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**COLLEGE OF SCIENCE AND TECHNOLOGY**

**AFRICAN CENTRE OF EXCELLENCE IN INTERNET OF THINGS (ACEIoT)**

**A NOVEL IoT BASED TAP AND GO CARD FOR INTELLIGENT TRANSPORT  
SYSTEMS AND MANAGEMENT**

*A dissertation Submitted in partial fulfilment of the requirements for the award of Masters of Science Degree in  
Internet of Things: Wireless Intelligent Sensor Network (WISeNet)*

Submitted By

**DUSENGE Sylvie**

**Ref No: 222023027**

**July, 2025**



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Supervised by:

**Dr. Omar GATERA (main supervisor)**

**Dr. Martin KURADUSENGE (co-supervisor)**

**July, 2025**

**Declaration**

I, **Sylvie DUSENGE**, Master’s student from the African Center of Excellence in Internet of Things, at University of Rwanda, declare that this dissertation is the result of my own work and it has not been submitted for any other degree at the University of Rwanda or any other institution.

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Signature: .....

Date: ...../...../.....

## Bonafide Certificate

This is to certify that this submitted Dissertation is a record of the original work done by **Sylvie DUSENGE (Ref. No: 222023027)**, MSc. IoT-WISNET Student at the University of Rwanda, College of Science and Technology, African Center of Excellence in Internet of Things, the Academic year 2023/2025.

This work has been submitted under the supervision of **Dr. Omar GATERA** and **Dr. Martin KURADUSENGE**

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May God Bless you all!

## **ABSTRACT**

In today's rapidly evolving urban environments, public transportation systems are increasingly in need of innovative, efficient, and user-friendly payment solutions. Traditional tap-and-go systems, while popular, often face challenges of limited functionalities such as inefficient card reloading processes. These issues create frustration for users and often hinder the smooth operation of public transport systems. This project seeks to address these challenges by developing a novel IoT-based Tap and Go Card system for intelligent transport systems and management, with an emphasis on improving the efficiency and convenience of prepaid card reloading. The system leverages Internet of Things (IoT) technology to enable real-time communication, seamless data transmission, and remote monitoring. Key features include coin-based card reloading, the ability to transfer funds between cards, and card swapping functionalities. The system eliminates the need for fixed terminals, offering greater flexibility through wireless connectivity. Furthermore, it aims to provide a more reliable, and user-friendly solution to modern transportation challenges. Built around an ESP32 microcontroller, the system integrates components such as a coin sensor, an RFID reader, and a GSM module for real-time updates and monthly transaction reports via email. This approach significantly enhances the user experience and provides smarter fund management. The solution is designed to be scalable and adaptable for broader urban deployment. This project represents a major step forward in the development of intelligent, IoT-driven transport payment systems that can meet the growing demands of modern cities.

**Keywords:** IoT, AI, Tap and Go, ESP32, GSM Module, Smart card, RFID technology, Cashless payment, User experience, Reload machine, Wireless sensor network.

## **LIST OF ACRONYMS**

**ACEIoT:** African Center of Excellence Internet of Things **UR:** University of Rwanda

**AI:** Artificial Intelligence

**CST:** college of science and technology

**GSM:** Global System for Mobile Communications **WIFI:** Wireless Fidelity

**IIoT** - Industrial Internet of Things **ML:** Machine Learning

**ITSM:** Intelligent Transport Systems and Management

**LCD:** Liquid Crystal Display

**RFID:** Radio Frequency Identification

**SQL:** Structured Query Language

**TFT:** Thin-Film Transistor

**WISENET:** Wireless Intelligent Sensor Networking **IoT:** Internet of Things

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# CHAPTER I: GENERAL INTRODUCTION

## 1.0 Introduction

In recent years, technological advancements have significantly transformed daily transactions by enhancing convenience, security, and efficiency. One notable innovation is the rise of contactless payment and card reloading systems, which have gained popularity in public transportation and retail sectors.[1] These systems offer quick and efficient solutions for reloading prepaid cards through various platforms. However, current card reload machines face limitations in user experience and operational efficiency due to high costs, lack of user-friendly interfaces, and absence of advanced features like real-time monitoring and remote management.[2]

Intelligent Transport Systems (ITS) are sophisticated solutions designed to improve various transportation modes and traffic management. By integrating communication technologies, data analytics, and automation, ITS aims to provide users with better information, enhance safety, and promote more coordinated and efficient use of transport networks. These systems help optimize transportation, improve safety, and minimize environmental impact

This research project proposes the development of a Novel IoT Based Tape and Go Card for Intelligent Transport Systems and system. This machine aims to provide an efficient and affordable solution by leveraging modern technology. The proposed system will integrate a range of sensors and components, including a coin sensor, RFID reader, ESP32 microcontroller, and GSM module, to streamline the process of reloading cards. [3] a Novel IoT Based Tape and Go Card for Intelligent Transport Systems will feature a user-friendly interface, enabling users to perform various transactions such as reloading cards, transferring funds between cards, and generating transaction reports. The integration of the GSM module will facilitate real-time communication with cloud servers, allowing for remote monitoring and management of the machine. [4]

A key differentiating factor of this system is its ability to learn and adapt to user behavior through AI-driven predictive analytics. By analyzing transaction patterns and user preferences, the system enhances the efficiency of the reloading process and provides personalized recommendations and optimizations.[2] This capability makes the system more responsive and tailored to individual user needs. To evaluate the effectiveness of the proposed system, the project will include a thorough assessment of its usability, efficiency, and user satisfaction in real-world scenarios. Data collected from these evaluations will inform further refinements and improvements, ensuring that the final product meets user needs while maintaining high standards of reliability and security. [2]

By addressing current limitations in card reloading systems and contributing to the field of IoT and AI in transaction management, this project aims to provide valuable insights and recommendations for future implementations. The successful development and deployment of this system will demonstrate the practicality of combining IoT and AI technologies in this context and pave the way for broader applications in various industries.

## **1.1 Background and Motivation**

The use of prepaid cards has become increasingly popular for various transactions, especially in public transportation. IoT and AI have significantly impacted various sectors, including transportation and payment systems. The evolution of tap-and-go payment systems has revolutionized how people interact with public transportation, retail, and other services. These systems offer users the convenience of quick and secure transactions through RFID-enabled cards, which can be tapped against a reader to complete payments.[5]

Current systems often lack integration with advanced technologies like AI, which could enable personalized and adaptive reloading options based on user behavior and preferences. Additionally, these systems typically do not offer real-time monitoring or comprehensive data analysis, limiting the ability to predict and manage demand, optimize resource allocation, and ensure system reliability. The motivation for this research project stems from these identified limitations and the potential to overcome them by integrating IoT and AI technologies.[6]

By developing a Novel IoT Based Tape and Go Card for Intelligent Transport Systems and management, it is possible to offer users a more efficient, adaptable, and user-friendly solution. This machine would utilize IoT to provide real-time data monitoring and connectivity, while AI algorithms could analyze user behavior to offer personalized reloading options, predict peak usage times, and optimize system performance. [7] [5] . The successful implementation of a Novel IoT Based Tape and Go Card for Intelligent Transport Systems would not only improve user convenience and system efficiency but also contribute to the advancement of intelligent payment solutions. Such a system could set a new standard in the field, paving the way for further innovations in public transportation, retail, and beyond.[8]

## **1.2 Problem Statement**

The current methods of reloading prepaid cards are often inconvenient, requiring users to visit specific locations or navigate complex online systems. These methods can be time-consuming and inaccessible, leading to frustration and delays for users. There is a need for a more accessible and efficient solution that allows users to reload their cards and perform transactions with ease, enhancing the overall user experience and operational efficiency.[6]

## **1.3 Study Objectives**

### **1.3.1 General Objective**

To develop a Novel IoT Based Tap and Go Card for Intelligent Transport Systems management that is affordable, user-friendly, and capable of performing various transactions efficiently, thereby improving the convenience and efficiency of managing prepaid card reloading for users.

