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Extended IoT Payment System Model for Rwanda Stadium Using Smart Cards Case Study: Pere Stadium

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Abstract: The concept of implementing an extended model of an Internet of Things (IoT)-based payment system at Rwanda's stadiums presents an innovative solution to enhance both the customer experience and operational efficiency. This technology will eliminate long queues at payment points, allowing customers to bypass ticketing delays and save valuable time. By utilizing RFID (Radio Frequency Identification) technology, the system enables the simultaneous scanning of multiple personal e-cards, automatically displaying card details and balances on an LCD screen. This ensures that customers can easily monitor their payment status, reducing any potential confusion. The primary objective of this research is to design and implement an IoT-based stadium payment system for "Pere Stadium," located in Nyamirambo Sector, Nyarugenge District, Rwanda. The proposed system is subscription-based and introduces a new form of digital payment for stadium services. It integrates an RFID reader, a database, and RFID cards, requiring customers to register with the stadium's administrator. Registration involves providing essential details, such as names, contact information, and funds to be loaded onto the card, which can be replenished after use. Upon registration, customers can access the stadium, and their RFID cards will be scanned at entry points to process payments. If the card's balance is insufficient, entry will be denied until the customer replenishes their funds with the assistance of stadium agents. The system will automatically update the database with each transaction, ensuring real-time record keeping.

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I. INTRODUCTION

In Rwanda, traditional ticketing and payment systems at stadiums often lead to long queues and inefficiencies. This research explores the implementation of an IoT-based payment system using RFID technology at PERE Stadium in Nyamirambo, Rwanda, to improve operational efficiency and enhance the customer experience. The system aims to streamline ticketing, reduce wait times, and ensure accurate, real-time payments by allowing customers to tap RFID cards at entry points.

The primary goal of this study is to design a modernized payment solution that addresses the challenges of manual processes and integrates seamlessly into stadium operations. This paper evaluates the feasibility and effectiveness of such a system, with potential for broader application in other stadiums across Rwanda.

II. STATEMENT OF THE PROBLEM

Traditional ticketing and payment systems at stadiums often result in slow, cumbersome, and error-prone processes. This not only creates a stressful experience for both attendees and staff but also leads to long queues and delays at ticket counters and entry points. These inefficiencies can compromise security, overburden operational resources, and negatively impact customer satisfaction.

These challenges are made worse by the lack of integration between various systems, such as ticketing, access control, and in-stadium transactions. The reliance on manual ticket verification and cash handling requires significant human intervention, which increases the potential for errors and delays. Additionally, the absence of real-time data synchronization makes it difficult for stadium management to effectively monitor and address operational issues, affecting both security and overall event management. In Rwanda, where there is a growing demand for modern, efficient, and secure event management solutions, there is a pressing need for a more advanced system. The current approaches do not fully capitalize on the benefits of modern technology to enhance user experience or streamline processes.

The key challenge is the need for an integrated Internet of Things (IoT)-based solution that improves both the security and operational efficiency of stadiums. By combining RFID technology, real-time data management, and automated processes, such a system can address critical issues like:

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- Extended Wait Times and Queues: Traditional methods lead to congestion and long waiting periods at entry and transaction points.
- Ineffective Payment Processing and Ticket Verification: Manual systems require extensive human labor and are prone to mistakes.
- Lack of Real-Time Data Integration: Disjointed systems hinder the ability to effectively monitor and manage stadium operations.

III. RESEARCH DESIGN AND METHODOLOGY

➢ *Sampling*

To accurately represent the target population, the sample was selected based on the data that had been previously collected. Sampling refers to the process of determining how many observations should be included in a statistical sample. When it is not feasible to study the entire population, a smaller sample is drawn using a random sampling technique (Cohen et al., 2011).

Slovin's formula provides researchers with a method to determine the appropriate sample size needed to achieve results with a desired level of accuracy. The formula helps estimate the sample size required to ensure that findings are reliable (Slovin, 1985).

