Unveiling Malaysians' Future Payment Preferences by Toll Users at Toll Plazas

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ABSTRACT

This study employs time series modeling to forecast Malaysians' toll payment preferences, providing insights for improving toll plaza management and promoting cashless systems. Results reveal a preference for Touch 'n Go, with projected growth for MyRFID and Bank Card methods. Findings suggest key strategies for enhancing service efficiency and reducing congestion at Toll Plaza along the North-South Expressways in Malaysia.

Keywords: Time Series Forecasting, Payment Preferences, Toll Plazas, Customer satisfaction, and Service level agreement.

INTRODUCTION

The escalation of vehicles in urban areas correlates with population growth. This trend is attributed to the collective pursuit of expeditious and convenient transportation options among individuals. Consequently, those who rely on roadways for daily commuting are compelled to dedicate a significant portion of their time to travel, rather than opting for public transportation, which many perceive as challenging and inconvenient. Kuala Lumpur, serving as Malaysia's capital city, harbors a population exceeding 9 million individuals (Statista, 2024). The Kuala Lumpur City Hall (DBKL) has reported that approximately 6 million cars traverse the roads of Kuala Lumpur daily, while only about 1 million commuters rely on public transport (WapCar, 2024). It is anticipated that this figure could reach around 8 million when including Selangor, as vehicles also navigate its federal roads and highways. Consequently, this surge in vehicular traffic contributes to the prevalence of traffic congestion within the city. Living in a capital city such as Kuala Lumpur presents challenges, as individuals are compelled to spend approximately 44 hours per month in their vehicles, primarily due to traffic congestion during their commutes to the workplace (Mat Hayin *et al.*, 2022).

According to Ilyas Syafiq et al. (2024), road traffic congestion causes stress among workers in Kuala Lumpur, however, the stress induced by road traffic congestion does not hinder their productivity at work. An analysis of traffic shows drivers in Kuala Lumpur lost 159 hours which is equivalent to RM 1,023 in fuel within peak hour traffic (Malaymail, 2023). Consequently, motorists incur an annual commuting expense totaling RM3100 (Tomtom.com, 2022). According to data provided by PLUS Expressways, the daily transactions recorded by its concessionaires within Peninsular Malaysia amount to 1.8 million (TheStar, 2022). This figure serves as a reliable indicator for discerning traffic patterns within the Klang Valley as a focal area (TheStar, 2022). Malaysia ranks 145th globally in 2022 in terms of traffic conditions, with motorists' average journey time per 10 kilometers capped at 16 minutes and the average speed during rush hour at 29km/h (Muritala et al., 2015). This study aims to ascertain the payment method preferences of toll users traveling along the North-South Expressways, specifically from the Pandan toll plaza in Johor Bahru to the Bukit Kayu Hitam Toll Plaza in

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Kedah. Additionally, time series modeling is employed to forecast the number of future transactions for each payment method made available in Malaysia under this study.

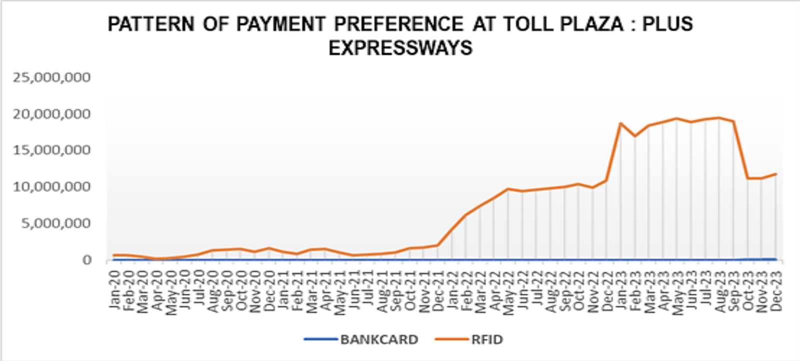

Figure 1 Cumulative Transactions for Bank Cards and MYRFID (2020–2023)

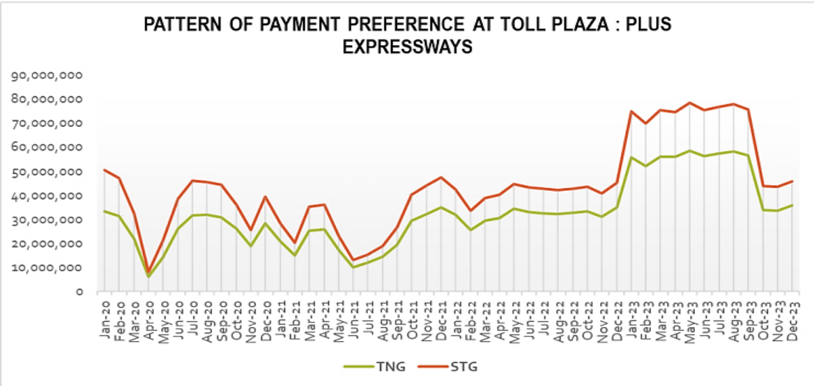

Figure 2 Cumulative Transactions for Touch N Go and SmartTag (2020–2023).