### **1.3.2 Specific Objectives**

1. To design and implement a card reloading system
2. Transfer money from one to another card or between cards and perform card swapping by using web app
3. To generate monthly transaction reports and send updates via email

## **1.4 Hypotheses**

This innovative system aims to enhance the efficiency of public transport by integrating Novel IoT Based Tap and Go Card for Intelligent Transport Systems. It reduces the time passengers spend in queues and minimizes the need for cash transactions, streamlining the payment process. The system also helps to lower operational costs by reducing the reliance on physical tickets and it provides real-time data that can be used to optimize route management and improve overall service quality, benefiting both passengers and transport operators.

## **1.5 Scope of the Study**

During this research, the system will be implemented in one public area for bus route.

## **1.6 Significance of the Study**

The deployment of the AI-IoT Based Tap and Go Card system contributes to the modernization of public transport by reducing the costs associated with traditional ticketing systems and enhancing the passenger experience. The system streamlines payment processes, reduces the time spent in queues, and provides real-time data for more efficient transport management. This innovation also supports contactless transactions,

promoting hygiene and reducing the risk of disease transmission, which is especially important in the context of public health.

### **1.7 Research proposal Contribution**

The AI-IoT Based Tap and Go Card system represents a significant advancement in intelligent transport management. By integrating AI and IoT technologies, the system facilitates real-time monitoring and data-driven decision-making, leading to more efficient and reliable public transport services. This solution enhances the passenger experience, reduces operational costs, and contributes to the overall improvement of urban mobility. It showcases the practical application of cutting-edge technologies in solving real-world challenges in the transport sector.

## CHAPTER II: LITERATURE REVIEW

### 2.0 Introduction

The integration of Artificial Intelligence (AI), Internet of Things (IoT), and Radio Frequency Identification (RFID) technologies has significantly transformed intelligent transportation systems (ITS). As urban populations increase and the need for efficient transport services grows, the adoption of smart fare collection systems is becoming indispensable. The deployment of Tap-and-Go cards powered by AI and IoT offers a practical solution to the challenges of traditional payment systems, such as long queues, agent fraud, and lack of remote access. These technologies facilitate secure, contactless, and real-time transaction processes that support data-driven decision-making, resource optimization, and enhanced commuter satisfaction.

#### Definition of Key Technologies

- ⊕ Internet of Things (IoT): A network of physical objects embedded with sensors, software, and connectivity to collect and exchange data, enabling automation and intelligent system behavior.
- ⊕ Radio Frequency Identification (RFID): A contactless communication technology used for identification and tracking using electromagnetic fields, commonly applied in smart cards for public transit.
- ⊕ Smart Card: A physical card embedded with an integrated chip or microprocessor that stores and processes data securely. In public transport, smart cards are typically contactless and use RFID or NFC technologies to enable quick and secure fare payments. They offer reusability, encrypted data storage, and can be used for multiple purposes such as identification, access control, and e-wallet services.
- ⊕ Intelligent Transport Systems (ITS): Advanced applications that aim to provide innovative services relating to different modes of transport and traffic management. ITS improves safety, efficiency, and sustainability by integrating communication technologies, data analytics, and automation. Components include smart traffic lights, vehicle-to-infrastructure (V2I) communication, real-time passenger information, and automated fare collection.
- ⊕ Artificial Intelligence (AI): A field of computer science concerned with creating systems capable of mimicking human intelligence, including reasoning, learning, and decision-making.

## **2.1 Related works**

### **2.1.1 Smart Card and Contactless Payment Systems**

Contactless smart cards have revolutionized fare collection in public transport, offering enhanced speed, reliability, and operational efficiency. RFID-enabled smart cards allow passengers to pay fares with a simple tap, eliminating the need for physical cash or manual validation. Al-Khouri [9] highlighted the convenience and speed of RFID systems, noting that they significantly reduce boarding times and improve commuter experience. Gill et al. [29] further proposed a smart fare collection framework leveraging IoT, which automates payment processes and enables real-time ticket validation.

Recent developments have expanded beyond physical cards to include mobile wallets and digital applications that support NFC-based payments. These advancements create a cashless ecosystem that promotes financial inclusion and aligns with smart city initiatives. In rural or underserved areas, mobile-enabled Tap-and-Go platforms allow users to reload cards remotely via smartphones, overcoming the problem of limited access to physical agents. QR-code scanning and mobile-to-card fund transfers are also gaining ground as flexible alternatives for fare reloading.

Despite these advancements, challenges remain. Some systems suffer from poor infrastructure maintenance, leading to transaction failures or card reader issues. Moreover, the lack of interoperability across different transport operators hinders seamless travel, especially in metropolitan regions with multiple service providers.

### **2.1.2 The integration of mobile applications with RFID**

The rise of mobile technology has created opportunities to enhance user access and interaction with smart fare systems. Studies have demonstrated that integrating mobile applications with smart card systems facilitates balance inquiries, fund transfers, remote reloading, and trip tracking [12]. Secure smart card web server models [4] also provide users with centralized platforms to manage their accounts and monitor travel behavior.

OTP (One-Time Password) authentication, biometric validation, and user notifications through SMS or mobile apps are being implemented to boost transaction security. These features provide transparency, reduce the risk of fraud, and increase user trust in digital fare systems. The use of cloud infrastructure ensures that data on usage patterns, travel history, and transaction logs are stored and synchronized across devices in real time.

The inclusion of remote access mechanisms further supports system scalability. Transport authorities can deploy cloud dashboards to monitor fare revenue, detect anomalies, and generate reports. This capability is particularly important for regional and national transport authorities managing multiple transport zones.

### **2.1.3 IoT Applications in Smart Transport Systems**

IoT plays a central role in real-time data acquisition and system automation. Through sensors and RFID readers, transport operators can track passenger flow, monitor fare payments, and manage vehicle availability. Applications such as RFID-based vehicle parking systems [13] and automated queue management tools [14] have proven effective in reducing congestion and enhancing customer experience.

Vemulapalli et al. [7] and Manikandan et al. [32] highlight the use of IoT in building dynamic fare systems that adjust rates based on peak hours, route popularity, or user profiles. These systems leverage edge computing to process data locally, ensuring that fare deductions and access control happen instantaneously without relying heavily on central servers.

RFID tags embedded in buses and bus stops also help with tracking vehicle movement and predicting arrival times. Decentralized IoT frameworks [17] are being explored to enable intelligent traffic signal control, thereby optimizing bus schedules and minimizing wait times. Such systems align closely with the objectives of this project, where real-time monitoring and automated fare reloading can significantly enhance commuter efficiency.