For this study, a sample size of 305 respondents was chosen from the target population. The population was divided proportionally into categories, including stadium guardians, clients, and cleaners. The calculation for the sample size is as follows:

➢ *Data Collection Methods and Instruments/ Tools*

Data collection refers to the process of gathering information through predefined procedures to address the research topic at hand. For this study, the researcher used a combination of research instruments, including a questionnaire, documentation, interviews, and observations, to collect primary data.

It is widely recognized that asking individuals questions is an effective method for obtaining both qualitative and quantitative information. In this study, data was gathered primarily through the survey approach (Walliman, 2011).

The specific data collection techniques used in this research included observation and interviews

➢ *Documentation*

Documentation refers to the evidence supporting information and ideas obtained from external sources, including both primary and secondary sources.

➢ *Internet Research*

Internet research refers to the process of gathering information from the Internet, especially freely accessible content on the World Wide Web or online resources such as discussion forums. With a simple search, thousands or even hundreds of pages related to a specific topic can often be quickly found.

The process of internet research has greatly influenced the generation of ideas and the creation of knowledge. It is commonly used for personal research on topics like news events or health issues, academic research by students for projects and papers, and by journalists or authors researching stories.

➢ *Interview*

Interviews, as a qualitative research technique, involve conducting in-depth, individual conversations with a small group of respondents to explore their perspectives on a specific idea, program, or situation. This method allows the interviewer to ask clarifying questions, enabling the respondent to answer in their own words. Additionally, the interviewer can observe both verbal and nonverbal behaviors, as well as gain insights from comments made during the interview. Unlike documentation or observation, interviews can provide valuable, deeper information, making this technique one of the most reliable for gathering data

➢ *Conceptual Framework*

A conceptual framework is an analytical tool that can be applied in various contexts and fields. It helps in organizing ideas and making conceptual distinctions. A well-developed conceptual framework captures essential concepts in a way that is both memorable and practical, providing a clear structure for understanding complex ideas.

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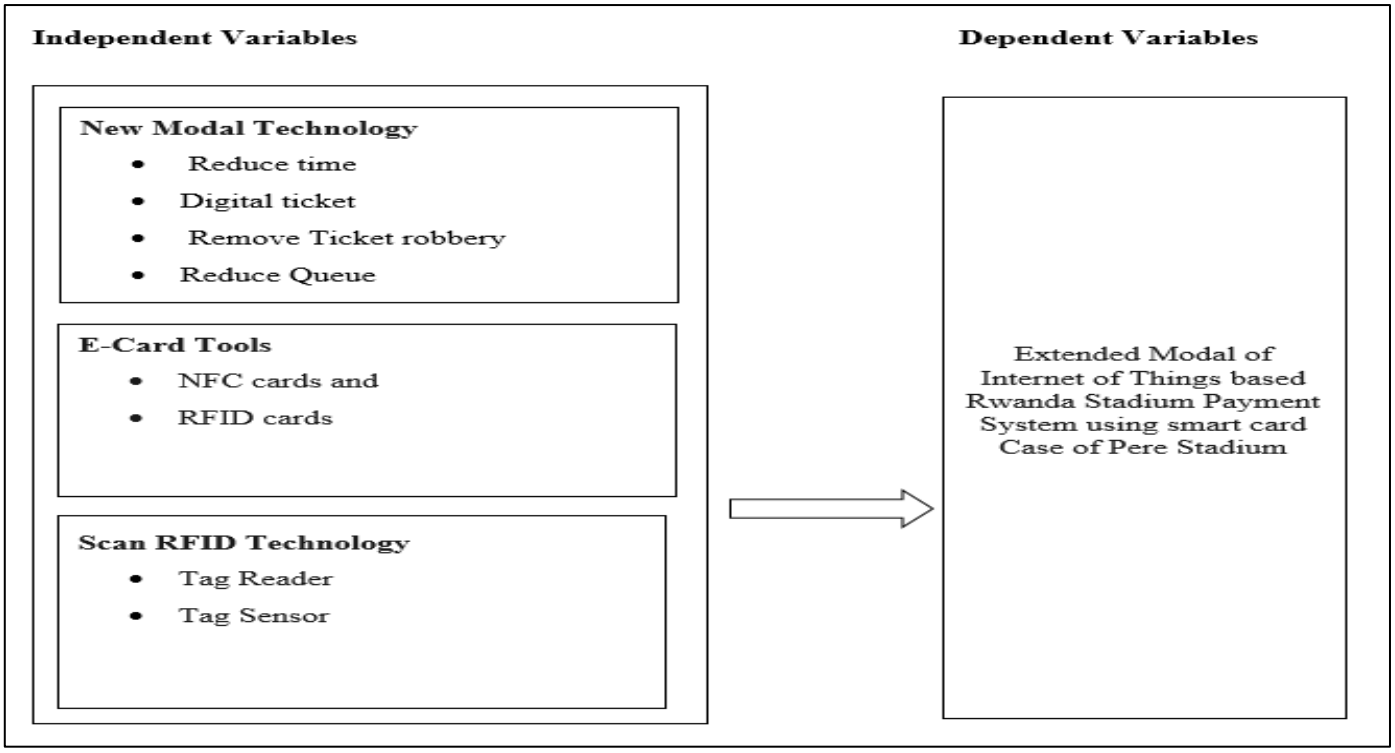