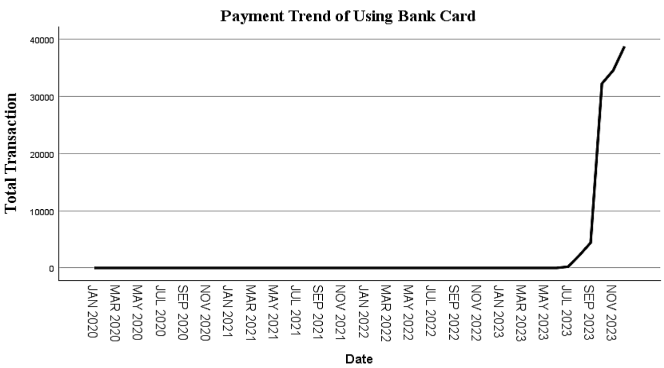

Figure 3 Payment pattern of Bank Cards from 2020 to 2023

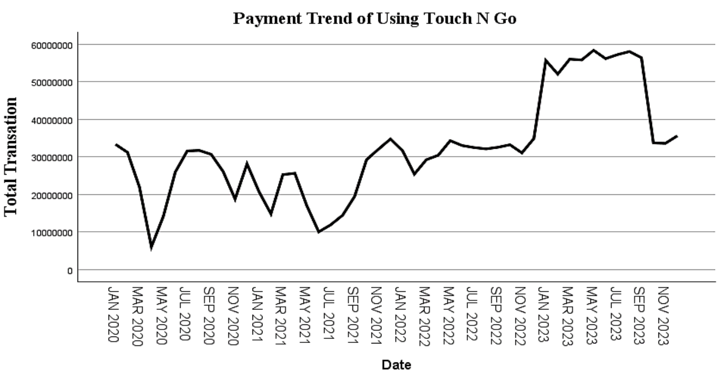

Figure 4 Payment pattern of Touch N' Go from 2020 to 2023

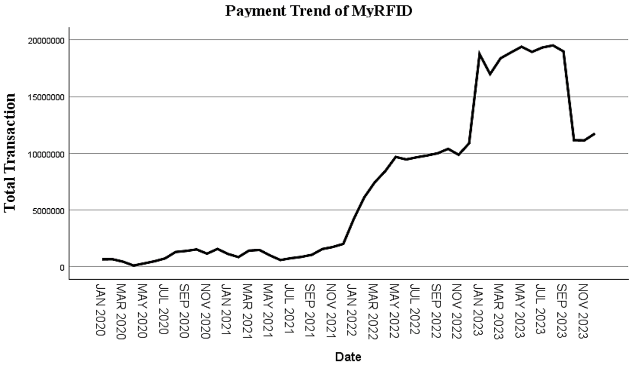

Figure 5 Payment pattern of MyRFID from 2020 to 2023

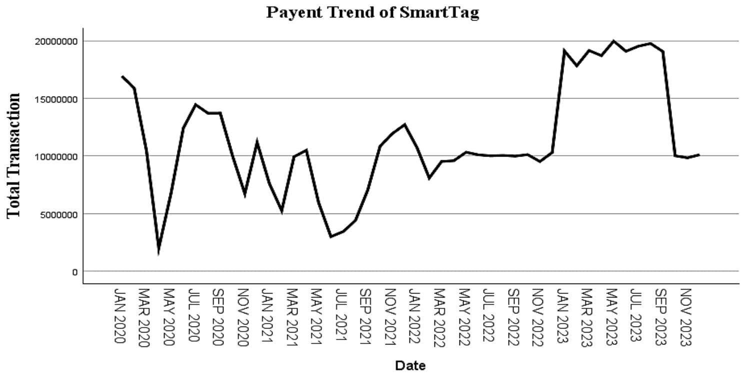

Figure 6 Payment pattern of SmartTag from 2020 to 2023

Figures 1 to 6 show the proportion of toll fee payments from 2020 to 2023. However, the data is non-stationary for analysis due to the enforcement of the Movement Control Order (MCO) and the post-Covid-19 situation. Nevertheless, the data has been standardized to facilitate subsequent analysis, as depicted in the graph below.