### **2.1.4 Security Frameworks for Smart Card Systems**

Security remains a major concern for any digital payment system. The literature highlights several frameworks for securing data transmission, access control, and user authentication. Blockchain-based card management systems [3] allow for immutable transaction records, ensuring transparency and reducing the chances of manipulation. Bio-cryptosystems [23] and elliptic curve cryptography (ECC)-based two-factor authentication models [24] further enhance identity verification processes.

Anomaly detection techniques based on AI can alert administrators to potential breaches or unauthorized recharges [6, 25]. These systems use real-time monitoring to flag unusual activity, such as simultaneous card use in different locations or abnormal reloading amounts. Encrypted RFID communication channels and Public Key Infrastructure (PKI) models are also employed to protect data from interception.

Additionally, the concept of tiered security is emerging, where users are granted different access levels depending on their profile. For example, student or elderly cards might have predefined limits or reduced access to prevent misuse. Such frameworks support the design of inclusive and secure Tap-and-Go card systems.

### **2.1.5 Emerging Trends and Smart Mobility**

Recent trends in smart mobility focus on real-time data sharing, decentralization, and sustainability. The concept of a “Transportation Internet” [20] enables seamless communication between vehicles, infrastructure, and users, facilitating predictive analytics and dynamic transport planning. This interconnected model enhances responsiveness and efficiency across urban mobility systems.

RFID technology is now widely applied beyond traditional public buses, including in campus automation [28], logistics, toll collection, and healthcare transport. These applications highlight its flexibility in enabling contactless, secure, and automated tracking systems.

Innovations like biometric smart cards [35], which use fingerprint or facial recognition, provide enhanced security and user convenience, minimizing reliance on PINs or passwords. Smart kiosks powered by AI and natural language processing (NLP) assist commuters in route selection and fare payments, especially in multilingual or high-traffic environments.

Sustainability is increasingly central to smart transport. Initiatives such as solar-powered recharge stations, biodegradable smart cards, and energy-efficient hardware contribute to green mobility goals. These developments reduce the environmental impact of fare systems while promoting broader digital transformation in transport.

## **2.2 Gaps to Be Addressed by the Proposed System**

The proposed IoT-AI-based Tap-and-Go card reload system aims to bridge the above-identified gaps shown in Table 1.

**Table 1: System Gaps Addressed**

<b>Identified Gaps in Literature</b>	<b>How Proposed System Addresses the Gap</b>
1. Lack of Integration Between Hardware Components for Card Reloading. Most systems do not integrate coin sensors, microcontrollers, and motors into a unified reload machine.	Designs a card reload machine using a coin sensor, ESP microcontroller, and DC motor, enabling transaction for passengers.
2. No Support for Coin-Based Reloading Systems. Existing smart card systems rarely accept coins for reloading.	Implements a coin-detection-based mechanism that allows users to reload their Tap-and-Go cards without needing an agent or waiting service in line.
3. Limited Card-to-Card Money Transfer and Swapping. Most systems do not support peer-to-peer transactions or card swapping via web platforms.	Provides a web app to enable card-to-card money transfer, swapping, and offering greater flexibility and usability for users.
4. Absence of Automated Transaction Reporting There is a lack of systems that generate detailed reports or provide updates to users.	Generates monthly reports and sends real-time email updates, improving transparency and user awareness.
5. Inadequate Real-Time Monitoring and Remote Access. Few systems utilize IoT (e.g., GSM or Wi-Fi) for real-time system control and feedback.	Utilizes the ESP microcontroller with cloud/GSM communication to enable real-time monitoring.
6. Poor System Usability and Personalization Existing systems do not offer personalized experiences or intuitive user interfaces.	Offers a user-friendly web dashboard for transactions, , and system interaction, enhancing accessibility.
7. Limited AI and Data Analysis for User Insights Lack of usage analysis and behavior prediction.	Integrates basic AI models to analyze user patterns and generate personalized suggestions or transaction history analysis.

The table outlines the gaps in existing smart card reloading systems, including limited integration, lack of real-time monitoring, and the absence of advanced features like coin-based reloading and card transfers. The proposed system aims to address gaps by incorporating difference sensor for card reloading with a web app for transferring funds between cards.

## 2.3 Anticipated Output

The anticipated output of this research includes:

- ⊕ Development of a functional prototype that demonstrates the integration of a Novel IoT Based Tape and Go Card for Intelligent Transport Systems
- ⊕ A system that offers personalized reloading options based on real-time analysis of user behavior, preferences, and transaction history.
- ⊕ Users will have the capability to transfer their money from one card to another by checking balance efficiently.
- ⊕ It will improve the service speed enhance overall user satisfaction. This machine will help transport operators such as an optimize routes, manage times, and improve service delivery.
- ⊕ The machine will have a system design, allowing for easy upgrades and customization based on specific needs. This flexibility will enable quick adaptation to new technologies and payment methods.
- ⊕ The machine will incorporate advanced security features to protect user data and transaction integrity. This includes encryption, secure authentication protocols, and regular security updates.

## 2.4 Research Impact

The proposed research is expected to make a significant and practical impact by improving the efficiency, accessibility, and security of digital payment systems in public transportation. It addresses key challenges such as long queues at card reloading stations, loss of money due to agent-based fraud, poor real-time monitoring, and limited service availability in rural or underserved communities.

By integrating Internet of Things (IoT) and RFID technologies, the system introduces an automated and user-friendly solution that allows for remote card reloading, secure transaction logging, real-time balance updates, and easy integration with existing transport management systems. This not only reduces the workload on human operators but also minimizes errors and delays in fare processing.

The system enhances operational transparency and can help transport service providers to monitor and manage transactions in real-time. This can significantly reduce fraudulent activities and ensure smoother operations, ultimately leading to improved public trust and satisfaction.

## **CHAPTER III: RESEARCH METHODOLOGY**

### **3.1 Introduction**

This chapter presents the research methodology applied in developing A Novel IoT Based Tap-and-Go Card Reload Machine for Intelligent Transport System Management It outlines the approach used to achieve the research objectives, including the research design, data collection techniques, sampling methods, system architecture, and the tools and technologies employed. Both hardware and software development processes are discussed, alongside the quantitative research method used to gather user data.

### **3.2 Research Design**

A descriptive quantitative research design was adopted to collect structured and measurable data from Tap-and-Go card users in Rwanda. The objective was to gain statistical insights into user experiences, challenges, and expectations related to card reloading services. Data collection was performed using a structured questionnaire distributed through Google Forms.

### **3.3 Population and Sampling**

The study focused on Tap-and-Go card users in Rwanda. A convenience sampling method was applied, targeting users who were readily available to participate. A total of 50 respondents completed the online survey.

- ⊕ Target Population: Tap-and-Go card users in Rwanda
- ⊕ Sampling Method: Convenience sampling
- ⊕ Sample Size: 50 respondents

This sample size was deemed sufficient for exploratory analysis of user challenges related to card reloading.

### **3.4 Data Collection Methods**

#### **3.4.1 Instrument Used**

A structured questionnaire was designed to gather quantitative data. It included closed-ended and Likert-scale questions on:

- ⊕ Frequency of Tap-and-Go reload usage
- ⊕ Challenges experienced during card reload
- ⊕ Opinions and acceptance of new system “A Novel IoT Based Tap-and-Go Card Reload Machine for Intelligent Transport System Management”

### **3.4.2 Procedure**

The questionnaire was shared via Google Forms using social media platforms such as WhatsApp and email. Participants were informed about the voluntary and anonymous nature of their participation.






