The Implications of Transitioning from RFID to QR Code Technology: A Study on Metro Manila Tollway Motorist Payment Methods

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Abstract: This research explores the dynamic transition from Radio-Frequency Identification (RFID) to Quick Response (QR) code technology in tollway payments, focusing on the experiences and perspectives of tollway employees. The study gathers responses from tollway users and employees to uncover the advantages, challenges, and recommendations associated with this technological shift. Through a combination of qualitative, the research investigates the time efficiency, convenience, and cost savings perceived by users with QR code technology. Additionally, the study delves into challenges such as adaptability, technological issues, and security concerns during the transition. Tollway employees' perspectives are examined through in-depth interviews, shedding light on their experiences and providing insights into the operational impacts of adopting QR code technology. The findings aim to contribute valuable information for tollway operators, policymakers, and technology providers to enhance the overall efficiency and user experience of tollway payment systems. Additionally, the research examines the training and development needs of tollway employees and their overall perceptions of organizational changes within the tollway system. The findings aim to contribute to a better understanding of the working lives of tollway employees and inform strategies for improving their job satisfaction, well-being, and safety in a rapidly changing technological landscape. As tollways globally consider technological advancements, this research serves as a timely exploration of the multifaceted dimensions surrounding the transition from RFID to QR code technology in tollway payments.

Cite as: C. Arvee Jay, F. F. Joanna Corazon, G. Efren, and L. Leah Jhane, "The Implications of Transitioning from RFID to QR Code Technology: A Study on Metro Manila Tollway Motorist Payment Methods," *FMDB Transactions on Sustainable Technoprise Letters*, vol. 1, no. 3, pp. 156–170, 2023.

1. Introduction

In recent years, the world of technology and data management has undergone enormous advancements, transforming how organizations run and engage with their clients. Radio Frequency Identification (RFID) and Quick Response (QR) codes have been developed as important instruments for controlling and tracking a variety of assets, goods, and services among these transformative technologies. While RFID has been widely embraced across industries, the possibility of QR code technology as a workable replacement or addition to RFID systems has been prompted by its growing popularity and versatility. The use of QR Codes and RFID tags has changed substantially over the past few years [5]. Originally used to track products in the business, these technologies have now helped to create a number of fresh ideas that merge the real world with the virtual one. RFID is defined as the usage of a wireless non-contact technology that transmits data from a tag affixed to an object using radio-frequency electromagnetic fields for automatic identification and tracking [8]. On the other hand, QR codes are a very

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practical approach to displaying a tiny amount of information that is readily scanned and processed primarily by mobile devices. By supplying information that is easily scanned, like a website URL, QR codes enable physical items to nearly become interactive.

Transitioning from RFID (Radio Frequency Identification) to QR code technology can have several implications depending on the specific use case and industry. The purpose of this study is to explore the implications of transitioning from RFID to QR code technology with a particular focus on its application for toll fee payments on expressways (i.e. TPLEX and NLEX). By examining the strengths and weaknesses of these technologies, we seek to provide valuable insights and recommendations for expressway corporations considering a transition or integration of these technologies into their operations.

1.1. Rationale of the Study

The study aims to assess the implications of transitioning from RFID to QR Code technology as a payment method in tollways. The main objective of this study is to Identify the factors that influence the choice of the users in the transition of these technologies, determine the benefits/advantages of using RFID and QR Codes, assess which technology is the most effective as a payment method in tollways, analyze the findings and interpret the results.

1.2. Background of the Study

Tollway systems play a critical role in modern transportation infrastructure, facilitating the efficient movement of vehicles between destinations. Over the years, various payment methods have been introduced to enhance the ease and speed of transactions for motorists.

Notably, Radio-frequency Identification (RFID) technology has been adopted as a means of contactless payment, streamlining toll collection processes. It was originally invented in 1980 by Charles Walton, and it is a technology that uses a radio to transmit information [1]. The device picked up popularity until it was created into a passive radio transponder with memory in 1973 to be utilized as a toll gadget. As demand developed for huge item inventories, a more capable innovation was required to keep track of individual items, which is where the present-day frame of RFID was put into activity.

RFID uses radio waves to recognize and track objects with labels. These labels are associated with other objects based on an electronic chip, in which the chip transmits the stock number to a radio wire and, after that, an RFID reader.

It enables real-time identification, tracking, and monitoring of different resources, items, or people. RFID frameworks have found wide applications in supply chain administration, stock control, resource following, get-to-control, and numerous other domains.

There are two kinds of RFID tags: active and passive tags. Active RFID tags are powered by a battery, making them clear from a distance up to hundreds of meters and passive RFID tags are powered by the radio waves themselves, and in either case, an extraordinary RFID reader is required to transmit the information from the RFID tag to the computer database. Their information capacity is completely adaptable depending on the setting [1].

However, in recent times, Quick Response (QR) code technology has emerged as an alternative, offering a different set of advantages and challenges. In 1994, QR Codes were, too, created to progress product inventory management systems; in any case, it does not utilize any radio-based innovation. QR codes are two-dimensional barcodes that can be checked utilizing smartphones or dedicated QR code perusers. They can store a significant sum of information, URLs, content, contact data, and more. They are commonly utilized in showcasing, publicizing, ticketing, instalment frameworks, and differeNt other applications.

QR code-based innovation gives high ease of access to the client users since it requires no special labels, such as RF labels. QR codes are made exceptionally effortlessly. As a result, they can be printed on any surface such as paper or plastic labels or any other surface), and they do not require any more specialized than a printer [4]; [7]; [10].