Fig 1 Concept Framework
Source: Own Drawing, 2024

IV. PRESENTATION, ANALYSIS AND INTERPRETATION OF FINDINGS

➢ *Introduction*

This chapter presents the results of the development and testing of the IoT-based stadium payment system for Pere Stadium. The primary goal of this system is to streamline the entry and payment process by using RFID technology integrated with an ESP8266 Node MCU microcontroller. In this chapter, the findings are organized into sections that illustrate the system's design, functionality, and implementation outcomes. I begin by describing the system's block diagram and circuit diagram, which demonstrate the connections and interaction among components. A flowchart of the system is provided to visualize the operational flow. Mathematical models essential to the system's operation are also developed, followed by a description of the specific materials used in the construction. The implementation process is discussed, outlining each step from initial setup to final testing. Lastly, an estimation of the project cost is provided, detailing the expenses associated with the system's development. Each section contributes to evaluating how effectively the designed system meets the objectives, focusing on enhancing customer experience through efficient and secure stadium entry and payment handling.

➢ *System Block diagram*

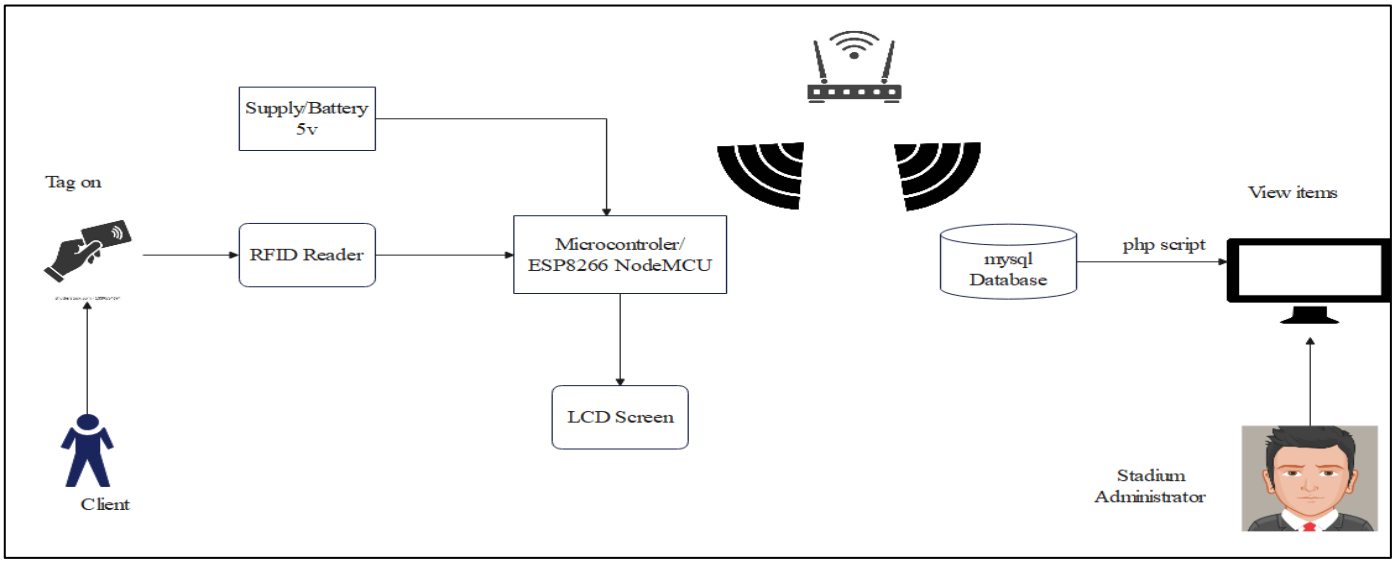

Fig 2 System Block Diagram

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This diagram represents the architecture of an IoT-based stadium entry and payment system using RFID technology, an ESP8266 NodeMCU, and a MySQL database. The client, or stadium attendee, carries an RFID tag, which is scanned by the RFID reader upon entry. The RFID reader is powered by a 5V battery supply, ensuring portability and ease of installation. Once the tag is scanned, data is sent to the microcontroller (ESP8266 NodeMCU), which processes the information and displays the tag owner's details and balance on the connected LCD screen. This setup allows customers to view their information in real time.

