient because it does not require road users to fully stop at the toll plaza to make a toll payment. Credit or debit cards were the least preferred mode of payment for tolls, accounting for 18% of the total. Due to their recent introduction and limited availability at the toll plaza, credit or debit cards have not gained widespread use. Road users prefer this mode because they receive more rewards or benefits when using their credit or debit cards.

We surveyed the respondents to understand the factors that influence their decision to use the toll-lane payment method. Users of TnG, SmartTAG, RFID, and credit/debit cards reported preferences for these payment methods due to their user-friendliness, convenience, dependability, simplicity, and speed in transactions, with approval rates of 74%, 65%, 64%, and 83%, respectively. 74% of TnG users asserted that TnG offers user-friendliness, convenience, dependability, simplicity, and speed, while 17% indicated that TnG typically offers more payment channels at the toll plaza. The remaining TnG users

indicated that TnG typically offers them greater advantages or promotions. Of the SmartTAG users, 65% asserted that SmartTAG is user-friendliness, convenience, dependability, simplicity, and speed; 15% indicated that SmartTAG typically offers more payment channels at the toll plaza; another 15% stated that SmartTAG device generally provides more benefits or promotions; and the remaining users reported that SmartTAG is their sole device for toll payment. Among RFID users, 64% asserted that RFID is user-friendliness, convenience, dependability, simplicity, and speed; 21% indicated that RFID typically offers more payment channels at toll plazas; 13% reported that RFID is their sole device for toll payment; and the remainder stated that RFID generally provides additional benefits or promotions. Among credit and debit card users, 83% asserted that utilising these cards for toll payments is user-friendly, convenient, dependable, simple, and speedy, while the remainder indicated that they derive greater advantages from using credit or debit cards.

The survey also asked respondents about the queuing time for their preferred mode of payment when they approach the toll plaza during the weekday and weekend. Bari *et al.* (2022) suggested that service time is a critical parameter to evaluate the efficiency of a toll booth. Typically, in this study, TnG experiences the longest queue during weekday morning peak hours, weekday evening peak hours, and weekends (Figure 3). The extended duration of service for TnG, which requires road users to halt their vehicles upon reaching the toll booth, lower the window, physically interact with their cards, and await clearance before they can leave the toll booth, largely accounts for this.

According to Figure 3, the TnG lanes had the highest average queuing time of 3.52 minutes during the morning peak on weekdays. Subsequently, the credit or debit card takes around 1.62 minutes, followed by SmartTAG at 1.45 minutes, and RFID at 0.83 minutes. RFID and SmartTAG toll lanes are significantly more efficient than TnG toll lanes, with RFID lanes being over four times (odds ratio = 4.24) more efficient and SmartTAG lanes being over two times (odds ratio = 2.43) more efficient. As RFID and SmartTAG employ RFID technology, shorter service times—approximately 5s, as indicated by Kim (2008)—could lead to lower queuing times at the toll plaza during peak hours.

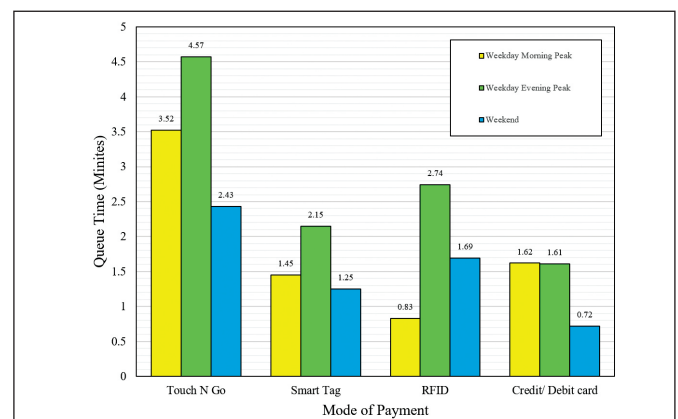


Figure 3: Queue time during weekday morning peak, weekday evening peak and weekend (Ave. Min.)

During the evening peak hours on weekdays, the TnG toll lanes experienced the longest average waiting time of 4.57 minutes. Following that, the RFID takes around 2.74 minutes, followed by SmartTAG at 2.15 minutes, and credit or debit cards at 1.61 minutes. RFID and SmartTAG toll lanes are considerably more efficient than TnG toll lanes. RFID lanes exhibit a 1.67 times higher efficiency (odds ratio = 1.67), while SmartTAG lanes have an efficiency that is almost 2.13 times higher (odds ratio = 2.13). While credit or debit cards and TnG have similar service times at toll plazas, during weekday evening peak hours, credit or debit cards are 2.83 times more efficient than TnG (odds ratio = 2.83). This means that using credit or debit cards results in a significantly faster transaction process.