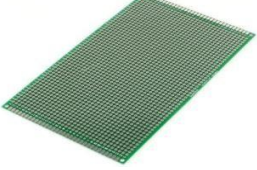

## **3.5 System Design and Implementation**

The system prototype was developed to automate the Tap-and-Go card reloading process using both hardware and software. It includes secure user authentication, real-time data communication, and cloud storage.

### **3.5.1 Hardware Components**

- ⊕ **ESP32 Microcontroller:** Core processor and communication controller
- ⊕ **RFID Reader:** Authenticates users via card scanning
- ⊕ **Coin Sensor:** Detects and quantifies inserted coins
- ⊕ **DC Motor & Motor Driver:** Facilitates coin handling and reload mechanisms
- ⊕ **GSM Module:** Enables real-time cloud communication
- ⊕ **Power Supply Unit:** Provides stable power to the system

**Table 2: Hardware requirement**

<b>HADWARE WORKING PRINCIPLE</b>			
<b>S/N</b>	<b>EQUIPMENT</b>	<b>IMAGE</b>	<b>DESCRIPTION</b>
1	ESP32 Microcontroller		A low-cost, low-power system-on-chip with integrated Wi-Fi and Bluetooth, used for managing and controlling devices.
2	RFID Reader		Used to scan RFID tags/cards for identification, commonly utilized in access control and payment systems.
3	Coin Sensor		Detects the insertion of coins for payment applications.
4	DC Motor		Converts electrical energy into mechanical motion, used in devices requiring rotation or movement.
5	GSM Module		Enables wireless communication via cellular networks, suitable for sending alerts or data remotely.
7	PCB (Printed Circuit Board)		Provides a physical platform for connecting and organizing electronic components.
8	TFT Display		Display interfaced to displays user feedback

### 3.5.2 Software Tools and Technologies

- ⊕ **Arduino IDE:** For programming the ESP32 microcontroller
- ⊕ **Python:** Backend server logic and cloud communication
- ⊕ **HTML, CSS, JavaScript:** Web dashboard development
- ⊕ **Machine Learning Libraries:** Python-based libraries for predictive modeling

#### Dashboard Development and Analytics

A responsive web dashboard was developed to:

- ⊕ Monitor system performance in real-time
- ⊕ Display transaction history and user activity
- ⊕ Provide administrative access to manage users and settings

Analytics tools helped identify user trends and optimize system usability.

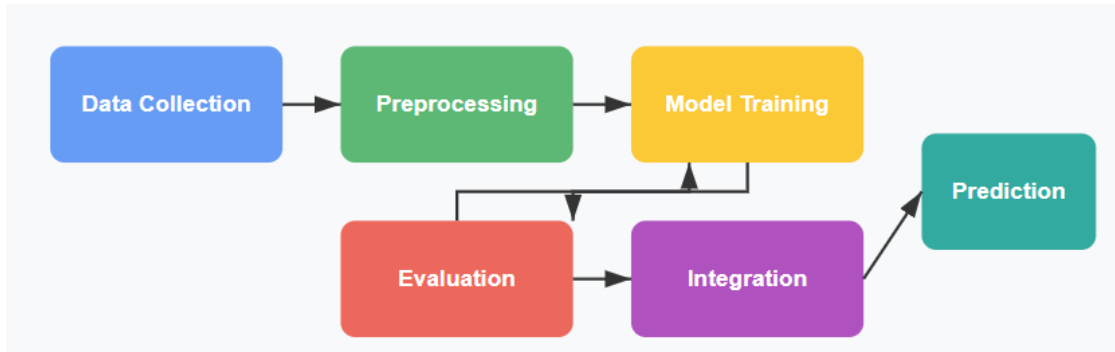
### 3.6 System Development

An IoT-integrated modular approach was used to develop the system architecture, combining smart sensors, actuators, cloud services, and wireless communication.

### 3.7 Data Flow Architecture

Figure 1 illustrates a machine learning workflow consisting of six key stages. It started with data Collection, where raw data is gathered for the problem at hand. This data then underwent preprocessing to clean, transform, and prepare it for analysis. The preprocessed data is used in Model training to develop predictive models. These models are then subjected to evaluation to assess their performance. Based on the evaluation results, models may be refined or retrained. Once validated, the models proceed to the integration phase, where they are incorporated into a

system or application. Finally, the integrated model is used for prediction to generate outputs or decisions based on new input data. The process is iterative, particularly between training, evaluation, and integration, to ensure optimal performance.



*Figure 1 System Modelling Workflow*

The data processing pipeline consists of:

- ⊕ Data Collection: From RFID taps and coin sensor inputs
- ⊕ Preprocessing: Cleaning, normalization, and feature extraction
- ⊕ Model Training: Pattern recognition, prediction, and anomaly detection
- ⊕ Evaluation: Model accuracy and refinement
- ⊕ Integration: Embedded models into system for live predictions
- ⊕ Output: Real-time predictions and automated decisions

### **3.8 Language Development and Integration**

The development of the Tap-and-Go card system involved a multi-layered integration of programming languages and tools, each responsible for a specific component of the system. This ensures seamless communication between the hardware and software, as well as a user-friendly interface.

#### **User Interface Development**

The frontend of the system was developed using HTML and CSS, providing a clean and structured

layout for the web-based dashboard. This dashboard enables users and administrators to interact with the system, view transaction history, monitor performance, and access real-time analytics.

### **Server-Side Logic**

The backend was implemented using Python, which handles server-side logic and API development. It is responsible for processing user requests such as checking balances, managing transactions, detecting anomalies, and updating user accounts. Python was also used to implement machine learning models that enhance the system's intelligence and predictive capabilities.

### **Real-Time Hardware Communication**

The Arduino IDE was used to develop firmware for the ESP32 microcontroller, enabling real-time communication between the hardware components (e.g., RFID reader, coin sensor) and the server. This ensures smooth and accurate handling of transactions, user authentication, and coin detection.

### **Integrated Language Stack Overview**

- ⊕ Frontend: HTML and CSS for layout design and visual presentation
- ⊕ Backend: Python for server logic, data processing, and machine learning integration
- ⊕ Firmware: Arduino IDE for controlling hardware components and real-time system operation

## CHAPTER IV. SYSTEM ANALYSIS AND DESIGN

The integration of IoT and AI technologies is essential for creating intelligent systems that enhance efficiency, accuracy, and user convenience. This chapter outlines the analysis and design of a Novel IoT Based Tap and Go Card System for Intelligent Transport Systems, detailing its architecture, functional requirements, and workflow

### 4.1 System block diagram

This block diagram presented as Figure 2, illustrates the architecture of system to designed to revolutionize intelligent transport payment and management. It addresses several critical limitations of existing transport systems by integrating diverse technologies to provide a seamless, secure, and efficient user experience.