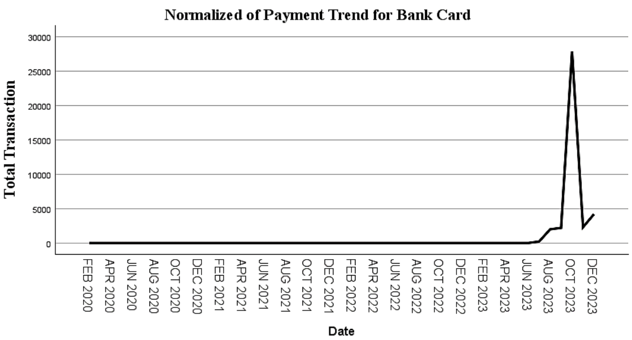

Figure 7 Normalized payment trend of Bank Cards from 2020 to 2023

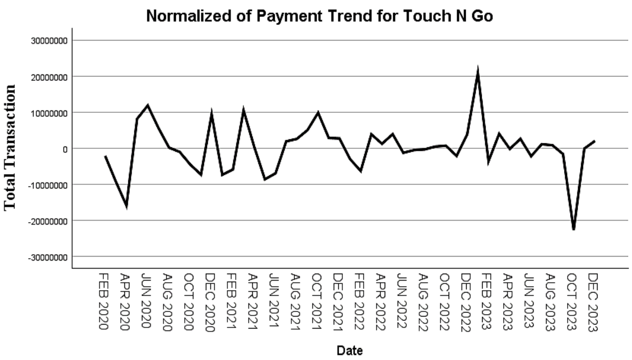

Figure 8 Normalized payment trend of Touch N’ go from 2020 to 2023

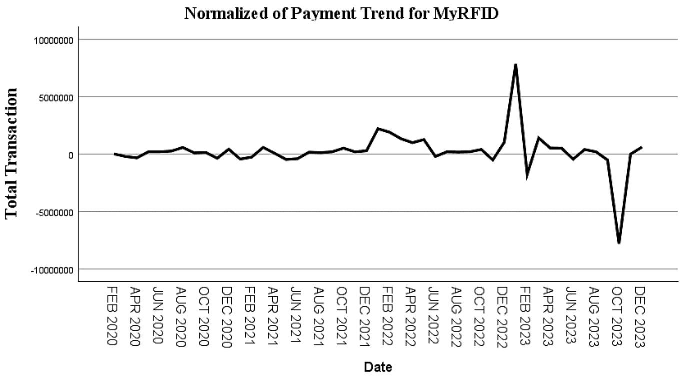

Figure 9 Normalized payment trend of MyRFID from 2020 to 2023

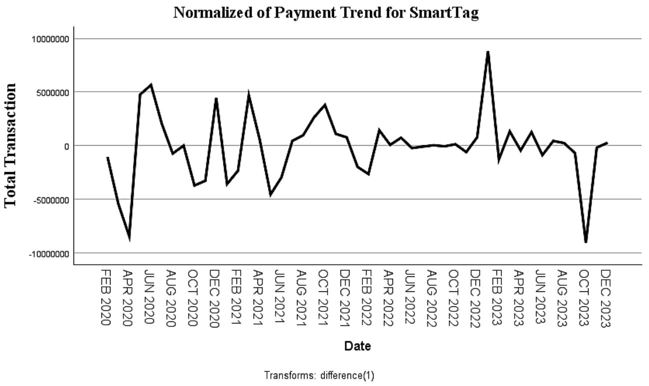

Figure 10 Normalized payment trend of SmartTag from 2020 to 2023

Figures 7 through 10 illustrate the normalized payment trends for toll fees by payment type from 2020 to 2023. Generally, data normalization ensures that time series data is more consistent, reliable, and ready for deeper analysis and modeling. In all circumstances, management forecasting plays a pivotal role in the decision-making process by providing a clear trajectory. Conversely, the absence of an appropriate guideline can engender uncertainty and uninformed decision-making for both organizations and individuals. The prognosis serves as a critical reference for predicting potential outcomes, addressing client needs, and ensuring optimal levels of satisfaction. Moreover, accurate planning and risk mitigation through precise forecasting are essential for averting revenue losses (Julia *et al*., 2024; Ittner et al., 2017). Management's consistent proactivity in preparing for potential threats underscores the significance of forecasting in strategic planning. Nevertheless, relying solely on historical data to forecast future demand may not yield the desired outcomes without employing appropriate methodologies and utilizing advanced analytical tools. This highlights the importance of integrating comprehensive approaches to forecasting that incorporate both historical data and sophisticated analytical techniques to enhance predictive accuracy and inform strategic decision-making effectively.

The study aims to explore the application of time series modeling in predicting trends related to payment preferences. In an era marked by rapid technological advancements and shifting consumer behaviors, understanding payment preferences is vital for businesses and policymakers alike. Leveraging the time series model, renowned for its efficacy in time series analysis and forecasting, provides a robust framework for analyzing and predicting fluctuations in payment methods, such as credit cards, mobile payments, and traditional cash transactions. The study will offer a comprehensive overview of its theoretical underpinnings and practical implementation techniques. This introduction will lay the foundation for understanding how the time series model can accurately forecast payment preferences. Subsequently, the thesis will delve into the specifics of payment preferences, examining historical data and identifying key factors influencing the adoption of various payment methods. Through rigorous analysis and modeling using time series data, the thesis aims to uncover patterns, trends, and seasonality in payment preferences, empowering stakeholders to make informed decisions and devise future strategies. Furthermore, the thesis will discuss the implications of time series model-based forecasts for businesses, financial institutions, and policymakers. By anticipating shifts in payment preferences, organizations can tailor their products, services, and marketing efforts to effectively meet evolving consumer demands. Policymakers can also utilize these insights to formulate regulations and initiatives that promote innovation and efficiency in the payment ecosystem. In conclusion, the outcomes derived from the time series model offer valuable contributions to the fields of economics, business analytics, and financial technology. By bridging the gap between theoretical concepts and practical applications, this thesis equips stakeholders with actionable insights to navigate the dynamic landscape of payment preferences in the digital age.