Since smartphones are broadly utilized over different life domains, reading and translating QR codes has ended up much easier than utilizing frameworks based on complex innovation. A QR code framework has another advantage over RFID-based frameworks: since reading QR codes requires closer vicinity, it is nearly impossible to read an undesired code. From this viewpoint, QR code reading is unambiguous because it requires close vicinity of the reader gadget to examine the code [4]; [7]; [10]. QR code-based innovation is additionally prevalent in other ways, such as higher information storage capacity, lower usage cost, technical simplicity, broad use, and broadly accessible, free programs for reading and translating by camera-equipped smartphones.

This transition from RFID to QR codes presents a significant shift in the payment landscape within tollways. As the transportation industry continues to evolve, understanding the implications of this transition is essential for policymakers, toll operators, and motorists alike. Therefore, this study aims to delve into the consequences of adopting QR code technology as an alternative payment method for motorists in tollways. By investigating factors such as efficiency, cost-effectiveness, user satisfaction, and potential obstacles, this research seeks to provide valuable insights that can inform decision-making processes within the tollway industry and contribute to a more seamless and user-friendly experience for all stakeholders involved.

Hence, this study will serve as a premise to assess the implications of transitioning from RFID to QR codes and help the users make informed decisions regarding the potential benefits, costs, information capacity, and security suggestions related to the transition. Conducting this study is particularly significant in the present day due to its relevance to a wide range of contemporary issues, from health and sustainability to user experience and technological integration. It offers valuable insights that can inform the development of transportation infrastructure and payment systems for the future.

1.3. Conceptual Framework

The study aims to explore the implications of transitioning from RFID to QR Code technology as a payment method in tollways. As for the conceptual framework, the researchers employed the independent-dependent variable diagram. In the study, the independent variable is the choice of payment technology, which is RFID and QR Code, and the dependent variable is the implications or outcomes of this choice or transition (Figure 1).
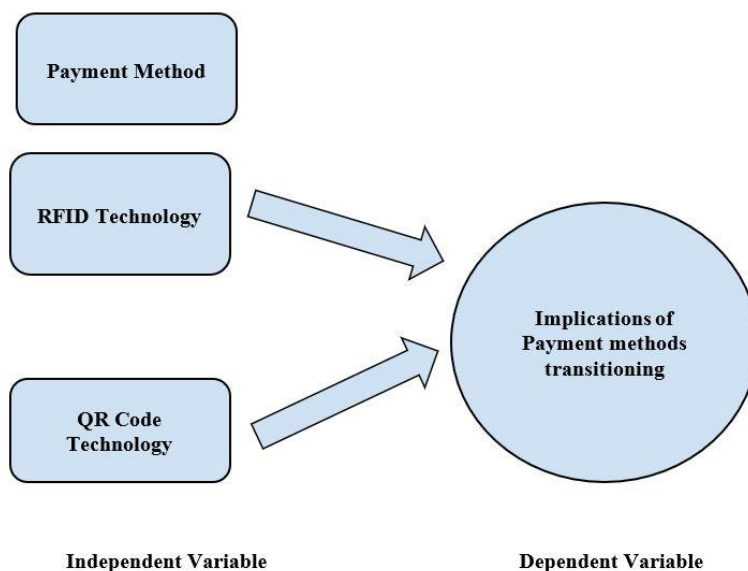
Figure 1: Conceptual Paradigm

1.4. Statement of the Problem

- What are the factors that influence the choice of the users in the transition from RFID to QR Code technology?
- What are the benefits/advantages of using QR codes vs RFID?
- What is the most effective RFID or QR?

1.5. Scope and Limitations of the Study

The study is limited to the respondents to the written interview questionnaire. The primary attention of this study is to explore the implications of transitioning from RFID to QR Code technology as a payment method in tollways.

1.6. Significance of the Study

The research is significant as it addresses practical issues in the tollway industry, contributing to the efficient functioning of transportation infrastructure and enhancing the experience of motorists and toll operators alike.

To the Tollway Authorities and Operators: This study is beneficial for the tollway authorities and operators to make informed decisions about the adoption of payment technologies. The study's insight can help them optimize toll collection processes, reduce operational costs, and enhance user experience.

To the Motorist: This study will benefit the motorist by knowing the improved and efficient payment methods. Understanding the implications of the transition can lead to efficiency and more convenient payment options.

To the Government and Policy Maker: This study is beneficial to the government and policymakers as they can use the study's results to develop policies and regulations that support the integration of advanced payment technologies into transportation infrastructure. This can contribute to improved transportation efficiency and safety.

To the Technology Providers: Companies that offer RFID and QR code technology solutions can gain insights into user preferences and the market demand for their products. This information can guide product development and business strategies.

To the Financial Institutions: Financial institutions involved in payment processing can adapt their services and infrastructure based on the preferences of tollway users, potentially offering new payment solutions.

To the Data Privacy Advocates: The study's examination of security and privacy aspects can be beneficial to individuals and organizations concerned with data protection and privacy in digital transactions.

Academic and Research Community: Researchers and scholars in the fields of transportation, technology, and urban planning can use the study as a reference and foundation for further research in related areas.

In essence, a wide range of stakeholders, including those involved in transportation management, policy-making, and technology development, will find value in the findings of this study. It has the potential to impact various facets of tollway operations and user experience positively.

1.7. Definition of Terms

The definition of terms are as follows:

Tollways: As used in the study, it refers to highways or roadways where motorists are required to pay a fee or toll to use the infrastructure, and these are typically collected through various payment methods.

RFID Technology: In the context of the study, it refers to the use of RFID tags or cards that are attached to vehicles, allowing for automatic and contactless toll payment as the vehicle passes through RFID-enabled toll booths. RFID technology is widely known for its ability to quickly and efficiently process toll payments without the need for physical contact.