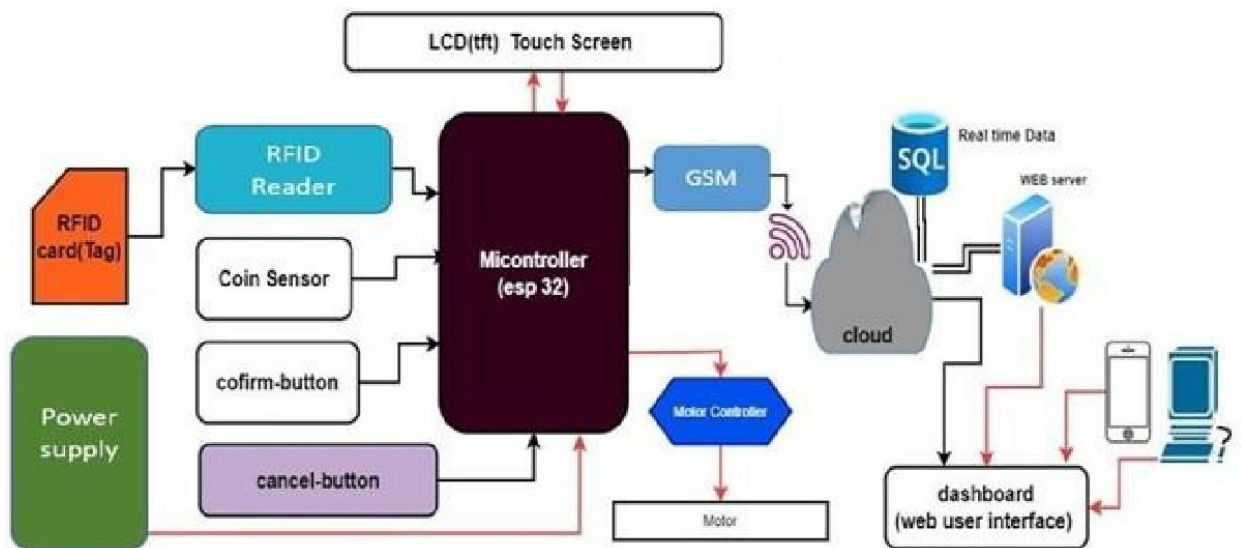


Figure 2 System's Block Diagram

#### 4.1.1 Addressing Existing Problems

- i. Inefficient Payment Methods: Traditional transport systems often rely on cash, leading to delays and inconvenience. Our system tackles this by utilizing RFID technology for quick and contactless transactions, significantly reducing boarding times and improving passenger flow.

- ii. **Lack of Real-Time Data and Monitoring:** Many systems lack real-time data access. The integration of GSM and Wi-Fi modules in our design enables constant cloud connectivity, providing administrators with immediate access to transaction data and system status.
- iii. **Limited User Interaction and Feedback:** Traditional systems often lack interactive interfaces. Our system incorporates TFT screen for real-time user feedback and menu navigation, enhancing user experience and providing immediate transaction.
- iv. **Reloading Inconvenience:** Existing reloading systems can be inconvenient, our system uses coin sensors for direct reloading, and money transfer to another card.

#### **4.1.2 Uniqueness of the System**

- v. **Integrated AI-IoT Approach:** The seamless integration of IoT devices (RFID reader, coin sensors, ESP32 microcontroller) with machine learning capabilities sets our system apart. This combination enables intelligent data processing and real-time decision-making.
- vi. **Comprehensive Data Management:** The use of SQL databases and cloud storage provides a robust framework for secure data management and analysis, enabling administrators to generate insightful reports and optimize system performance.
- vii. **Real-Time Remote Control and Monitoring:** The web dashboard offers administrators remote access to system data and control, facilitating immediate response to issues and enabling proactive system maintenance.
- viii. **Enhanced User Experience:** The combination of RFID, TFT screen, and intuitive menu options provides users with a convenient and user-friendly payment experience.
- ix. **User-Initiated Transactions via Web App:** The use of coin sensors for direct reloading, and money transfer to another card, makes the system more convenient.

## 4.2 System Flow Chart

The flowchart in Figure 3 outlines a payment system's workflow. The process begins with a user tapping a card. If the card is valid, menu options are displayed, allowing the user to choose an action. If the user opts to insert a coin, it is validated before proceeding with a transaction. If invalid, an error is displayed. Alternatively, for money transfers, the user must enter a target card, which is also validated.

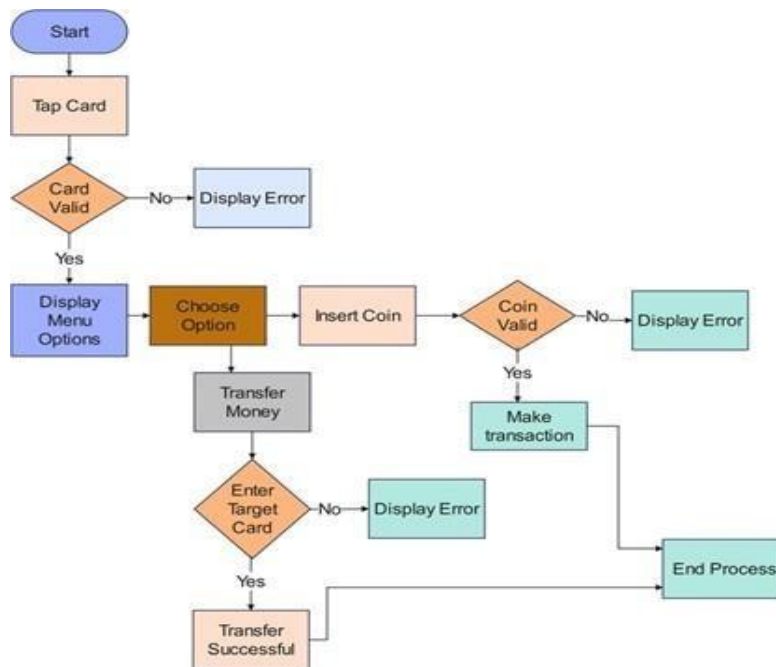


Figure 3 Payment workflow

A successful transaction leads to completion, while errors result in process termination. The system ensures validation at every step, guiding users toward either a successful transaction or an error message.

## **CHAPTER V. RESULT AND ANALYSIS**

### **5.1 Introduction**

In this chapter, we present the results and analysis of A Novel IoT based Tap and Go Card system designed for intelligent transport systems and management. The study aimed to evaluate the system's performance, user experience, and the potential impact on the efficiency and reliability of fare collection processes. To ensure a comprehensive assessment, both quantitative and functional evaluations were conducted.

Quantitative data was collected through a structured Google Form survey targeting 38 respondents, including public transport users and system stakeholders. The survey aimed to capture insights on current system challenges, such as accessibility, transaction delays, security concerns, and user satisfaction. These results provide a baseline for comparing the effectiveness of the existing system with the proposed IoT-based Tap-and-Go solution.