Current payment mechanism available at toll plazas in Malaysia

The 20-kilometer (12-mile) Tanjung Malim-Slim River tolled road (Federal Route 1), which commenced operation on March 16, 1966, marked Malaysia's inaugural tolled roadway. However, on January 14, 1983, the North-South Expressway, the nation's primary thoroughfare, inaugurated its toll booth, marking the commencement of toll collection for roadway usage indirectly. During the initial stages of Malaysia's tolling system, toll users were required to obtain a transit ticket at the toll plaza upon entering the designated entrance point (Hashim, 2006; Williamson, 2003). Subsequently, the aforementioned ticket was intended for toll payment before the implementation of the Touch 'n Go, SmartTag, and MyRFID systems. In 2023, a governmental directive instructed the Malaysia Highway Authority (MHA) to enable toll payments through the use of Bank Cards. This initiative aims to introduce alternative payment methods and reduce the monopoly held by Touch 'n Go.

Praiseye *et al.* (2018), explored the widespread adoption of wallet payment systems in India, identifying them as one of the most convenient methods for digital transactions. The study noted that factors like ease of use, speed, and the ability to handle multiple types of transactions encouraged mass adaptation of mobile wallets among Indian consumers. It highlighted that the convenience provided by e-wallets, such as seamless payment for goods, services, and even peer-to-peer transfers, made them highly attractive to the masses. In Indonesia, security concerns remain a significant barrier for many consumers, particularly when it comes to high-frequency transactions like toll payments (Prasetya *et al*., 2023). Similarly, in Malaysia, consumers are also concerned about the security of wallet payments, which necessitates enhancements in payment policies to prevent scams and fraudulent activities (Abu Bakar et al., 2024; Subbiah, 2022)

Touch ‘n Go

The implementation of the Touch 'n Go reusable transit cards (E-toll card) also known as the transit cards Syarif et al., (2019) commenced on June 18, 2013, across the entire network of PLUS expressways. These cards were introduced as a replacement for traditional transit tickets. Since April 26, 2017, the issuance of the PLUS Transit Card has been discontinued due to the complete implementation of electronic toll collection at all toll plazas operated by PLUS (Thomas, 2003). Consequently, customers are now required to touch their Touch ‘N Go card upon entry and exit to determine the distance of their journey as well as the total toll fares. Alternatively, the Touch 'n Go card has gained prominence as a convenient payment method for public transportation fares in Malaysia which added convenience for users. With advancements in electronic toll collection systems, the use of prepaid toll cards is gradually declining in favor of cashless and digital solutions like RFID tags, mobile payment apps, and license plate recognition. However, prepaid cards remain an essential option in regions with limited infrastructure or for users who prefer not to adopt digital technologies. Integrating these cards into broader ecosystems (e.g., public transport and retail payments) may help sustain their relevance.

SmartTag

The Smart Tag was introduced as one of the payment channels in 1999. It is an on-board unit (OBU) vehicle-based device used as an electronic toll collection (ETC) system over long distances (up to a maximum of 15 meters), serving as a complement to the Touch 'n Go card-based system. However, the mechanism relies on Touch 'n Go cards, which are required for operation and must be inserted into the device. The study has shown that providing toll users with the tag at no cost would be an effective approach to encourage individuals to adopt electronic tolling and utilize toll roads more frequently, owing to the advantages offered by ETC systems (Javier H. Molina, 2019). The adoption of similar payment mechanisms, such as Fastag, has raised concerns about overall security, including issues like device loss, theft and potential technical glitch (Pandit, 2021).

MyRFID as an e-wallet tolling system

A new payment system was implemented in January 2022, a system that tracks, recognizes, and autonomously manages toll collection via radio waves. The RFID system has been widely discussed in Malaysia, with ideas proposed to enhance toll payment systems by minimizing human interaction and aiming to improve traffic flow at Malaysian toll plazas (Kamarulazizi *et al.*, 2010). Additionally, MyRFID is a smart toll-collection system utilizing IoT based on Arduino (Noor et al., 2016). With the shift to an e-toll system where all transactions are conducted through mobile applications, this announcement inadvertently marks another milestone in the positive adaptation to digital disruption which aligned with the N initiative by the Malaysian government, eliminating the need for drivers to physically touch their cards on card readers while using Smart Tag devices.