QR Code Technology: In the study, QR code technology is the method by which motorists can make toll payments by scanning a QR code displayed at the toll booth or on a mobile app. It is a contactless payment technology that has gained popularity for its ease of use and versatility.

Motorist: In the context of the study, a motorist refers to the users of tollways who are responsible for paying tolls for the use of the infrastructure.

These definitions should provide a clear understanding of the key terms used in the study and help establish a common understanding of the subject matter.

2. Review of Related Literature and Studies

This paper presents a review of the study taken from sources such as articles, journals, and theses, including synthesis. The researchers have gone through intensive readings of materials in online sources that are believed to be helpful in the advancement of awareness concerning the study. The literature gathered consists of information regarding the implications of the transition of RFID to QR code technology.

2.1. RFID as a payment method in Tollways

RFID was proposed and introduced to the country by Japan last July 2013 in a forum attended by 61 individuals from different organizations in the Philippines such as DPWH, MMDA, DOTC, NEDA, TRB, NCTS, O&M Company, Japan Embassy, JICA

Manila and JIDA Study Team. The forum objective is to explain the objective, scope, work, schedule, study procedure and methodology of the study and to introduce the current status and future directions of the Intelligent Transport System in the Philippines [9].

Currently, there are 9 expressways in the Philippines, according to expressways.fadom.com, and there are 2 kinds of RFID systems being used this is EASYTRIP and AUTOSWEEP. All expressways are using the RFID system for motorist convenience and efficiency. In addition, this will reduce cash handling and fast data collection and also bring environmental benefits by reducing the need for vehicles to idle at toll booths. RFID technology can help reduce fuel consumption and emissions, contributing to environmental sustainability. RFID systems are still in continuous improvement and modification. Using RFID has a high implementation cost. In addition, it needs to resolve the issues for privacy and compatibility and it is vulnerable to hacking.

The use of RFID for tollway payments in the Philippines has been expedited during the COVID-19 pandemic under the Department of Transport Department Order 2012-012 [6], which requires cashless or contactless transactions for all vehicles travelling on toll expressways. The Order was implemented initially as a measure to mitigate the transmission of COVID-19 and, subsequently, as a means to ensure a more efficient flow of traffic within expressways.

However, the implementation of cashless payments brought about more traffic congestion at the onset, and it appeared that motorists are still inclined on the traditional cash payment method. There are bottlenecks on the Cash Lanes, and only a few motorists pass on the RFID Lanes. Installation sites were also full of motorists, which brought more traffic. Currently, although the majority of the lanes on toll gates are converted to RFID lanes, tollway corporations still retain 2 to 3 Cash lanes to accommodate motorists with no RFID tags; these lanes still cause bottlenecks on toll gates.

It should also be noted that, currently, during rush hours in the Morning and Evening, there is still a build-up of traffic in toll gates, even in the RFID lanes, which can be attributed to RFID system downtimes and readability issues on RFID tags. Another concern is the user experience; apart from the installation concerns, it should also be noted that to top-up or "Load" on the RFID tags, motorists should line up in loading stations, which also causes traffic, or transfer digitally through online banking or e-wallets which requires additional processing fees. These issues lead to the consideration of possible alternatives to the use of RFID as a tollway payment mode.

2.2. QR Code as a payment method

Although no tollway operators in the Philippines have adopted the use of QR Code as a possible alternative to the RFID for tollway payments, several studies and forecasts revealed that the Philippines' high smartphone penetration and high percentage of unbanked population is conducive to the adoption of QR code payments not only for Point of Sale transactions but also as transportation payments.

A study conducted on the development of QR Code-Based Mobile Payments in East Asia [3] revealed that China is one of the leading countries active in adopting QR codes in transmitting payment information. Its neighbouring countries, Japan, Singapore and Hong Kong, are lagging despite being the earliest adopters of contactless payments. The reason behind China's lead as compared to its neighbours is attributable to differences in consumers' ownership of bank accounts, credit and debit cards, and smartphones. China's unbanked population is significantly higher, while its smartphone ownership rate is higher than those of its neighbours. Limited payment methods, coupled with a relatively high rate of smartphone ownership, led China to leapfrog the use of cards, going straight from cash to mobile payments once mobile wallets were introduced. The same circumstances are observed in the Philippines, having a high percentage of unbanked population but with a high rate of smartphone ownership.

A forecast of Smartphone penetration in the Philippines [11] revealed that there will be a continuous increase in smartphone penetration between 2024 to 2028, with a peak at 47.14%. This will be conducive to a more mobile-based payment economy, including QR Code, considering almost half of the population has access to smartphones, which will allow contactless mobile payments.

Moreover, the 2021 Financial Inclusion Survey report [2] revealed that 44% of the adult population, or 34.3 million adult Filipinos, remain unbanked. Out of those with formal accounts, 36% owned e-money accounts (i.e. e-wallets like gcash). This revealed that still a lot of Filipinos remain unbanked, which may be attributed to a lack of financial literacy or the complication of requirements of owning a formal account. It can be further noted that, out of those with formal accounts, the majority only owned an e-money account, not a formal bank account. This can be attributed to the easy registration of e-wallets and easy access through smartphones. These circumstances, similar to China, open up the possibility that the Philippines can also be a leading country in terms of the use of mobile payments, including QR codes.

2.3. Difference of RFID and QR Codes

QR codes and RFID offer unique features and capabilities for data encoding, transmission, and retrieval. The choice between the two depends on the specific use case, desired functionality, budget considerations, and the level of security and scalability needed. By leveraging the unique features of QR codes and RFID, organizations can enhance data management, streamline processes, and provide engaging customer experiences. Table 1 indicates the major differences between RFID and QR codes according to tritonstore.com.au.

