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Research Article

A NodeMCU-Based Contactless Fare Management System for Tricycle Commuters

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ABSTRACT

As cashless transactions continue to gain popularity, digital payment solutions have become essential in various sectors, including public transportation. This study focuses on the development and implementation of a tricycle cashless payment system utilizing NodeMCU and Radio-Frequency Identification (RFID) technology. The system allows passengers to conveniently pay their fares by swiping an RFID card, eliminating the need for cash. It consists of an RFID reader, a NodeMCU microcontroller, a GSM module for data transmission, and a web server for real-time monitoring of fare transactions. The tricycle's battery serves as the primary power source, ensuring continuous operation. This innovation enhances efficiency in fare collection, reduces the risk of theft, and minimizes germ transmission through cash handling. Additionally, it promotes fair and accurate transactions for both passengers and drivers. The study encompasses hardware design, system development, and an evaluation of its effectiveness in real-world applications. Results indicate that the contactless payment system is both feasible and reliable, providing a modern alternative to traditional fare collection. Future improvements include replacing the GSM module with an Ethernet shield for more stable internet connectivity, enhancing the system's interface, and incorporating additional features such as travel history tracking for better user experience.

Keywords: *Radio-frequency identification, cashless, embedded system, tricycle fare, contactless payment*

1. INTRODUCTION

Radio-frequency identification (RFID) uses electromagnetic fields to automatically identify and track tags attached to objects. An RFID system consists of a tiny radio transponder, a radio receiver, and a transmitter. When triggered by an electromagnetic interrogation pulse from a nearby RFID reader device, the tag transmits digital data—usually an identifying inventory number—back to the reader. This number can then be used for tracking and identification purposes. [1]

Since its initial use during World War II to differentiate enemy and friendly aircraft, RFID has evolved into a crucial tool for identification, security, and automation. Recognized as a potential successor to traditional barcoding and other identification technologies, RFID offers a significant advantage with its contactless and non-line-of-sight functionality. In recent years, it has gained momentum as a transformative technology that enhances data handling processes across various industries. [2]

Cash transactions, while common, come with several disadvantages. Carrying cash increases the risk of theft and loss, and it lacks fraud protection. Additionally, physical money can act as a carrier of bacteria and viruses, raising health concerns—especially during the COVID-19 pandemic. Recognizing these risks, the World Health Organization has encouraged the adoption of digital and contactless payment methods to minimize physical contact and prevent the spread of infectious diseases. [3]

Similarly, credit and digital payment systems offer both benefits and challenges. Responsible use of these financial tools enables consumers to make essential purchases and manage expenses effectively. However, mismanagement can lead to financial burdens and increased debt. [4]

RFID is widely used across industries, from manufacturing and logistics to asset management and transportation. Its ability to collect real-time data reduces transcription errors, eliminates duplication, and enhances operational efficiency. By integrating RFID into fare collection systems, transportation services can streamline payment processes, improve commuter convenience, and ensure fair transactions. [5]

This study aims to develop a NodeMCU-based contactless fare management system for tricycle commuters**.** By integrating RFID technology with a NodeMCU microcontroller, the system will enable passengers to pay fares electronically, reducing the need for cash transactions. This innovation is particularly relevant in the wake of the COVID-19 pandemic, where minimizing physical contact remains a priority. The developed system ensures safer, faster, and more efficient fare collection, benefiting both tricycle drivers and commuters.

1.1 Related Literature

This section presents a review of relevant studies on contactless payment systems and fare management technologies.

RFID-based mobile payment systems (MPS) have emerged as innovative solutions that integrate with digital wallets and financial services to facilitate seamless transactions. These systems function similarly to bank cards, supporting both online and offline micropayments while also serving as an identification tool. The RFID technology embedded in these systems allows for automatic data transmission, eliminating manual input errors and streamlining payment processes. However, data privacy remains a critical concern, as users must ensure that sensitive information is protected from unauthorized access. [5]

Contactless smart card technology, powered by RFID, has gained widespread adoption in modern payment transactions. These smart cards provide a convenient alternative to cash, enabling faster and more secure financial exchanges. Many financial institutions and transportation systems worldwide have embraced RFID-enabled payment methods, revolutionizing how consumers conduct transactions. The ability to process payments with a simple tap has significantly improved efficiency in public transportation, retail, and other industries. [6]