The initiatives aim to reduce waiting time for toll payment at toll plazas, with the secondary goal of alleviating traffic congestion. According to Anabesa Acopiado (2022), the adoption of digital payments has potentially aided enterprises in growing their businesses during the COVID-19 pandemic. However, toll users express concerns about data security, particularly regarding the potential leakage of data to other parties in the absence of adequate firewall protection.

Bank Card

The implementation of Bank Cards as a payment mechanism for toll collection took place in September 2023, as part of an initiative by the Government's plans through the Malaysian Highway Authority (MHA). The objective of this initiative is to enhance toll payment diversity by offering an alternative method instead of relying solely on Touch 'n Go as the payment gateway for all types of payments associated with tolls. Ultimately, the goal is to reduce the monopoly of Touch 'n Go as the primary payment channel for toll roads, which seems unhealthy as it indirectly forces toll users to use Touch 'N Go without any flexibility.

Preference in selecting payment type at the toll plaza

The awareness of technological advancement is somehow inclined toward males compared to females, as noted by Lee et al. (2010). Cheung and Le (2011) discovered that perceived utility had a beneficial impact on users' attitudes toward utilizing technology, specifically e-wallets. In India, E-toll card users at the Suramadu toll plaza have expressed their dissatisfaction with the lengthy queues for toll payments (Rachmad, 2019). Although the e-wallet payment system in Malaysia can be considered new, the rates of acceptance are positive. However, users are more concerned about data leakage (Sabli et al., 2021).

Conceptual Framework

The variables outlined below have the potential to directly or indirectly influence the payment preferences of toll users at toll plazas. Figure 11 presents the conceptual framework of the methodology.

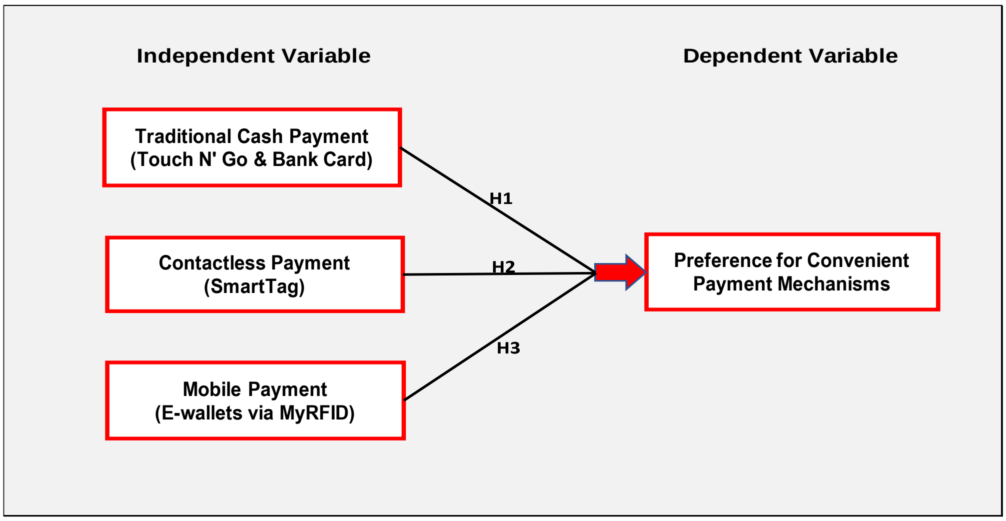

Figure 11 Conceptual Framework

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Hypotheses of the study

Based on the literature review, secondary data, and the unified theory of acceptance along with the developed conceptual framework the following hypotheses have been proposed.

H1: Traditional Cash Payment (Touch N' Go and Bank Card) is the most preferred payment mechanism at toll plazas.

H2: Contactless Payment (e.g., SmartTag) is the most preferred payment mechanism at toll plazas.

H3: Mobile Payment (e-wallets through MyRFID) is the most preferred payment mechanism at toll plazas.

METHODOLOGY

The study employs time series modeling, a statistical technique used to analyze sequential data for predicting future values. Unlike cross-sectional data, which represent single observations, time series data are chronologically ordered, allowing for the capture of trends and dependencies over time. This research specifically examines payment methods used by toll users along Malaysia's North-South Expressways, utilizing transaction data from PLUS Expressways Berhad.

Time series modeling incorporates several components, including trends (representing long-term movement), seasonality (reflecting recurring patterns at fixed intervals), and cyclicality (which introduces longer-term fluctuations often linked to economic factors). Additionally, random components account for unexplained variations. Time series models can be categorized as either descriptive, summarizing past patterns, or predictive, which forecast future values based on historical data.

Predictive models, such as ARIMA (AutoRegressive Integrated Moving Average), SARIMA (Seasonal ARIMA), and ETS (Exponential Smoothing State Space), are widely used for forecasting future trends. These models leverage sophisticated algorithms to capture temporal dependencies and deliver accurate predictions (Arumugam et al., 2023; Kramar et al., 2023; Shi et al., 2020). Each model comes with its strengths and limitations, requiring careful consideration of the characteristics of the data and the analytical objectives. Whether aimed at gaining insights into past trends or forecasting future outcomes, selecting the appropriate model plays a pivotal role in maximizing the predictive power of time series analysis.In this study, time series modeling was applied to identify seasonality, patterns, and trends in toll users' payment preferences. The findings from this analysis have significant implications for technological advancements and lane management strategies, offering valuable insights for strategic preparation and enhanced efficiency.