Table 1: Comparison of QR Code versus RFID Technology

Criteria	QR Code	RFID
Reading Method	Scanned using smart devices or a dedicated QR Code Reader	Transmits data wirelessly to an RFID reader using Radio Waves
Technology Used	Two-Dimensional Barcode System	Radio waves
Data Storage	Few bytes to several kilobytes	Few bytes to several kilobytes or even more
Range and Interaction	Requires proximity between the scanner and the code	It can be read from a few centimetres to several meters away
Cost and Complexity	Relatively simple and inexpensive to implement, it can be printed on a piece of paper or displayed on a screen	RFID tags, especially active ones, are more expensive and complex to implement and required specialized hardware for reading and writing
Capacity and Speed	Hols less data than RFID tags	It can typically hold more data and be read more quickly and simultaneously
Application and Usage	Used for ticketing, inventory management system, tracking shipments, etc.	Used in inventory tracking, Supply chain management, Access control, contactless payment systems, asset tracking, animal tracking, etc.
Cost and Scalability	Scalable and can be produced in large quantities at a low cost	Cost depends on the type of RFID System, tag functionality, and required range
Security and Privacy	Can be easily replicated or tampered with	It can be encrypted, and data can be protected

2.4. Synthesis of Related Studies and Literature

As discussed above, while the use of RFID for toll payments has already been in effect in all expressways in the country, recent studies and research conducted show that the QR Code technology offers an alternative that may be cheaper, faster, convenient and secure. The difference in the technology used range and interaction, cost and complexity, capacity, speed and security makes QR technology a viable alternative to RFID in terms of toll payments. However, related studies and literature available are conducted/written during pre-covid 19 or the Covid-19 pandemic. No available data yet on the advantages and acceptance of transitioning from RFID to QR Code technology after the pandemic, where restrictions are lifted and businesses are slowly moving into the new normal. This is the research gap that this study will aim to answer through conducting a Focus Group Discussion (FGD) with toll-way employees using the expressways on a daily basis in the post-Covid 19 period.

3. Methodology with Ethical Considerations

This paper presents the research design, the respondents' profile, the location where the study will be done, the population and sample of the study, the sampling technique used, the research instruments, the data gathering procedure, and the statistical instrument used by the researchers of this study.

3.1. Research Design

The research design used in this study is a semi-structured interview or focus group discussion with a subset of participants to explore in-depth qualitative insights. Capture nuanced responses to challenges and recommendations. It involves collecting data from employees of Tollway Companies, specifically NLEX (North Luzon Expressway) and TPLEX (Tarlac-Pangasinan La Union Expressway), to determine the impact or implications of transitioning from RFID to QR codes technology as a payment method in tollways.

3.2. Research Subject

This research was conducted on the employees of Tollway Companies, specifically NLEX (North Luzon Expressway) and TPLEX (Tarlac-Pangasinan La Union Expressway). It is performed with a sufficient number of participants from the tollway employees and management to achieve data saturation and capture diverse perspectives.

3.3. Research Locale

The study made by the researchers will focus on motorists mostly travelling to North and NCR (National Capital Region), where the transition from RFID to QR code technology is actively taking place or has recently occurred. The researcher chose North and NCR travellers with a significant volume of traffic to ensure a diverse range of experiences and perspectives.

3.4. Population and Sample of the Study

In this study, the researcher's target population are employees from Tollway Companies, specifically NLEX (North Luzon Expressway) and TPLEX (Tarlac-Pangasinan La Union Expressway), who are available and willing to participate in the study and can answer the survey questionnaire.

3.5. Sampling Techniques

The researchers will use convenience sampling in selecting respondents to participate in the study. Which, motorists who are using QR code/ RFID as a payment method in passing by the tollways are selected based on their availability and willingness to take part in the study and can answer the survey questionnaire. Convenience sampling will be utilized since bus drivers may be a specific and somewhat hard-to-reach population. Using convenience sampling can make it easier to access this group of individuals, saving time and resources.

In the study of Stein [12] used convenience sampling to select the respondents in the study. The total number of respondents of their study is (30) thirty. The respondents included in their study were all pregnant women attending the two antenatal clinics and willing to be interviewed by the researcher excluded from the study were those respondents not willing to participate in the study, pregnant women younger than 18 years of age, and mentally ill or mentally retarded pregnant women attending the antenatal clinic with no guardian to give informed consent. The researcher interviewed five respondents each day from among the women patients waiting to be seen in a clinic. The main assumption associated with convenience sampling is that the members of the target population are homogeneous. This sampling method should be used with caution as the respondents may be atypical and introduce bias into the study. To prevent bias, only respondents who met the criteria were selected.

3.6. Research Instruments

The researchers employed a survey questionnaire as a technique to obtain and collect data or information from respondents, with the formed questions focusing on determining the impact or implications of transitioning from RFID to QR code technology as a payment method in tollways. The questionnaire includes the following sections:

- Demographic Profile of the Respondents: This section collects information about the respondents' demographic characteristics such as gender, age, vehicle type, occupation and frequency of using the expressway. These demographic factors can provide insights into how tollway operators perceive the implications of transitioning from RFID to QR code technology as a payment method in tollways.
- Factors Affecting in transitioning from RFID to QR code technology as a payment method in tollways: This section explores the various factors that can influence transitioning from RFID to QR code technology as a payment method in tollways. The questionnaire may include questions about familiarity with RFID and QR codes. The opinion about the feasibility of transitioning from RFID to QR code technology as a payment method in tollways. The advantages and disadvantages of using QR Codes.