Microcontroller-based platforms, such as NodeMCU, play a crucial role in the development of automated payment systems. NodeMCU is a low-cost, Wi-Fi-enabled microcontroller that facilitates wireless communication between devices, making it an ideal choice for contactless fare management applications. Similar to Arduino, NodeMCU allows for the integration of various sensors, RFID modules, and payment gateways, enabling real-time data transmission and processing. Its ease of programming and strong community support make it a preferred choice for developers working on smart transportation solutions. [7][8]

The implementation of contactless fare systems in public transportation offers numerous advantages. By eliminating the need for physical cash, these systems reduce transaction times, minimize the risk of theft, and ensure accurate fare collection. A well-structured and transparent fare management system benefits both commuters and transportation operators by improving efficiency and revenue accountability. [9]

Building on these existing studies, this research focuses on the development of a NodeMCU-Based Contactless Fare Management System for Tricycle Commuters**.** Unlike traditional fare collection methods, which rely on cash transactions, this innovation introduces a modern and efficient payment system specifically designed for tricycles**,** a mode of transport where such technology has not been widely implemented. The system leverages RFID technology to provide a secure, fast, and efficient payment process, ensuring fair fare collection and eliminating the need for direct cash handling.

This innovation is particularly beneficial for tricycle drivers and owners as it enhances operational efficiency, reduces the risk of fare disputes, and ensures proper fare remittance. For tricycle owners, the system offers a transparent and accountable method for tracking daily earnings, helping prevent revenue leakage. Additionally, by reducing reliance on physical cash, the system improves security and hygiene, making it a practical and forward-thinking solution for urban transportation.

1.2 Theoretical Framework

Radio Frequency Identification (RFID) is a widely used wireless identification technology that enables contactless data transmission. Similar to barcode identification, each RFID tag carries a unique identifier (UID), allowing it to be recognized within a system. A standard RFID system consists of three main components: the Tag, the Reader, and the Application. When an RFID tag comes within range of an RFID antenna, electromagnetic induction occurs, enabling the antenna to retrieve the encoded data from the tag. This information is then processed by the RFID reader, which translates it into computational data that can be used for tracking, authentication, and transaction processing. Because of its portability and seamless data transmission capabilities, RFID technology has been widely adopted for tracking, tracing, and automation in various industries. [10]

In embedded systems, microcontrollers play a crucial role in processing and executing programmed commands. NodeMCU, a microcontroller platform similar to Arduino, is a Wi-Fi-enabled microcontroller that facilitates wireless communication between devices, making it an ideal choice for contactless payment applications. It allows for real-time processing of RFID transactions, ensuring seamless communication between the RFID reader, payment interface, and database system. NodeMCU can function as a standalone system or be connected to networks and cloud platforms, enabling automated fare collection and remote monitoring of transactions. [11]

In the context of this study, the integration of RFID and NodeMCU forms the foundation of the NodeMCU-Based Contactless Fare Management System for Tricycle Commuters. The RFID technology enables secure and efficient fare transactions, while NodeMCU processes the payments in real-time, ensuring accurate fare collection. This framework ensures that the system operates seamlessly for both passengers and tricycle operators, improving the overall efficiency, transparency, and security of fare payments in the tricycle transport sector.

1.3 Conceptual Framework

In Figure 1, the system's inputs include the RFID tag, RFID tag reader, NodeMCU microcontroller, GSM module, and a web server, all of which are essential for the development of the NodeMCU-Based Contactless Fare Management System for Tricycle Commuters.

The process stage follows a structured development cycle, consisting of the Planning Phase, Analysis Phase, Design Phase, Implementation Phase, and Maintenance Phase. Each phase ensures the effective design, functionality, and sustainability of the system.

The final output of this study is the development of an innovative contactless and cashless fare management system for tricycles, enhancing convenience, security, and efficiency for both passengers and tricycle operators. This system modernizes the traditional fare collection process, ensuring accurate transactions, reducing physical cash handling, and promoting a more efficient payment experience in public transportation.