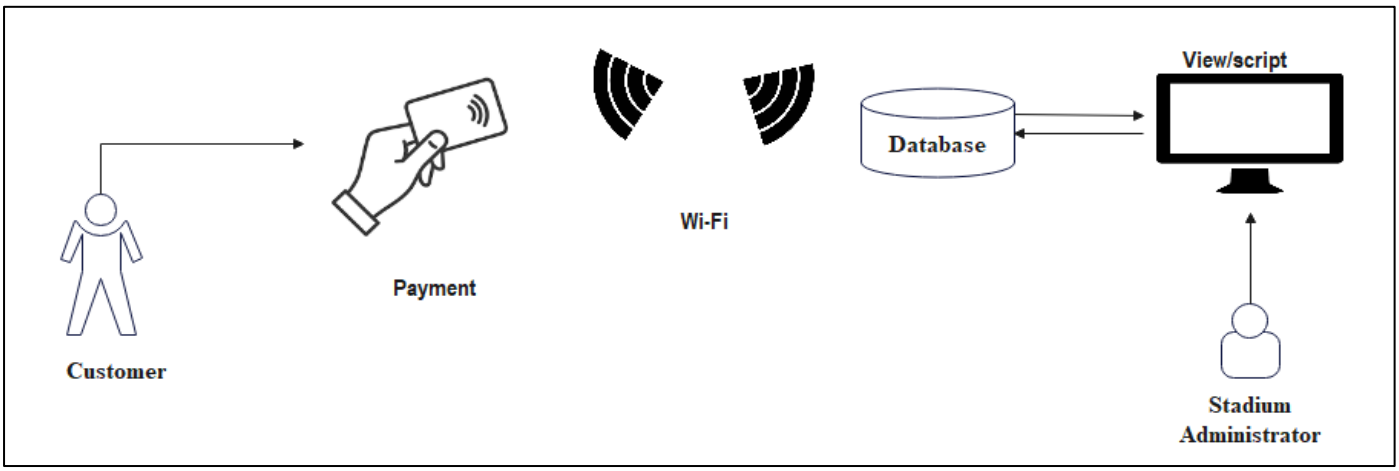

Fig 3 Flow of System

The ESP8266 is connected to a Wi-Fi network, allowing it to communicate with a remote MySQL database where all transaction and balance details are stored. When a customer's payment is processed, their updated information is saved in the database. A PHP script provides an interface for the stadium administrator to access and view transaction details on a computer, allowing for easy management of customer accounts and balances. This system streamlines stadium entry by enabling quick, contactless payment verification and record-keeping for administrators.

➢ *Circuit Diagram*

This circuit diagram illustrates an RFID-based payment system using a NodeMCU, an OLED LCD, a buzzer, and an RFID module (MRC522). The NodeMCU acts as the central microcontroller, connecting to the RFID reader, LCD screen, and buzzer. The RFID module is used to scan tags, with its data pins (SCK, CE, SDA, and SDO) connected to the NodeMCU's GPIO pins for communication. When a valid tag is scanned, the system displays the user's information on the OLED LCD screen (OLED12864), allowing customers to view their balance or status. The buzzer provides an audible alert to indicate successful or failed scans, and the system is powered by a 5V battery, making it portable and easy to deploy at stadium entry points.