- Effect or implications in transitioning from RFID to QR code technology as a payment method in tollways: This section explores the impact or effectiveness of transitioning from RFID to QR code technology as a payment method in tollways. The questionnaire may include questions about the payment efficiency using a QR code. The consideration/concerns regarding the use of QR Code for Tollway. It is cost-efficient, and the overall experience if the QR code is utilized.

The survey questionnaire aims to gather comprehensive data on the implications of transitioning from RFID to QR code technology as a payment method in tollways and its impact on motorists. This data will enable the researchers to identify what are the implications of transitioning from RFID to QR Code.

3.7. Data Gathering Procedure and Validation of Instruments

The researchers will have two data-gathering procedures: primary data and secondary data. First, the primary data will be gathered through a survey questionnaire. The questionnaire is submitted for verification to analyze and approve the questionnaire. The researchers let the respondents first give a consent form for their approval, then administered the questionnaires, including the Demographic Profile, which is the personal information Questionnaire. Then, the researchers distributed questionnaires among the target respondents and waited to finish answering to get their final results. The data to be collected will be tallied with the use of Microsoft Excel. On the other hand, secondary data will be gathered through internal sources such as online articles, journals, and thesis.
Ethical Consideration Section

3.7.1. Voluntary Participation and Withdrawal

Participation is completely voluntary. The participants are at least 18 years of age, and they are aware that they may choose to terminate their participation in the study at any time and for any reason. The study would not require the participant to indicate their name and other personal and/or confidential information. Basic personal details, however, are necessary for the students profiling. Regardless, all received data will be confidential and will not be released. The participants may withdraw from the research by informing the researchers through writing, verbally, or by failure to further participate in the study. By the said withdrawal, the participant's information and data will no longer be collected.

3.7.2. Removal for Research and Termination of Research

A participant in this research study has the freedom to withdraw at any time. When withdrawing from the study, the participant may inform the researchers of his/her decision. A participant may give the research team their reason(s) for leaving the study, but they are not obligated to do so. A participant may also be dismissed if there is a need to protect them from potential harm or if a scenario requires their removal to ensure data accuracy.

3.7.3. Potential Risk and Discomfort

The respondents may have to deal with information risk or discomfort in terms of confidentiality. The answers provided by the respondents in the questionnaire may consist of some of their policies in terms of their standards in choosing potential. Thus, possible discomfort might arise. Some statements used in the instrument might also be too straightforward; thus, the respondents are encouraged to answer neutrally if they were uncomfortable in doing so. However, unless the researchers have the express agreement and permission of the participant, the confidentiality of identifiable information and all data gathered in the survey is presumed in all aspects of the study and will always be safeguarded. The data gathered will be used academically and solely to determine the factors affecting their learning condition during online classes.

Direct Benefits: The potential benefits to be received by the subjects of this research, the researchers are as follows:

- Have the means of conveying their recommendations to the experience of bus drivers in using better payment methods in tollway.
- To communicate the suggestions of the researchers to the respondents
- The findings of this study will also help the drivers to be aware and improve their payment experience in using tollways

4. Compensation

The researchers will not provide any monetary or in-kind compensation to the respondents in exchange for the time and effort of the respondents for the fulfilment of this research study. Participation is fully voluntary.

4.1. Confidentiality and Disposal of the Data

The responses generated will remain confidential and anonymous in accordance with the Data Privacy Act of 2002. Data from this research will be kept where only the researchers have access. Only the researchers will be aware of the individual survey answers. The data collected from the participants as well as from those who would later decide to withdraw their consent, will be disposed of. After the use of the data gathered from the respondents, these collected data will then be disposed of. The data will only be kept as long as it is necessary. Disposal of data will be monitored; of what data is disposed of, when and how. Documentation of the disposal will be ensured. The respondents should also be informed that the data gathered from them is disposed of and confidentiality and anonymity are maintained. The data generated from their response will be used for academic purposes only, solely for the research, and only the general summarized results will be used publicly if needed.

5. Analysis, Results, and Discussion

In this paper, the results of the study are presented, providing an in-depth analysis of user perceptions regarding tollway payment systems. The research aimed to compare the effectiveness and user satisfaction associated with RFID and QR code technologies. The findings are presented through qualitative responses where certain limitations were implemented. A comprehensive data analysis was performed to extract more granular insights. Here are the data analysis components based on the given questionnaires:

Time Efficiency: QR code technology is known for its swift readability, enabling quicker transactions at toll booths. The simplicity and speed of scanning QR codes contribute to reduced waiting times for users, leading to a more time-efficient toll payment process compared to RFID.

Faster Readability: The quick readability of QR codes plays a crucial role in expediting the payment process. Unlike RFID, which requires proximity and line-of-sight for communication, QR codes can be scanned rapidly from a distance, allowing for faster and more efficient tollway transactions.

Convenience: QR code technology offers a high level of convenience to users. The ease of generating and displaying QR codes on mobile devices makes it a user-friendly option. Users can present their smartphones for scanning, eliminating the need for additional physical devices like RFID cards or tags. This convenience contributes to a smoother and more accessible toll payment experience.

Cost Efficiency: QR code technology is often perceived as a cost-effective solution for tollway payments. The implementation and maintenance costs of QR code systems are generally lower compared to RFID infrastructure. Additionally, users can easily adopt QR code technology using their existing smartphones, reducing the need for expensive RFID tags or cards. This cost efficiency is a notable advantage in the widespread adoption of QR code payment systems (Table 2).

Table 2: What do you see as the primary advantages of QR code technology over RFID for tollway payments?