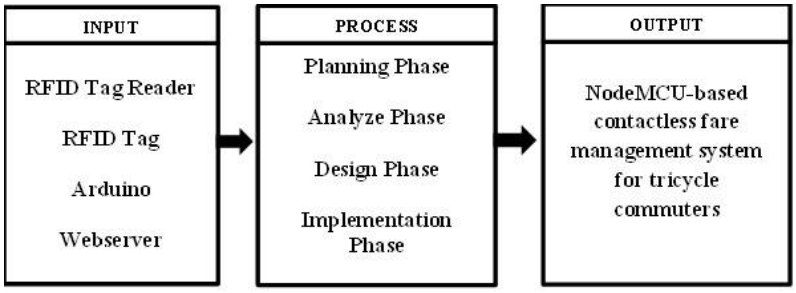

Fig 1. The I/O diagram of the System

1.4 Objectives

The general objective of this study is to design and implement a NodeMCU-Based Contactless Fare Management System for Tricycle Commuters to streamline fare transactions, ensuring convenience, security, and fairness for both passengers and tricycle operators.

The specific objectives are:

1. To develop a contactless fare management system specifically designed for tricycle commuters, utilizing RFID and NodeMCU technology.

2. To evaluate the effectiveness, efficiency, and reliability of the proposed system in enhancing fare collection, minimizing transaction time, and ensuring accurate payments.

2. METHODS

2.1 Research Design

The researchers utilized hardware design principles in developing the NodeMCU-Based Contactless Fare Management System for Tricycle Commuters. Unlike software, hardware design is constrained by physical components and operational conditions. The synchronous design approach was applied to ensure the system's reliability, modularity, and efficiency. This methodology, widely used in hardware development, has also been effectively integrated into embedded systems, such as the RFID-based fare management system developed in this study.

2.2 Project Design

The communication between the NodeMCU microcontroller and the GSM module in the NodeMCU-Based Contactless Fare Management System operates in a bidirectional manner. The NodeMCU sends transaction-related data, such as the commuter's RFID card details, fare deduction requests, and transaction status, to the GSM module. The GSM module then transmits this data to the webserver, ensuring real-time updates on fare transactions and commuter balances.

Conversely, the GSM module also receives responses from the webserver, including balance verification, transaction approval, or error notifications, which it then sends back to the NodeMCU. This bidirectional communication is crucial as it allows the system to verify if a commuter has sufficient balance before deducting the fare, ensures that all transactions are properly recorded, and provides real-time updates to both tricycle drivers and commuters. This seamless exchange of data enhances the efficiency, security, and reliability of the contactless fare management system. Figure 2 shows the complete block diagram of the study.

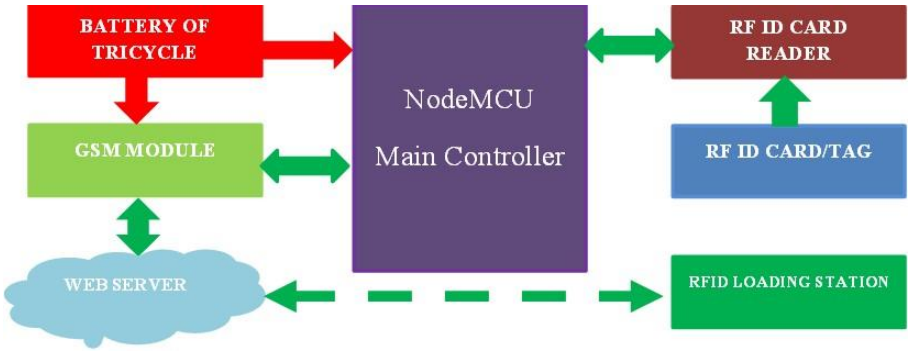

Fig 2. The Project Design Block Diagram

2.3 Project Development

This project aims to develop a NodeMCU-Based Contactless Fare Management System for tricycle commuters, providing a cashless and efficient payment solution. By integrating RFID technology and microcontroller-based processing, the system eliminates the need for physical cash transactions, ensuring a faster, safer, and more convenient fare collection process for both tricycle drivers and passengers.