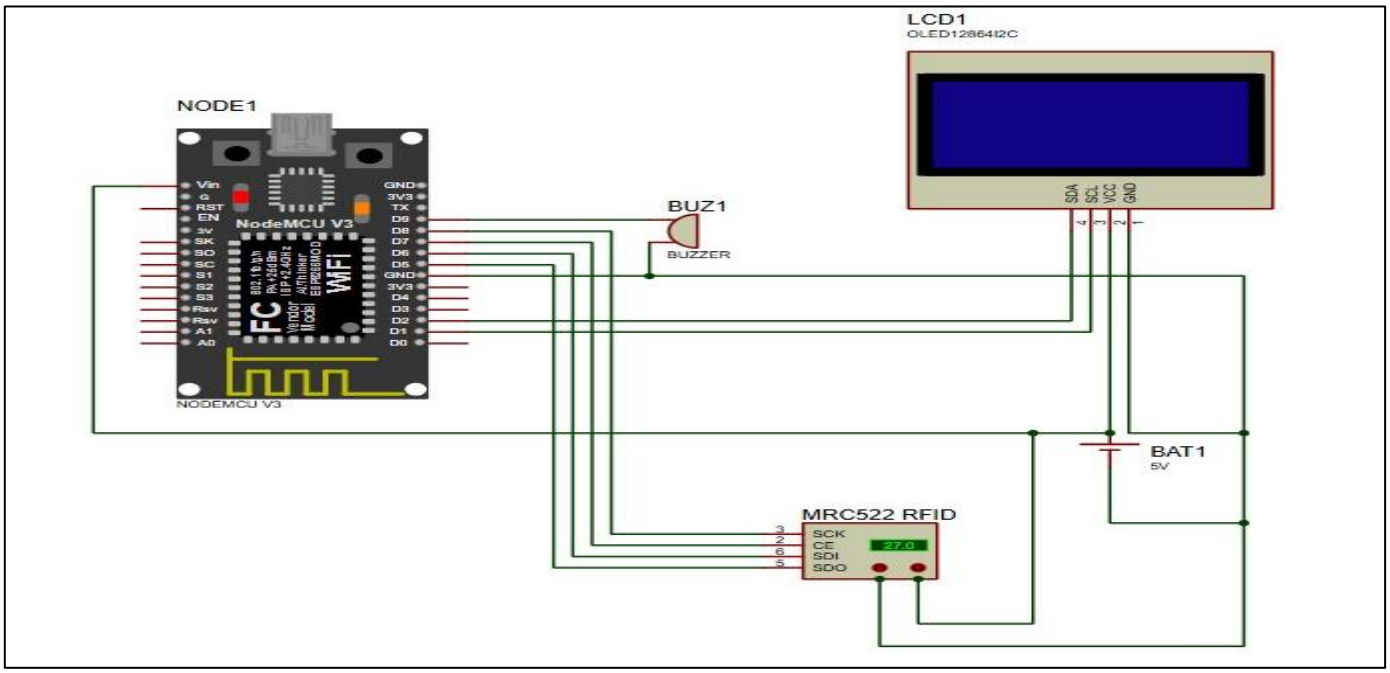

Fig 4 System Circuit Diagram

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➢ *Flowchart of System*

This flowchart illustrates the process flow for a stadium entry and payment system using RFID technology. The process starts with initializing the RFID reader, LCD screen, and buzzer. Next, customer details are registered in the system, which is necessary for linking each RFID tag to a specific individual. Once registration is complete, the system waits for a customer to scan their RFID tag. If the scanned tag is found in the database (i.e., the customer is registered), the system proceeds to the next steps; otherwise, the user must register before entry.