Feature	QR Code	RFID
Readability	Faster	Slower
Convenience	Easier to use	Requires specialized hardware
Cost	Less expensive	More expensive
Security	Can be encrypted	Less secure
Versatility	Can store more information	Can only store a limited amount of information
Scalability	More scalable	Less scalable

In summary, the primary advantages of QR code technology time efficiency, faster readability, convenience, and cost-effectiveness highlight its suitability for tollway payments, providing a seamless and user-friendly experience for both operators and users alike (Table 3).

Table 3: What do you see as the primary challenges or disadvantages of transitioning to QR code technology for tollway payments?

Challenge	Description
Initial costs	Implementing QR code technology would require an initial investment in hardware and software.
Adaptability	Commuters may need to adjust their habits to use QR codes for toll payments.

Technology issues	QR codes can be affected by technical glitches, such as poor internet connectivity or software bugs.
Security concerns	QR codes can be forged or intercepted, potentially leading to fraudulent transactions.
User Acceptance	Not all commuters may be comfortable using QR codes for toll payments.

In summary, transitioning to QR code technology for tollway payments offers potential advantages in terms of convenience and faster transaction speeds. However, careful consideration should be given to the initial costs, adaptability challenges, technology risks, and security concerns before deciding to implement QR code technology. The success of QR code adoption will depend on addressing these challenges and ensuring a smooth transition for both tollway operators and commuters.

How do you think the transition from RFID to QR code technology may impact tollway payment efficiency and waiting times? As a result of these advantages, QR code technology has the potential to significantly improve tollway payment efficiency and reduce waiting times at toll plazas. This can lead to several benefits, including:

Reduced Congestion and Traffic Jams: Shorter processing times at toll plazas can help reduce congestion and traffic jams, leading to smoother traffic flow and improved travel times for commuters.

Enhanced Driver Satisfaction: Faster and more convenient toll payments can improve driver satisfaction and reduce frustration, leading to a more positive commuting experience.

Cost Savings for Tollway Operators: Efficient toll payment systems can reduce labour costs associated with toll collection and minimize maintenance expenses.

Environmental Benefits: By reducing congestion and vehicle idling, QR code technology can contribute to lower emissions and improved air quality.

While there may be some initial costs associated with transitioning to QR code technology, the potential long-term benefits in terms of efficiency, convenience, and cost savings make it a compelling option for tollway operators. In summary, the anticipated impacts of transitioning from RFID to QR code technology include expectations of increased efficiency, faster transaction times, and improvements in traffic flow by quickly processing payments, but also a recognition of the potential need for additional costs to facilitate the technological shift.

What security considerations or concerns do you have regarding the use of QR code technology for tollway payments?

Mas ligtas at mas mabilis (More secure and faster): This interpretation suggests that QR code technology is a more secure and faster option for tollway payments than traditional methods, such as cash or credit cards. QR codes are difficult to counterfeit and can be scanned, which can help to reduce traffic congestion.

None that I can think of: This interpretation suggests that the person does not have any security concerns regarding the use of QR code technology for tollway payments. They may believe that QR codes are secure enough for use in this application, or they may not be familiar with the potential security risks.

No idea: This interpretation suggests that the person does not know enough about QR code technology to assess its security risks. They may not be familiar with how QR codes work, or they may not be aware of the potential security vulnerabilities that exist.

Misused of QR code (Misuse of QR code): This interpretation suggests that the person is concerned about the potential for QR codes to be misused for tollway payments. For example, QR codes could be used to create counterfeit tickets, or they could be used to steal personal information from unsuspecting drivers.

In summary, the results suggest a range of perspectives on security considerations for QR code technology in tollway payments, including positive perceptions of safety and speed, a lack of identified concerns, a lack of knowledge about potential issues, and a specific concern about the misuse of QR codes. Each response reflects different attitudes toward the security aspects of adopting QR code technology in tollway payment systems.

Do you anticipate any cost savings for tollway operators or users by transitioning to QR code technology? If so, please explain. Based on the responses provided, it seems likely that there are potential cost savings for both tollway operators and users by transitioning to QR code technology. However, the specific amount of savings will likely vary depending on the specific circumstances of each tollway.

For tollway operators, the potential cost savings from QR code technology include:

- Reduced costs for implementing and maintaining toll-collection equipment
- Reduced costs for producing and distributing toll stickers
- Reduced labor costs for toll collection

For tollway users, the potential cost savings from QR code technology include:

- Eliminated costs for purchasing toll stickers
- Eliminated fees for reloading toll stickers
- Reduced travel time due to faster transactions

Overall, it seems that QR code technology has the potential to be a cost-effective solution for tollway payments. However, more research is needed to determine the specific amount of savings that can be achieved.

How do you think this transition might affect the overall user experience for tollway users?

The responses collectively convey an optimistic perspective on how the transition to QR code technology might influence the overall user experience for tollway users. The first response suggests that users might initially find the change unfamiliar, but it emphasizes the positive aspect of adapting to more advanced technology. The second response directly links the transition to an improvement in user experience by anticipating a reduction in waiting times at toll gates. The third response emphasizes positive effects overall, highlighting the convenience associated with QR code technology. The fourth response succinctly expresses a strong positive sentiment, stating that the transition is expected to be "very convenient." In summary, the consensus among respondents is that the adoption of QR code technology in tollway transactions is likely to bring about positive changes, enhancing user experience through advancements, reduced waiting times, and overall convenience.