Formulation of Time Series Model

Autoregressive (AR) Model:

$$yt=c+\phi 1yt-1+\phi 2yt-2+...+\phi pyt-p+etyt=c+\phi 1yt-1+\phi 2yt-2+...+\phi pyt-p+et \qquad (1)$$

Equation (1) shows the equation of AR, ytyt represents the value of the time series at time tt, cc is a constant, ϕiϕi are the autoregressive coefficients, pp is the order of the autoregressive process, and etet is the error term assumed to be white noise.

Moving Average (MA) Model:

$$yt=\mu+et+\theta 1et-1+\theta 2et-2+...+\theta qet-qyt=\mu+et+\theta 1et-1+\theta 2et-2+...+\theta qet-q \qquad (2)$$

Equation (2) shows the equation of MA, ytyt is the value of the time series at time tt, μμ is the mean of the time series etet is the white noise error term at time tt, θiθi is the moving average coefficients, and qq is the order of the moving average process.

Autoregressive Integrated Moving Average (ARIMA) Model:

$$yt'=c+\phi 1yt-1'+\phi 2yt-2'+...+\phi pyt-p'+\theta 1et-1+\theta 2et-2+...+\theta qet-q+etyt'=c+\phi 1yt-1'+\phi 2yt-2'+...+\phi pyt-p'+\theta 1et-1+\theta 2et-2+...+\theta qet-q+et \qquad (3)$$

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Equation (3) shows the equation of ARIMA, In this equation, yt'yt′ represents the differenced series at time tt, after applying differencing to achieve stationarity. pp is the autoregressive order, qq is the moving average order, cc is a constant, ϕiϕi are the autoregressive coefficients, θiθi are the moving average coefficients, and etet is the error term assumed to be white noise. These equations represent the core components of autoregressive (AR), moving average (MA), and autoregressive integrated moving average (ARIMA) models, which are commonly used in time series analysis.

Analysis tools

Time series modeling is a powerful statistical technique used to analyze data collected sequentially over time. One commonly used approach in time series analysis is the Autoregressive Integrated Moving Average (ARIMA) model. The ARIMA model consists of three main components: autoregressive (AR), differencing (I), and moving average (MA). Each component is represented by a parameter: p, d, and q, respectively. For the analysis, ARIMA (0,1,0) (0,0,0) is employed in this study, which indicates that there are no autoregressive or moving average terms (p and q are both 0), but one order of differencing is applied (d is 1). Additionally, we considered the seasonal aspect by specifying the seasonal component as (0,0,0), meaning no seasonal terms were included. Another model we explored is the Simple Seasonal Model, which is designed to capture seasonal patterns in the data. This model does not involve autoregressive or moving average terms but focuses solely on the seasonal component. It is represented by the equation $Yt=St+et$Yt=St+et, where YtYt represents the value of the time series at time tt, StSt represents the seasonal component, and etet represents the error term.

Furthermore, we investigated Winter's Additive Model, which extends the Simple Seasonal Model by incorporating an additional term for trend. This model aims to capture both seasonal patterns and underlying trends in the data. The equation for Winter's Additive Model is $Yt=Tt+St+et$Yt=Tt+St+et, where TtTt represents the trend component, StSt represents the seasonal component, and etet represents the error term. By employing these models, the study will gain valuable insights into the temporal patterns present in the data, including trends, seasonality, cyclicality, and random fluctuations. Such insights are essential for making informed decisions and accurate forecasts in various fields, including economics, finance, and environmental science. Effective time series modeling enables us to better understand the dynamics of sequential data and anticipate future trends and behaviors, thereby facilitating proactive decision-making and planning.

Data compilation

This study employed a quantitative research design and analyzed the data using descriptive and comparative analysis techniques. Quantitative research entailed the utilization of secondary data alongside videos obtained from PLUS Expressways Berhad. Additionally, efforts were made to enhance observational capabilities and gain a deeper understanding of actual incidents at the Toll Plaza through on-site activities. This study utilized a quantitative research design to conduct data analysis employing descriptive and comparative analysis techniques. The quantitative approach involved the utilization of secondary data in conjunction with videos procured from PLUS Expressways Berhad. Furthermore, endeavors were undertaken to augment observational capabilities, thereby facilitating a comprehensive understanding of real-time transactions at the Toll Plaza through on-site activities for better observation.