The results are organized into the following key sections:

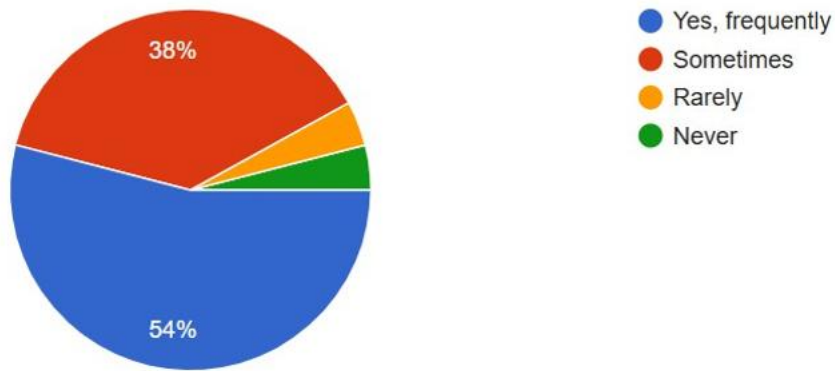
1. **User Experience Evaluation:** Survey results showing pain points and expectations of the current fare collection system.
2. **System Testing and Functional Validation:** Demonstrates hardware-software integration and user/admin interface performance.
3. **Machine Learning Model Performance:** Presents the classification model for transaction anomaly detection.

### **5.2 User Experience Evaluation**

The quantitative research with user experience was provided in survey form by using Google Forms platform and it was aimed to inquire how commuters experience the current Tap and Go system and understand users' challenges with the existing card reloading process.

- a. Population facing with transport for card reloading

Figure 4 presents survey findings from 50 respondents who completed your online survey about the current Tap-and-Go system in Rwanda.



*Figure 4 Population facing with transport for card reloading*

The survey data from 50 respondents shows that an overwhelming majority of users experience delays when waiting for agents to reload their cards. The largest segment (54% shown in blue) reports experiencing delays "frequently," while another substantial portion (38% shown in red) encounters delays "sometimes." Only a small fraction of users indicated they "rarely" experience delays (the small yellow segment), and an even smaller number (the small green segment) report "never" experiencing delays.

b. Population Engaged with new system

Figure 5 demonstrates how users would engage with a new system card reload system, highlighting the priorities and preferences across your target population. The survey of 50 respondents reveals important insights about user engagement.

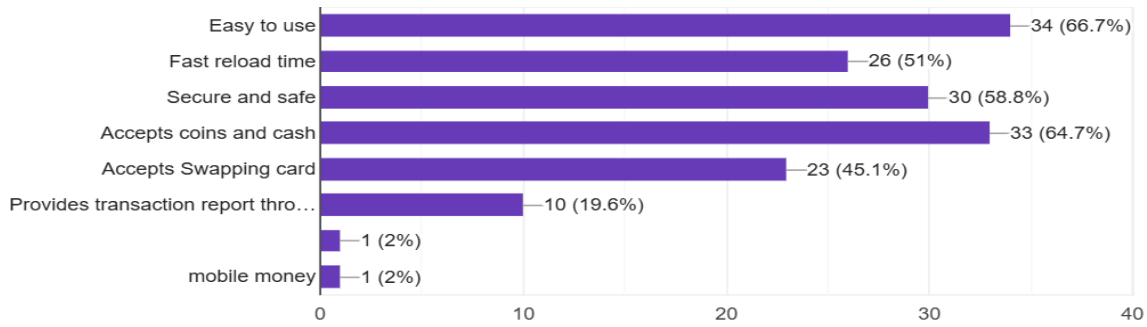


Figure 5 Population Engaged with new system

### 5.3 Hardware Connection

As shown in Figure 6, the hardware connections involve integrating the ESP32 microcontroller with multiple components to ensure seamless operation. The RFID reader connects for authenticate users, while the coin sensor is linked through GPIO pins for transaction validation. Push buttons provide manual input options. The motor controller, connected to the ESP32 via DC motor for card reloading. Wi-Fi and GSM modules enable cloud communication. A TFT Display interfaced to displays user feedback. Power is supplied through a regulated DC source, ensuring stable voltage levels for all components to function efficiently.



Figure 6 System Prototype and Hardware connectivity

A Novel IoT Based Tape and Go Card for Intelligent Transport Systems designed by integrating of various components to ensure smooth and efficient operation. The ESP32 microcontroller is the core unit that processes and coordinates the different modules, ensuring the system functions seamlessly. The RFID reader is connected to the ESP32 for card authentication, allowing users to access the system by tapping their cards. Coin sensors are interfaced with GPIO pins to detect the inserted coins and validate the payment process. Push buttons enable manual user input for various actions.

Actuators such as a motor controller and DC motor are connected to the ESP32 for physical tasks like card reloading. Wi- Fi and GSM modules ensure cloud communication, allowing for real-time updates and monitoring of transactions. An LCD touchscreen is interfaced with the ESP32 to display real-time information and provide user feedback, while the web dashboard provides remote access for administrators to monitor and control the system. Power for the system is provided through a regulated DC source, ensuring stable voltage levels for reliable performance across all connected components. The system is designed to operate efficiently, providing users with a seamless and secure payment experience.

#### **5.4 System Testing and Functional Validation**

The system's functionality was rigorously tested to ensure seamless integration of hardware and software components. The ESP32 microcontroller successfully processed data from RFID readers, coin sensors, and buttons, enabling efficient user authentication and transaction processing. The LCD touchscreen provided clear menu options for card reloading and money transfers. Coin sensors accurately validated input, and error messages were displayed for invalid transactions. The motor controller facilitated smooth card reloading, while Wi-Fi and GSM modules enabled real-time cloud communication for data storage and remote administration.

### 5.4.1 User and Admin Interface Performance and Functionality

#### *Admin Tasks*

The Admin Dashboard serves as the centralized control center for the AI-IoT Tap and Go Card payment system, offering secure, real-time oversight to transport authorities and system administrators. Designed with usability and efficiency in mind, the dashboard integrates all essential administrative functions into a single, web-based app, enabling effective monitoring and management of the entire fare collection ecosystem. Figure 7 presents the user role distribution within A novel IoT Based Tape and Go System for Public Transport Services and Management through two pie charts.



*Figure 7 Admin Managing User*

The visualization illustrates the proportion of registered users categorized as either administrators or clients. And it demonstrates 5 clients and 3 admin registered. The system admin dashboard is shown in Figure 7.