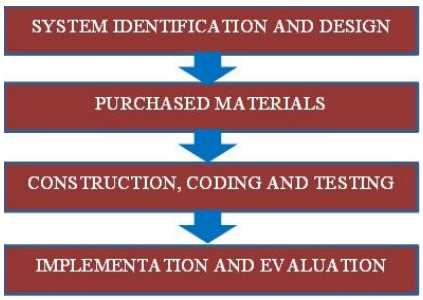

Fig 3. The Project Development block diagram

Figure 3 presents the block diagram illustrating the step-by-step development process of the project. The research began with an extensive online study to gather relevant information about contactless payment systems and RFID technology. Following this, the system design phase was carried out, where the overall structure and functionality of the fare management system were planned. Once the design was finalized, the necessary hardware components were procured, with some materials sourced online due to local unavailability. The next phase involved the construction and testing of the system to ensure proper functionality and integration of all components. Finally, the project underwent system evaluation, where its performance, reliability, and effectiveness were assessed to validate its efficiency as a contactless fare management solution for tricycle commuters.

2.4 Project Implementation

The NodeMCU-Based Contactless Fare Management System was designed to enable tricycle commuters to pay their fare using an RFID card, which was tapped on the RFID reader installed inside the tricycle. This eliminated the need for cash transactions, ensuring a safer and more convenient payment process for both passengers and drivers.

The system was integrated into the tricycle and powered by its battery**,** ensuring continuous operation without the need for an external power source. Once a commuter tapped their RFID card, the system automatically deducted the fare from the card's balance and logged the transaction. Additionally, the system allowed the tricycle driver to track and manage their earnings efficiently, reducing the risks of lost or mishandled cash payments. Through this implementation, the project improved the overall fare collection process, enhanced security, and promoted a more modernized public transportation system for tricycle commuters.

2.5 Project Setting

The pilot implementation of the NodeMCU-Based Contactless Fare Management System was conducted in Dumaguete City, focusing on routes with a minimum standard fare to ensure a straightforward and controlled testing environment. This setting allowed the researchers to evaluate the system's functionality, efficiency, and reliability in a real-world scenario while minimizing potential complexities.

During this phase, the researchers gathered feedback from tricycle drivers, commuters, and stakeholders to identify possible modifications and improvements for the system’s final implementation. The insights obtained helped refine the technology, ensuring a more seamless and user-friendly contactless fare management solution. Figure 4 presents the route map where the pilot testing took place.

Fig 4. The Project Setting of the Study

2.6 Participants of the Study

The participants of this study included tricycle drivers, passengers, and an engineer who was directly involved in testing and evaluating the NodeMCU-Based Contactless Fare Management System. The tricycle drivers and passengers assessed the usability, efficiency, and convenience of the cashless payment system, while the engineer provided technical insights regarding system implementation and performance.

The breakdown of participants is presented in Table 1, showing that passengers comprised the majority (83%), as they were the primary users of the system. Meanwhile, one tricycle driver (8.3%) tested the system from the driver’s

perspective, ensuring its functionality in a real commuting environment. Additionally, one engineer (8.3%) was included to oversee the technical aspects of the project.

Table 1. Participants of the Study

Participants	f(n=X)	%
Tricycle Driver	1	83%
Passengers	10	83%
Engineer	1	83%

2.7 Instruments

The following instruments were utilized in the development and implementation of the NodeMCU-Based Contactless Fare Management System for Tricycle Commuters**:**

- **RFID Tag Reader** – A device that gathers information from an RFID tag, enabling the system to identify and process fare transactions. It uses radio waves to transfer data from the tag to the reader.
- **RFID Tag** – A small, encoded device that stores essential data, enclosed in a protective material suited for environmental conditions depending on its application.
- **Arduino** – An open-source microcontroller that manages data processing and communication between the RFID reader, GSM module, and web server, facilitating seamless system operations.
- **Web server** – A hardware and software system that processes fare transaction requests and maintains commuter and driver data for real-time fare management.
- **GSM Module** – A wireless communication device that enables the system to send transaction details via SMS or network connectivity, ensuring remote accessibility.
- **LED** – A visual indicator that signals successful fare transactions and system status, enhancing user interaction.
- **Buzzer** – An audio signaling device used to confirm transactions, alert users of errors, or notify the driver and passengers of the system's status.
- **Resistors** – Essential circuit components that regulate current flow, ensuring the proper operation of the Arduino, RFID reader, GSM module, and other electronic parts of the system.