RESULT AND DISCUSSION

Model description

Model Description

			Model Type
Model ID	BANKCARD	Model_1	ARIMA(0,1,0)(0,0,0)
	TNG	Model_2	Simple Seasonal
	RFID	Model_3	Winters' Additive
	STG	Model_4	Simple Seasonal

Table 1. The model encompasses all payment types, including Bank Cards, Touch 'N Go, MyRFID, and

SmartTag

Model Fit

Fit Statistic	Mean	SE	Minimum	Maximum	Percentile 5	10	25	50	75	90	95
Stationary R-squared	.427	.301	-2.220E-16	.672	-2.220E-16	-2.220E-16	.110	.518	.653	.672	.672
R-squared	.781	.138	.614	.951	.614	.614	.655	.780	.909	.951	.951
RMSE	2765586.194	2.8E+6	4103.305	6489094.204	4103.305	4103.305	394050.259	2284573.633	5618134.690	6489094.204	6489094.204
MAPE	43.122	24.976	20.210	76.481	20.210	20.210	22.266	37.898	69.201	76.481	76.481
MaxAPE	344.756	163.55	203.065	579.353	203.065	203.065	221.823	298.304	514.142	579.353	579.353
MAE	1822354.353	1.9E+6	1463.861	4368740.059	1463.861	1463.861	203300.756	1459606.747	3804155.557	4368740.059	4368740.059
MaxAE	7967607.142	7.8E+6	27008.745	18779737.19	27008.745	27008.745	1576012.818	6531841.316	15794967.29	18779737.19	18779737.19
Normalized BIC	26.753	6.783	16.721	31.533	16.721	16.721	19.733	29.380	31.148	31.533	31.533

Table 2. Model fit for all payment types

Model Statistics

Model	Number of Predictors	Model Fit statistics: Stationary R-squared	Ljung-Box Q(18): Statistics	DF	Sig.	Number of Outliers
BANKCARD-Model_1	0	-2.22E-16	3.067	18	1.000	0
TNG-Model_2	0	.596	20.737	16	.189	0
RFID-Model_3	0	.441	8.944	15	.880	0
STG-Model_4	0	.672	21.885	16	.147	0

Table 3. Model statistics based on different payment types.