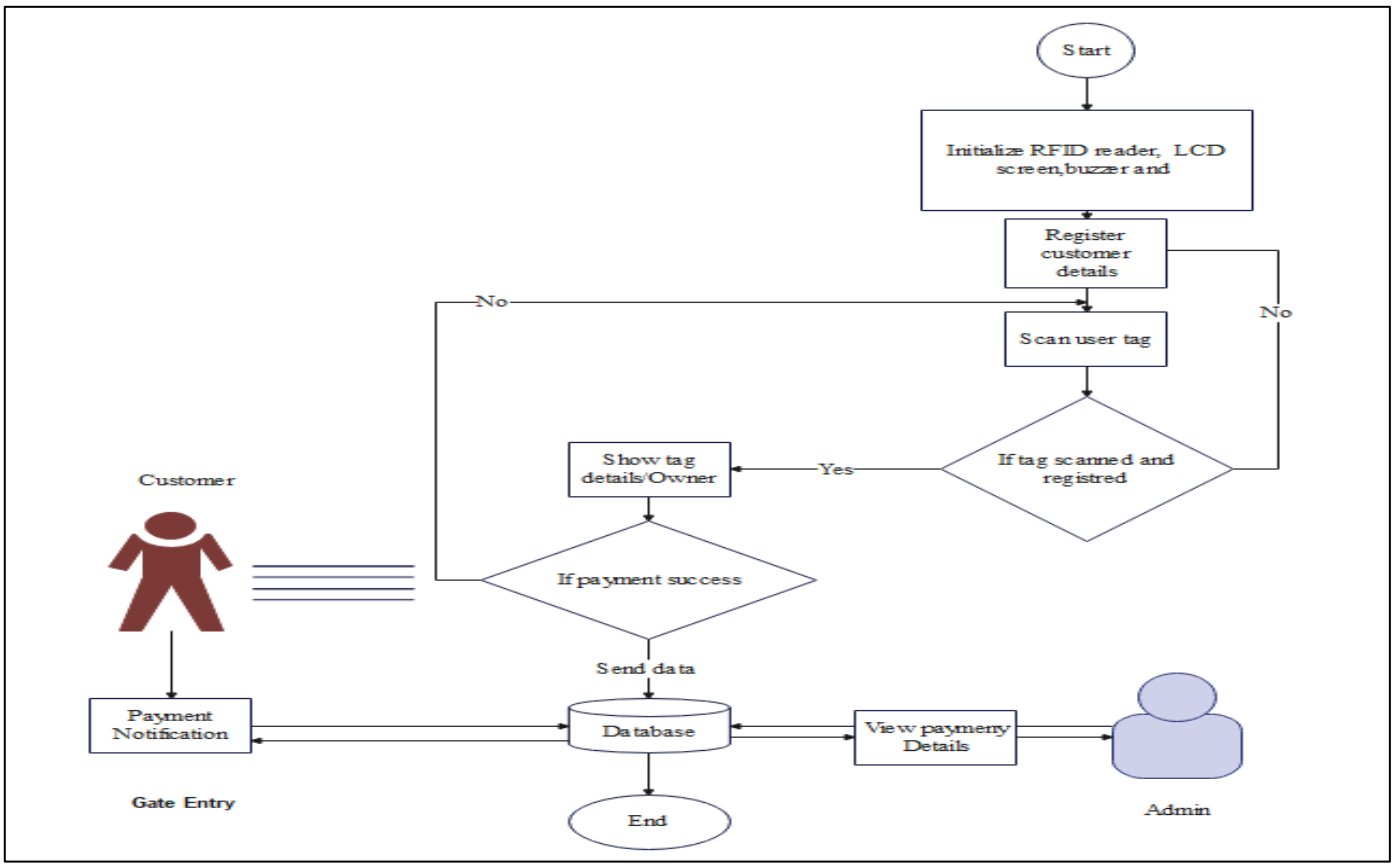

Fig 5 System Flow chart

If the tag is recognized and registered, the system displays the tag owner's details on the LCD screen. Then, it checks if there are sufficient funds for entry. If payment is successful, the transaction details are sent to a database, which stores the payment information and updates the balance. The system then notifies the customer at the gate entry, allowing them access. The database also allows an admin to view payment details, providing a record of transactions and facilitating monitoring of entry payments. If payment is unsuccessful, the system does not allow entry, and the customer will need to top up their card.

➢ *Specific materials*

The following table provides a detailed list of the materials and components used in the development of the IoT-based stadium payment system. Each component has been chosen for its compatibility, functionality, and contribution to the overall system design.