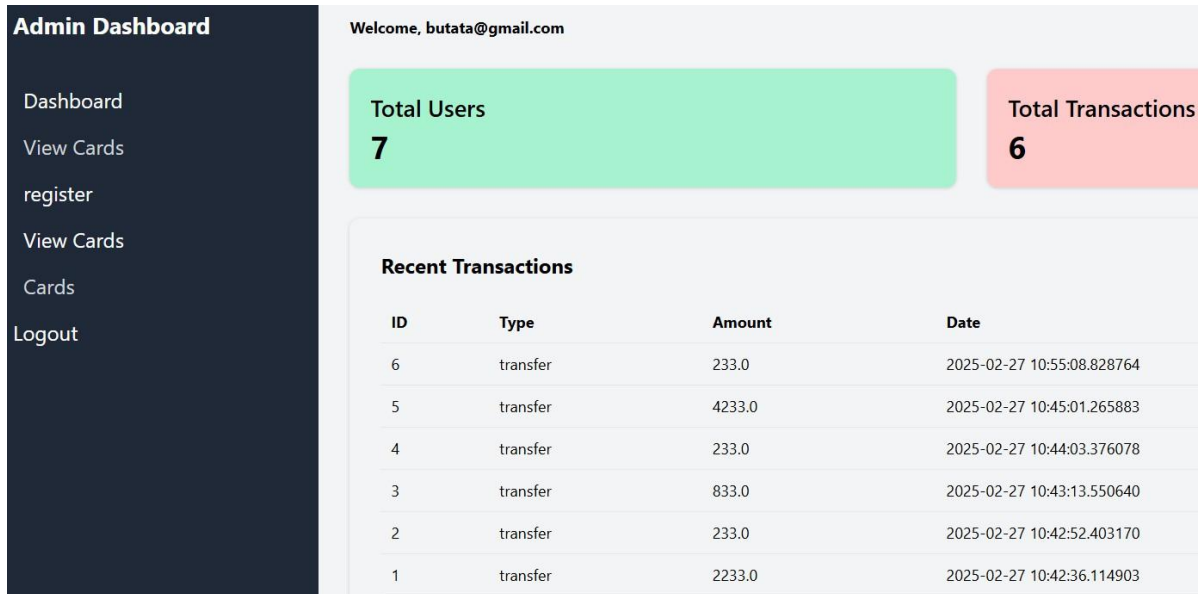


Figure 8 Admin Home/view card

### 5.4.2 Key Features of the System Dashboard

- i. Administrators can instantly view the total number of registered users and monitor adoption trends. The dashboard includes tools to:
  - ⊕ Register new users
  - ⊕ Update or deactivate existing accounts
  - ⊕ Assign and manage user responsibilities or roles within the system
- ii. Card Admin management
  - ⊕ Viewing all active cards
  - ⊕ Checking individual card balances
  - ⊕ Enabling and updating card statuses
- iii. Transaction Tracking
  - ⊕ Real-time display of total transactions
  - ⊕ Access to detailed transaction logs and histories

## User Interface

User can make, payment transaction by inserting coin and tapping card automatically received money to the card, registration card and swapping card payment themselves by mobile app and also user can receive email transaction for each payment transport cost. Figure 8 presents the user interface dashboard.

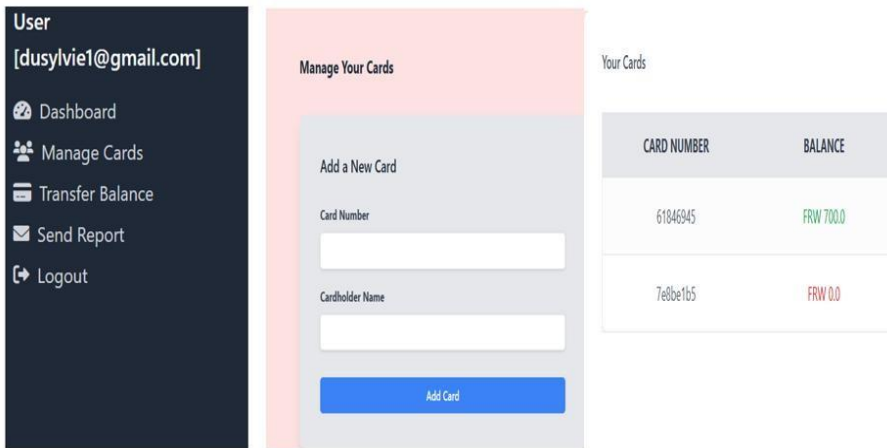


Figure 9 user interface

Figure 9 display user interface demonstrates a functional user dashboard designed to manage smart transport cards within the A novel IoT Based Tape and Go System for Public Transport Services and Management.

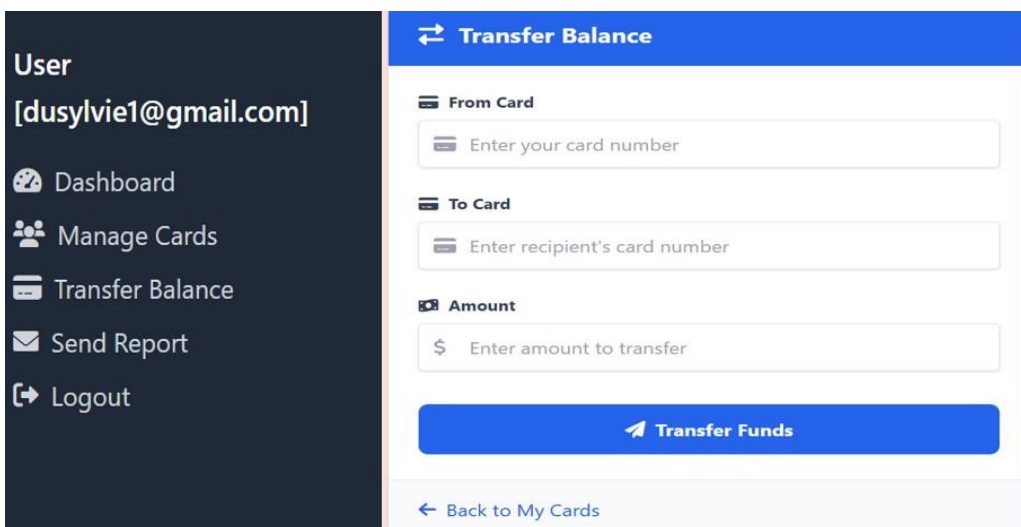


Figure 10 Swapping Card

The figure 10 above demonstrates the card swapping interface, which enables users to transfer balance from one card to another within the system. This feature is particularly useful for users who manage multiple cards or wish to share credit with other commuters. Using the web dashboard, the user simply selects the source card, enters the destination card number, and specifies the amount to be transferred.

### 5.5 Model Accuracy

As shown in Figure 12, the model's accuracy was 87%.

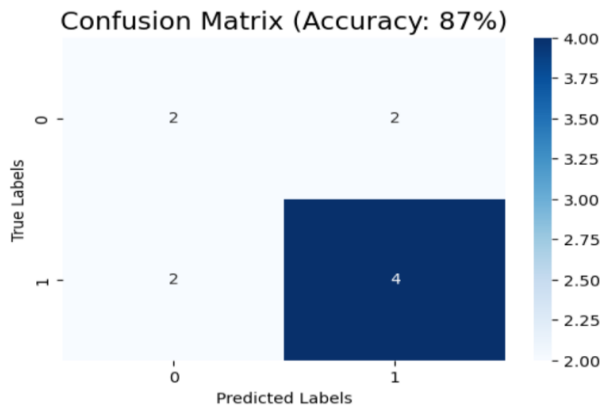


Figure 11 Accuracy

### 5.6 Classification Performance

This classification report metrics chart in Figure 12 compares precision, recall, and F1-score for a binary classifier. For class 0 and class 1 and the balanced values within each class indicate consistent performance, though the classifier is significantly more effective at identifying class 1 instances compared to class 0.