The average queue time for credit and debit cards during the weekday morning and evening peak periods are nearly identical, with an odds ratio of 1.01. Typically, the average queue time is greater during weekday evening peaks for RFID, SmartTAG, and TnG lanes compared to weekend morning peaks. During the weekday evening peak, the average queue times in RFID, SmartTAG, and TnG lanes are 3.3, 1.48, and 1.3 times higher, respectively, compared to the morning peak.

The average time spent queuing in line at the toll plaza on weekends is significant. RFID and SmartTAG are generally more efficient ways of paying than TnG, with efficiency rates of 1.43 and 1.9 times higher, respectively. Using a credit or debit card is the most convenient way to pay on weekends, resulting in a queue at the toll plaza that is 3.38 times shorter than TnG lanes. Overall, we observed a similar weekend queuing time pattern to the weekday evening pattern, albeit with a lower average queue time.

To summarise, ETC technologies such as RFID, SmartTAG, and TnG, as well as credit/debit cards, offer effective options for alleviating traffic congestion in comparison to MTC. Previous studies had suggested that ETC technologies have the potential to alleviate traffic congestion at toll plazas (Abuzwidah and Abdel-Aty, 2015; Abuzwidah and Abdel-Aty, 2018; Lai *et al.*, 2021) by allowing vehicles to pass through the toll booth without stopping, hence increasing traffic flow. Studies conducted in Taiwan have demonstrated that ETC technologies facilitate drivers' ability to traverse the toll lane at an average velocity of around 50 kilometres per hour (Lai *et al.*, 2021). Similarly, the implementation of RFID technology in India has the potential to improve toll collection efficiency and reduce operational costs at toll plazas (Dhilipkumar and Arunachalaperumal, 2020).

5.0 CONCLUSIONS

The objectives of this study are to identify (i) the preferred mode of payment among toll-lane users in the Klang Valley, (ii) the factors that influence the mode of toll-lane payment, and (iii) the queue time at a toll plaza for each mode of toll-lane payment. The questionnaire survey revealed that the respondents overwhelmingly favour using RFID as their preferred payment mode for toll plaza transactions. This is because the system has the capacity to offer a simplified and accelerated transaction process for toll payments. To pay the toll, the vehicle only needs to reduce its speed rather than stop completely. TnG is the second most preferred option, with SmartTAG as the subsequent choice. Credit or debit cards are the least preferred method of payment.

Each road user has their own unique rationale for selecting their preferred mode of payment while using toll highways. The primary factors influencing the selection of a given mode were its user friendliness, convenience, dependability, simplicity, speed, and other relevant considerations. Each mode demonstrates unique attributes and efficacy, leading individuals to select it based on their specific needs. However, it is suggested that toll highway service providers could provide sufficient toll lane payment mode to ease congestion at the toll plaza, especially during weekday peak hours. For instance, options to pay with RFID could also be enhanced by providing an alternative to pay with a credit or debit card at the same lane to avoid road users having to reverse or switch lanes to use an alternative payment method in case the transponder fails to detect their RFID.

According to the results, TnG consistently has the longest wait time at the toll plaza, taking an average of 3.5 minutes to complete the toll payment process. The large number of TnG users or transaction methods that require a vehicle to stop completely and physically interact with their cards could potentially be the cause of the significant delay at the toll plaza. To promote sustainable transportation at the toll plaza, the concessionaire should consider increasing the number of lanes for each payment method based on the preferences of the drivers. Alternatively, the concessionaire could organize the toll payment methods in a hierarchy based on choice, prioritizing the most-chosen method over the least-favoured one.

This study only considers respondents working in UPM premises. We recommend enhancing this questionnaire survey by including a wider range of toll highway users to effectively address the issue of congestion and accidents at the toll plaza. Alternatively, we could compare the data collected from the questionnaire with real-time data from various toll agencies for verification purposes.

AUTHORS' CONTRIBUTIONS

- **Muhammad Ashraf Abd Mokti:** Data collection, Methodology, and Formal analysis, Writing—original draft preparation and literature review
- **Choy Peng Ng:** Conceptualisation, Study Design, and Supervision, Formal Analysis, Data validation, Visualisation, and Software Implementation, Literature Review, Writing—review, editing, and final manuscript approval
- **Faridah Hanim Khairuddin:** Supervision, Literature Review, Writing—review, editing, and final manuscript approval
- **Vikneswaran Munikanan:** Supervision, Literature Review, Writing—review, editing, and final manuscript approval
- **Chee Fui Wong:** Writing—review, editing, and final manuscript approval. ■

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