➢ *Implementation*

The implementation of the IoT-based stadium payment system involves integrating all the hardware components with the necessary software to facilitate RFID-based payments, real-time data transmission, and user interaction. The key steps in the implementation process are outlined below:

➢ *Hardware Setup*

The first step is to properly assemble and connect all the hardware components. Below is a breakdown of the hardware setup:

- NodeMCU (ESP8266): This microcontroller will be responsible for connecting to the Wi-Fi network and interfacing with the RFID module, LCD display, and other components. It will manage the data transmission to and from the MySQL database.

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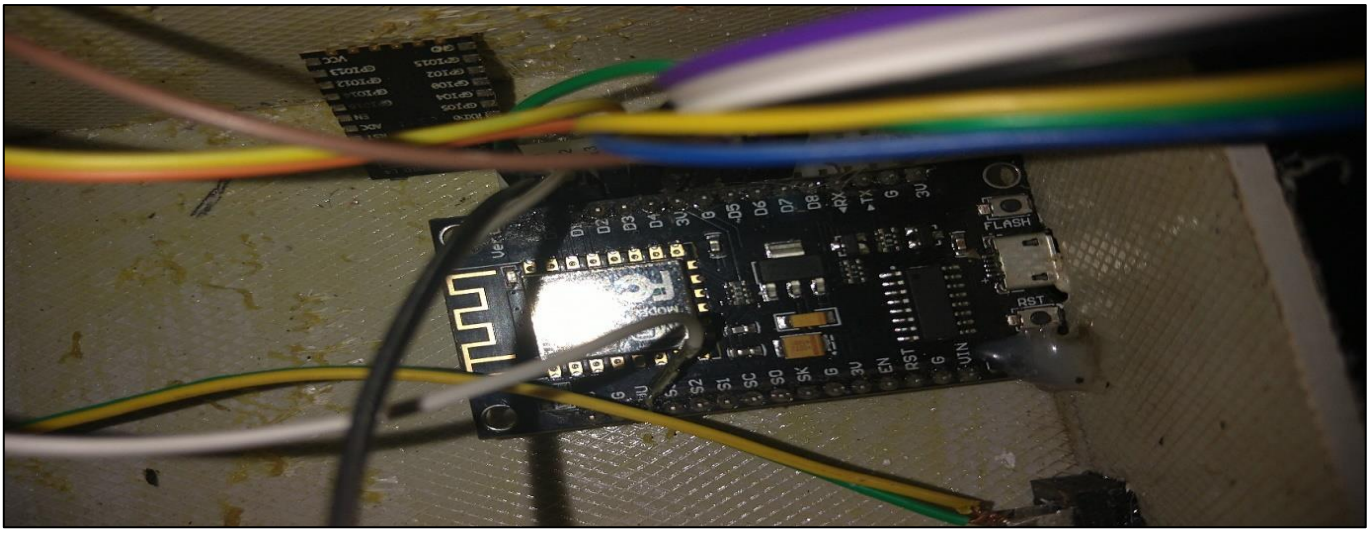