2.8 Research Ethics

The researchers ensured that the study adhered to ethical guidelines and legal regulations throughout its development and implementation. Data privacy and security measures were strictly observed, particularly in handling commuter and transaction information. Additionally, no environmental laws were violated, and the system was designed to be energy-efficient and sustainable, minimizing its impact on the tricycle's power source**.**

2.9 Data Collection Procedure

The data for this study was collected through investigation and survey methods to analyze the current tricycle fare system**.** The researchers conducted a fare assessment by gathering information on the existing fare rates, commuter payment behaviors, and the challenges faced by tricycle drivers and passengers. Surveys were distributed to tricycle drivers, passengers, and other stakeholders to evaluate the feasibility and effectiveness of implementing a contactless fare management system. The collected data provided insights into fare discrepancies, transaction efficiency, and user acceptance, which guided the system's development and improvements.

2.10 Statistical Tools

In this study, the researchers utilized statistical analysis to interpret data effectively. The mean was used to determine the central tendency of collected data. This was calculated by summing all data points and dividing the total by the number of observations. By using the meanmean, the study was able to assess the effectiveness and user experience of the contactless fare management system based on survey responses from tricycle drivers and passengers.

2.11 Financial Analysis

A Break-Even Analysis was conducted to evaluate the financial feasibility of the NodeMCU-based Contactless Fare Management System for Tricycle Commuters**.** This method determined the level of production or the targeted sales mix required to recover the initial investment. The break-even analysis was primarily for management purposes, providing insights into the system's cost-effectiveness and sustainability. It was not intended for external investors, regulators, or financial institutions but served as an internal tool to guide decision-making regarding implementation and scalability.

3. RESULTS AND DISCUSSIONS

After thorough development and testing, the researchers successfully created the NodeMCU-Based Contactless Fare Management System for Tricycle Commuters**.**

Figure 6 presents the web interface of the system, which displays essential data, including registered passengers and drivers, along with their respective travel details. The administrator manages the user accounts and their balance, ensuring secure and organized financial transactions. While users cannot register independently, they can view their account details, including their available balance, after the administrator registers them in the system.

Fig 6. The Web Server Interface of the Contactless Fare System

Figure 7 illustrates the Cashless Payment Device for Tricycles used by the tricycle driver for fare transactions. To process a payment, the passenger taps their RFID card on the RFID reader, which then retrieves the card's data and transmits it to the web server. The corresponding fare amount is deducted from the passenger's balance and credited to the driver's account. When the driver wishes to withdraw their accumulated earnings, they can do so at the nearest TriPay station.

Fig 7. Cashless Payment Device for Tricycles

Figure 8 demonstrates the hardware connections between the system components, ensuring the seamless interaction between the RFID reader, microcontroller, GSM module, and web server. These connections enable real-time transaction processing and secure data communication.

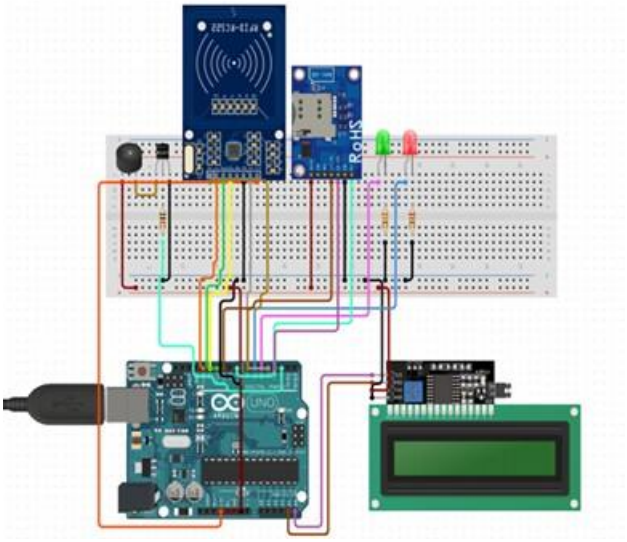

Fig 8. The Hardware Component Connections

CONCLUSION

The study successfully demonstrated that an RFID-based contactless fare management system can be effectively implemented for tricycles. The integration of RFID technology allowed seamless fare transactions, enhancing the efficiency, security, and convenience of payments. Additionally, the GSM module facilitated communication between the hardware device and the web server, ensuring accurate fare collection and real-time balance updates. However, its functionality depended on the availability of a stable network signal and sufficient mobile data load**.**

The cashless payment system promoted fairness for both tricycle drivers and passengers by eliminating payment disputes, ensuring proper fare collection, and providing a transparent transaction history.