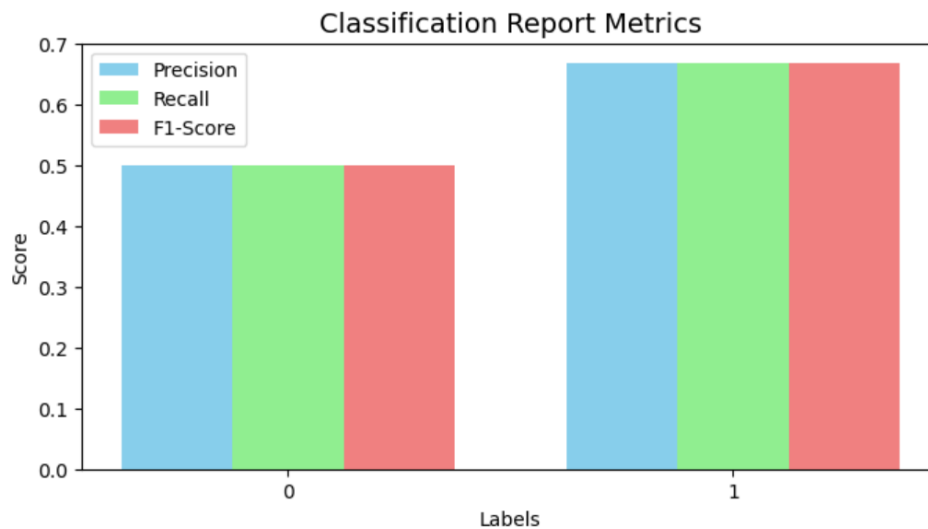


Figure 12 Classification

The classification report further breaks down performance by class (0 and 1), showing precision, recall, and F1-score. The model exhibits higher performance for class 1 (likely valid card transactions) compared to class 0 (likely invalid or problematic transactions).

### 5.7 Implications for Transport System Accuracy

A 87% accuracy rate highlights potential issues such as incorrect fare charging and invalid access. Enhancing the model's accuracy, particularly for class 0, is crucial for maintaining system integrity and passenger trust.

## 5.8 Temporal Analysis and Prediction with ARIMA Model

### 5.8.1 Passenger Type Distribution Analysis

This balanced distribution is crucial for ensuring fairness and inclusivity in transport planning and policy-making. To understand the demographic composition of passengers, we analyzed the distribution of passenger types. Figure 13 shows an equal distribution of female, children, and male passengers, with each group having a count close to 320.

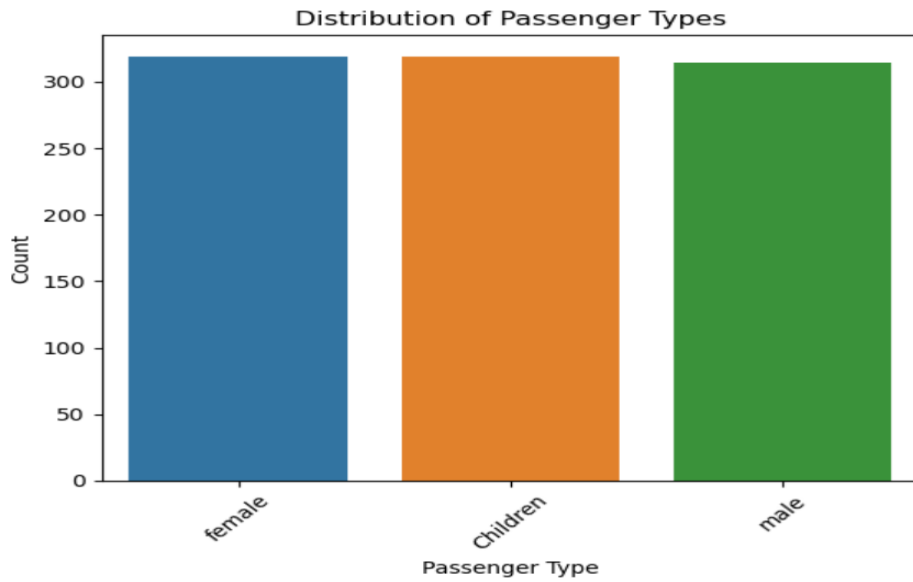


Figure 13 Passenger type

### 5.8.2 Monthly Transport Cost Analysis

As shown in Figure 14, the monthly transport expenses, categorized by passenger are into three passenger categories: children, female and male.

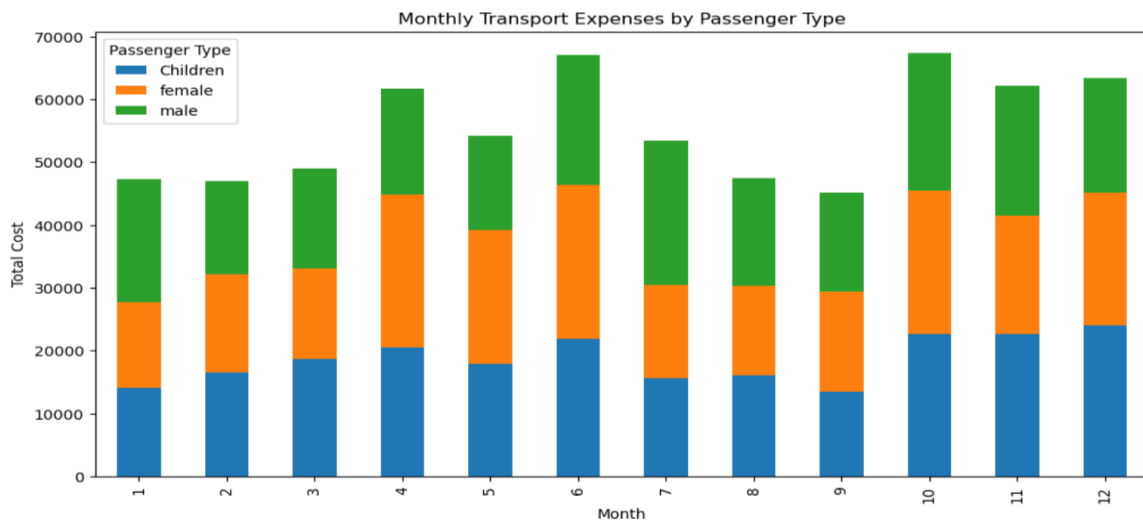


Figure 14 Monthly Transport Expenses

- ⊕ Male passengers consistently account for the largest portion of transport expenses throughout the year, representing the top segment of each bar
- ⊕ Female passengers form the middle segment with moderate transportation costs
- ⊕ Children's expenses, shown in blue at the bottom of each bar, represent the smallest portion but remain relatively stable.

## **CHAPTER VI. CONCLUSION AND RECOMMENDATION**

### **6.1 Conclusion**

The development of the Novel IoT-Based Tap and Go Card System has successfully met its objectives and presents a significant improvement over traditional fare systems. By integrating a coin sensor, ESP microcontroller, and DC motor, the system enables agent-free, coin-based card reloading, enhancing accessibility and automation.

Notable innovations include card reloading system, card swapping via a web application, and generating report with email notifications. The web-based dashboard also supports real-time system monitoring and informed decision-making. Overall, the system offers a smart, user-friendly, and efficient solution for modern public transport fare management.

### **6.2 Recommendation**

Based on the system's capabilities and performance, it is highly recommended for adoption by public transport operators, city authorities, and smart mobility planners. The solution offers practical advantages, including card reloading, cashless and agent-free transactions, inter-card money transfer, and real-time system insights. These features help reduce operational costs, minimize human errors, and streamline the boarding process.

Future work should focus on integrating GPS and location-based services to allow passengers to track buses in real time, receive system alerts, and plan their journeys more efficiently.

Additionally, future improvements should include support for a wider range of currency denominations. The current prototype coin sensor is configured to detect and count only 100 Rwandan Franc coins. It is recommended that future versions be enhanced to recognize other coin values such as 50, 20, and 10 RWF, as well as paper notes. This would increase flexibility for users and improve the accessibility of the system for all passengers.

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