On a scale of 1 to 5, how would you rate your overall perception of transitioning from RFID to QR code technology for tollway payments? (1 = Strongly Disapprove, 5 = Strongly Approve)

The provided responses indicate a generally positive perception of transitioning from RFID to QR code technology for tollway payments, with ratings ranging from 4 to 5 on a scale of 1 to 5. The consistently high ratings suggest a strong approval of the transition, reflecting a favourable outlook on the potential benefits and improvements associated with adopting QR code technology. The respondents, on average, perceive the shift positively, indicating a belief that QR code technology is likely to enhance the tollway payment experience. The ratings align with expectations of efficiency, convenience, and positive impacts on user experience, as discussed in previous responses. Overall, the collective ratings suggest a high level of approval and optimism regarding the transition to QR code technology for tollway payments.

Please provide any additional comments or insights you have regarding this transition and its potential impact on tollway systems.

Overall, the respondents are supportive of the transition to QR code technology for tollway payments. They believe that QR codes offer several advantages over RFID tags, including increased convenience, reduced costs, and improved security. However, they also acknowledge the importance of carefully considering the costs and time involved in making the switch. Here are the most specific insights from the responses:

Response 1: "Keep it up."
- This response expresses support for the transition to QR code technology and encourages continued efforts in this direction.

Response 2: "I think transitioning will be feasible; however, the costs and time of adjustments due to the transition should be considered."
- This response acknowledges that the transition to QR code technology is feasible, but it is important to consider the costs and time involved carefully.

Response 3: "I think this will make it more convenient for customers to travel as it provides quick services than paying in cash."
- This response highlights the convenience of QR code technology for tollway payments. QR codes can make the payment process faster and more efficient, which can improve the customer experience.

Response 4: "Transitioning in QR code will be much easier."
- This response expresses confidence that the transition to QR code technology will be easy. QR code technology is relatively simple to implement and adopt, which can make the transition less challenging.

Based on these insights, it is clear that there is strong support for the transition to QR code technology for tollway payments. Tollway operators should carefully consider the potential benefits and challenges of this transition before making a decision. However, the overall consensus is that QR code technology has the potential to make tollway payments more convenient, efficient, and secure.

The need for additional adjustments for both tollway companies and users, potential issues with gadgets such as poor internet connection and bugs, and security concerns pose significant considerations. Addressing these challenges requires strategic planning, user education, and robust technological infrastructure development. The anticipated impacts on efficiency and waiting times are generally positive, with expectations of faster transactions and reduced congestion at toll plazas. Yet, the acknowledgement of additional costs for machine and system changes the need for a balanced approach to the transition. Security considerations present a mix of perspectives, with some expressing confidence in QR code security while others highlight concerns about potential misuse. Striking the right balance between convenience and security is crucial for fostering user trust in QR code technology. The overall user experience is expected to improve, with initial adjustments giving way to the benefits of advanced technology. Reduced waiting times and increased convenience are recurring themes in user responses, reflecting a positive outlook on the transition.

The favourable ratings on a scale of 1 to 5 indicate a strong overall approval of transitioning to QR code technology for tollway payments. Users perceive this shift as a positive step toward efficiency and convenience in tollway transactions. Additional comments and insights from respondents' express support for the transition, with emphasis on the feasibility and convenience for customers. Acknowledgement of potential costs and the need for careful consideration indicates a pragmatic approach to the transition.

6. Conclusion

A multifaceted panorama of advantages, problems, and user perceptions is shown by the research that was conducted on the shift from radio frequency identification (RFID) technology to QR code technology in tollway payments. The advantages of QR code technology, which include the capacity to save time, read it more quickly, provide convenience, and potentially reduce costs, highlight the potential for this technology to transform the payment systems used for tollway. The fact that users anticipate a more streamlined and user-friendly experience using QR codes is indicative of a favourable shift in the landscape of toll payment. The transition to QR code technology in tollway payments presents exciting prospects for improved efficiency and user experience. However, in order to ensure that it is successfully implemented, it is imperative that careful planning, addressing challenges, and ensuring a balance between convenience and security be carried out. In order to give tollway operators relevant counsel, the pooled insights of users and workers provide valuable direction. This guidance encourages a careful and user-centric approach to technological improvements in tollway payment systems.

6.1. Recommendation

To facilitate a successful transition, tollway operators should embark on comprehensive planning and analysis. This involves conducting meticulous feasibility studies and cost-benefit analyses to ascertain the financial implications of implementing QR code technology. A thorough understanding of initial costs, long-term savings, and potential benefits to both operators and users is crucial for informed decision-making. Recognizing the challenge of adaptability, tollway operators must prioritize user education and support programs. Clear communication, instructional materials, and accessible customer support are integral components of a proactive strategy to guide and support users during the transition, ensuring a seamless adaptation process. Furthermore, the development of a robust technological infrastructure is paramount. Tollway operators should address potential issues related to technology glitches, ensuring seamless integration of QR code systems. Regular maintenance and updates are essential to guarantee the reliability and functionality of the technology. Security concerns necessitate the implementation of stringent security measures. Tollway operators should focus on encryption and secure authentication protocols to safeguard QR code transactions, fostering user trust and mitigating the risk of potential misuse. Continuous monitoring and improvement strategies are critical for the sustained success of QR code technology. Tollway operators should establish mechanisms for ongoing assessment, incorporating user feedback and advancements in technology to enhance the system's effectiveness over time. By adhering to these recommendations, tollway operators can navigate the transition to QR code technology with confidence, realizing the potential advantages while proactively mitigating challenges. The seamless integration of QR code technology stands as a transformative step toward revolutionizing tollway payment systems, offering users a more efficient and convenient experience and contributing to the overall advancement of transportation infrastructure. Recommendations for Future Research:

- Investigate the long-term impacts of the transition on user behaviour and satisfaction.
- Explore the perspectives of tollway operators and technology providers in subsequent studies.