Recommendations

As technology continues to advance, there are numerous opportunities to enhance and optimize the tricycle cashless payment system. While the current implementation has successfully demonstrated the feasibility of using RFID technology for fare collection, certain improvements can be made to increase its efficiency, reliability, and user-friendliness. Future researchers and developers may consider the following recommendations to further refine the system:

1. **Replacing the GSM Module with an Ethernet Shield** – Switching to an Ethernet shield would provide a more stable and reliable internet connection, reducing dependency on mobile network signals, which may sometimes be weak or inconsistent in certain areas.
2. **Developing a More Durable Casing** – A stronger and more protective casing should be designed to shield the device from environmental damage such as dust, moisture, and accidental impacts, thereby ensuring the longevity of the hardware components.
3. **Incorporating a Keypad** – Adding a keypad would allow manual fare input, enabling the system to accommodate various tricycle routes and special fare transactions, making it more flexible and adaptable to different scenarios.
4. **Implementing a Travel History Tracking Feature** – Introducing a travel history tracking function would provide passengers and drivers with a detailed record of their trips and payment transactions. This feature would improve transparency and accountability, helping to resolve disputes and offering an additional layer of security.

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REFERENCES

[1] Wikipedia, "Radio-frequency identification," 30 December 2020. [Accessed: 29-Dec-2020].
[2] M. Bin Ibne Reaz, "Radio Frequency Identification: From System to Applications," 5 June 2013. [Accessed: 29-Dec-2020].
[3] L. VanSomeren, "Disadvantages of Cash," 17 March 2020. [Accessed: 29-Dec-2020].
[4] D. Stern, "Consumer Credit Advantages and Disadvantages," 13 June 2017. [Accessed: 29-Dec-2020].
[5] CoreRFID, "Benefits of RFID - Why Do You Need RFID Solutions?" 2019. [Accessed: 29-Dec-2020].
[6] J. Téllez and S. Zeadally, "Mobile Payment Systems: Secure Network Architectures and Protocols," 2 October 2017. [Accessed: 30-Dec-2020].
[7] J. Banks, M. A. Pachano, L. G. Thompson, and D. Hanny, *RFID Applied*, 30 March 2007. [Accessed: 30-Dec-2020].
[8] M. Geddes, *Arduino Project Handbook: 25 Practical Projects to Get You Started*, 1 June 2016. [Accessed: 30-Dec-2020].
[9] M. McRoberts, *Beginning Arduino*, 29 July 2011. [Accessed: 30-Dec-2020].
[10] M. Khayesi and F. M. Nafukho, *Informal Public Transport in Practice: Matatu Entrepreneurship*, 3 March 2016. [Accessed: 30-Dec-2020].
[11] M. Bin Ibne Reaz, "Radio Frequency Identification: From System to Applications," 5 June 2013. [Accessed: 30-Dec-2020].
[12] Teleron, J. I. (2022). The implementation of distributed system application on periodic attendance of the faculty. *International Research Journal of Advanced Engineering and Science, 7*(1), 196-202.
[13] M. McRoberts, *Beginning Arduino*, 30 September 2013. [Accessed: 2-Jan-2021].
[14] Techopedia, "Radio Frequency Identification Reader (RFID Reader)." [Accessed: 30-Dec-2020].
[15] ABR, "What is RFID and How Does RFID Work?" 1 November 2020. [Accessed: 2-Jan-2021].
[16] Teleron, J. I. (2022). The implementation of multiple 89C51 microcontrollers through RS232C serial communication interface. *International Research Journal of Advanced Engineering and Science, 7*(2), 220–226.
[17] Hayes, "Break-Even Analysis," 13 December 2020. [Accessed: 2-Jan-2021].