Model description

Forecasted result for the year 2024

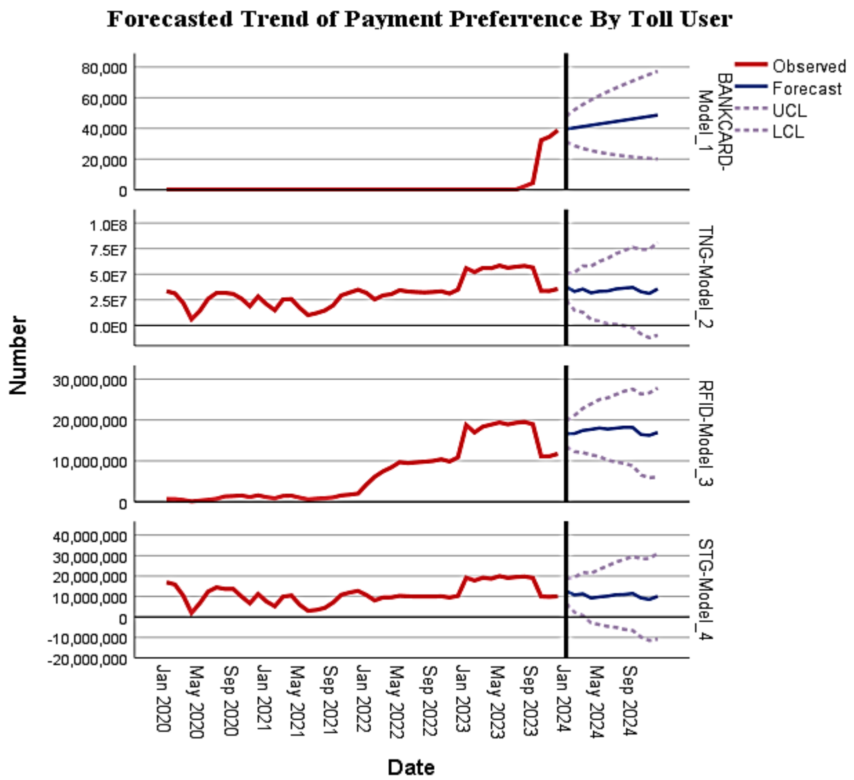

Table 4. The forecasted graph of payment preference for the year 2024

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Forecast

Model		Jan 2024	Feb 2024	Mar 2024	Apr 2024	May 2024	Jun 2024	Jul 2024	Aug 2024	Sep 2024	Oct 2024	Nov 2024	Dec 2024
BANKCARD-Model_1	Forecast	39564	40389	41213	42037	42861	43686	44510	45334	46158	46983	47807	48631
	UCL	47824	52069	55519	58556	61330	63917	66362	68696	70937	73101	75201	77243
	LCL	31305	28708	26907	25518	24392	23454	22657	21973	21380	20864	20413	20019
TNG-Model_2	Forecast	37647393	33155030	35401746	31761581	33243865	33571922	35579106	36371377	37052970	32851598	31149746	35615705
	UCL	50709262	51618073	58010494	57865737	62427739	65540187	70107957	73283611	76203763	74119698	74431701	80821890
	LCL	24585524	14691988	12792999	5657425	4059991	1603656	1050255	-540858	-2097823	-8416503	-12132209	-9590479
RFID-Model_3	Forecast	16648369	16681811	17427734	17700652	18033780	17780667	17996777	18225720	18171944	16444621	16246077	16948214
	UCL	19798207	21098332	22825176	23929756	24998967	25414064	26247025	27052240	27541651	26329893	26623411	27797312
	LCL	13498531	12265290	12030293	11471548	11068594	10147270	9746529	9399201	8802237	6559350	5868743	6099117
STG-Model_4	Forecast	12624706	10797569	11293518	9232710	9784743	10183451	10886894	11015843	11487551	9277486	8539625	10103475
	UCL	18673972	19348251	21764177	21322178	23300503	24988731	26878044	28110796	29619234	28389745	28584550	31039558
	LCL	6575439	2246886	822858	-2856759	-3731018	-4621829	-5104256	-6079110	-6644133	-9834774	-11505300	-10832608

For each model, forecasts start after the last non-missing in the range of the requested estimation period, and end at the last period for which non-missing values of all the predictors are available or at the end date of the requested forecast period, whichever is earlier.

Table 5. The forecasted figures of payment preference for the year 2024

The table 4 and 5 highlights the projected future trends for various payment types, offering an optimistic outlook for systems like Bankcard, Touch 'n Go, and SmartTAG. Transactions using Touch 'n Go are projected to exceed 3.6 million by Q4 2024, Bankcard transactions are expected to reach 48,631, and SmartTAG is also showing a positive trajectory, reflecting an increase in user preference. The upper control limit (UCL) indicates growing interest in these payment channels. In contrast, according to the UCL, MyRFID is projected to experience a slight increase averaging 17 million transactions monthly or potentially surpassing 27 million transactions by the end of Q4 2024. These trends indicate a potential increase in usage of MyRFID possibly driven by growing awareness. Toll users may find reloading credit through an e-wallet system seamless and practical for their busy schedules. Nevertheless, transactions under Touch 'n Go could exceed 80 million if toll users continue to perceive it as the preferred payment mechanism for all transportation systems in Malaysia. Conversely, SmartTag utilization may decrease, potentially reducing by 10% by the end of December 2024, as toll users shift their focus toward an open system where toll users could eliminate the tagging devices and ignore its maintenance. MyRFID requires less maintenance than SmartTag devices and has a better ESG rating for enterprises listed on the KLSE. The results from time series modeling suggest that the government needs to expedite the implementation of barrier-free toll plazas accessible to all, with the Multi-Lane Free Flow (MLFF) system being a step in that direction. Based on the analysis, it is recommended that the Malaysia Highway Authority (MHA) prioritize implementing a gantry system associated with RFID-type payment, which could streamline usage and facilitate faster toll payments. This could also lead to a change in user behavior and alleviate traffic congestion during peak hours, while also accommodating technological disruptions anticipated by Malaysians in 2025. It will be interesting to observe how these changes shape the future payment methods at toll plazas in the country.

Research on RFID payments highlights that users' willingness to adopt RFID technology is driven by their perceived benefits and convenience (Hossain & Prybutok, 2008). However, when users associate the technology with potential risks, such as security vulnerabilities, their acceptance decreases (Hoffman, 1999). In particular, concerns arise around wallet systems that require real-time location updates, as users fear their location could be tracked through RFID technology, raising significant privacy concerns (Spiekermann et al., 2005). As a result, the open payment system could offer an ideal solution for toll payments, allowing users to pay with their bank cards or continue using Touch 'n Go without security concerns. This system reduces reliance on proprietary payment methods and provides greater flexibility and peace of mind for users (Technave, 2023).

CONCLUSION

This study employed time series modeling to analyze and forecast payment preferences at toll plazas using data from PLUS Expressways Berhad. The data was transformed to achieve stationarity, ensuring accurate modeling by addressing trends and seasonality. Various models, including (0, 1, 0), (0, 0, 0), simple seasonal, and Winters' additive, were applied to identify the best-fit approach. These models revealed historical patterns that helped optimize operations and improve service levels, despite added complexity from pre-COVID-19 and endemic-period variations. The findings provided actionable insights for toll operators to prepare for the Multi-Lane Free Flow (MLFF) system in 2025. Analysis of North-South Expressway transactions highlighted key trends in payment methods—Bank Cards, Touch 'n Go, SmartTag, and MyRFID—with projections showing Touch 'n Go's continued dominance alongside significant growth in MyRFID and Bank Cards. The transition to advanced RFID technology promised smoother traffic flow, better user experiences, and reduced congestion-related emissions. To support Malaysia's digital transformation goals, the study underscored the importance of inclusive policies and innovative payment systems, aligning with initiatives like the Malaysian Research Accelerator for Technology and Innovation (MRANTI).

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