Appendix

Survey Questionnaire

Exploring the Feasibility and Implications of Transitioning from RFID to QR Code Technology for Tollways

Directions: Please answer the following questions with HONESTY and SINCERITY and to the best of your knowledge and experience. You will be presented with information relevant to our research study.

Your input is essential for our research on the transition from RFID to QR code technology for toll-way systems. Rest assured that your answers will be kept highly confidential.

Section 1: Demographic Information

Name:
      Contact Detail:
      Email Address:
Gender:
- Male
- Female
- Prefer not to say

Age:
- Under 18
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 or older

Do you live in or frequently use tollways in the Philippines?
- Yes
- No

Do you have a valid driver's license?
- Yes
- No

What type of vehicle do you primarily drive on tollways? (Check all that apply)
- Car
- Motorcycle
- Truck
- Bus
- Other (please specify): _____

Are you a frequent tollway user?
- Daily
- Weekly
- Monthly
- Seldom
- Never

Section 2: RFID and QR Code Technology

Are you familiar with RFID technology for tollway payments?
- Very Familiar
- Somewhat Familiar

- Not Familiar

Are you familiar with QR code technology for tollway payments?
- Very Familiar
- Somewhat Familiar
- Not Familiar

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Section 3: Transition Feasibility

In your opinion, do you think transitioning from RFID to QR code technology is feasible for tollway payments in the Philippines?

- Yes
- No
- Not sure

What do you see as the primary advantages of QR code technology over RFID for tollway payments?

What do you see as the primary challenges or disadvantages of transitioning to QR code technology for toll-way payments?

Section 4: Implications of the Transition

- How do you think the transition from RFID to QR code technology may impact tollway payment efficiency and waiting times?
- What security considerations or concerns do you have regarding the use of QR code technology for toll-way payments?
- Do you anticipate any cost savings for tollway operators or users by transitioning to QR code technology? If so, please explain.
- How do you think this transition might affect the overall user experience for tollway users?

Section 5: General Perception

- On a scale of 1 to 5, how would you rate your overall perception of transitioning from RFID to QR code technology for toll-way payments?

(1 = Strongly Disapprove, 5 = Strongly Approve)

- Please provide any additional comments or insights you have regarding this transition and its potential impact on toll-way systems.

Thank you for taking the time to complete this survey. Your input is essential for our research on tollway payment technologies.

Conflicts of Interest Statement: No conflicts of interest are declared by the author(s). This is the authors' fresh work. Citations and references are mentioned as per the used information.

Ethics and Consent Statement: The consent was taken from the colleges during data collection, and they received ethical approval and participant consent.

References

1. S. Amsler and S. Shea, "RFID (radio frequency identification)," IoT Agenda, 31-Mar-2021. [Online]. Available: https://www.techtarget.com/iotagenda/definition/RFID-radio-frequency-identification. [Accessed: 11-Feb-2023].

2. Banko Sentral ng Pilipinas. 2021 Financial Inclusion Survey Report, 2021. Retrieved from: https://www.bsp.gov.ph/Inclusive%20Finance/Financial%20Inclusion%20Reports%20and%20Publications/2021/2021FISToplineReport.pdf. [Accessed: 11-Feb-2023].

3. B. Hayashi, Developments of QR Code-Based Mobile Payments in East Asia, 2019. Retrieved from: https://www.kansascityfed.org/Payments%20Systems%20Research%20Briefings/documents/7599/psr-briefingjun2019.pdf. [Accessed: 11-Feb-2023].

4. Denso, ADC. QR code essentials. Denso Wave, 2011. Retrieved from: https://www.nacs.org/LinkClick.aspx?fileticket=D1FpVAvvJuo%3D&tabid=1426&mid=4802. [Accessed: 11-Feb-2023].

5. Department of Transportation - Department Order 2020-12 on Requiring Cashless or Contactless Transaction for all Vehicles Traveling on Toll Expressways. https://dotr.gov.ph/2014-09-02-05-03-02/11-issuances/7-department-orders.html#y2020. [Accessed: 11-Feb-2023].

6. M. Francisco, "Using RFID/NFC and QR-code in mobile phones to link the physical and the digital world," Interactive Multimedia, vol. 12, pp. 219–242, 2012.

7. R. I. García-Betances and M. K. Huerta, "A review of automatic patient identification options for public health care centers with restricted budgets," Online J. Public Health Inform., vol. 4, no. 1, 2012.

8. T. Lotlikar, "Comparative study of Barcode, QR-code and RFID System," International Journal of Computer Technology and Applications, vol. 4, no. 5, pp. 1-5, 2013.

9. Mega Manila Region Highway Network Intelligent Transport System (ITS) Integration Project. https://openjicareport.jica.go.jp/pdf/12122099_01.pdf. [Accessed: 11-Feb-2023].

10. T. J. Soon, "There are several types of 2D codes in use by the industry, one of which is QR Code. This article provides an overview of QR Code, the standardisation activities on this technology and its applications in the various sectors," Foxdesignsstudio.com. [Online]. Available: https://foxdesignsstudio.com/uploads/pdf/Three_QR_Code.pdf. [Accessed: 10-Feb-2023].

11. "Philippines: smartphone penetration as a share of population 2020-2029," Statista. [Online]. Available: https://www.statista.com/statistics/625427/smartphone-user-penetration-in-philippines/. [Accessed: 11-Feb-2023].

12. A. Stein, "RFID tags vs. QR Codes: What are the key differences to know?," QR Code Generator, 06-Feb-2023. [Online]. Available: https://www.qr-code-generator.com/blog/difference-between-rfid-tag-qr-code/. [Accessed: 10-Feb-2023].