Fig 6 Node MCU

RFID Module (MFRC522): This module will be connected to the NodeMCU and will be used to read the RFID tags presented by users at the stadium. It communicates with the microcontroller to retrieve the unique identifier (UID) from the tag.

Fig 7 RFID Reader

RFID Tags: Customers will be issued RFID tags (or cards) that store essential details, such as user ID and balance. These tags will be used for stadium access and payment processing.

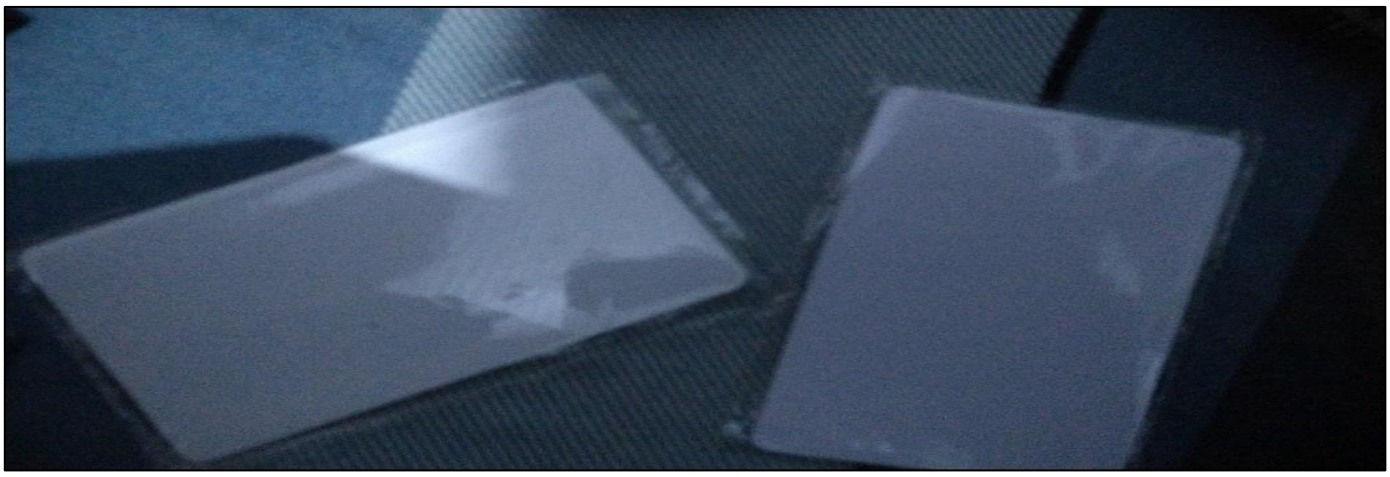

Fig 8 RFID Tags

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- CD Display: The LCD display will show the user's details and balance after scanning the RFID tag. It will update in real time based on the data received from the RFID module.

Fig 9 LCD Screen

- uzzer: The buzzer will emit an audible sound to provide feedback to the user, indicating whether the RFID scan was successful or if there was an error

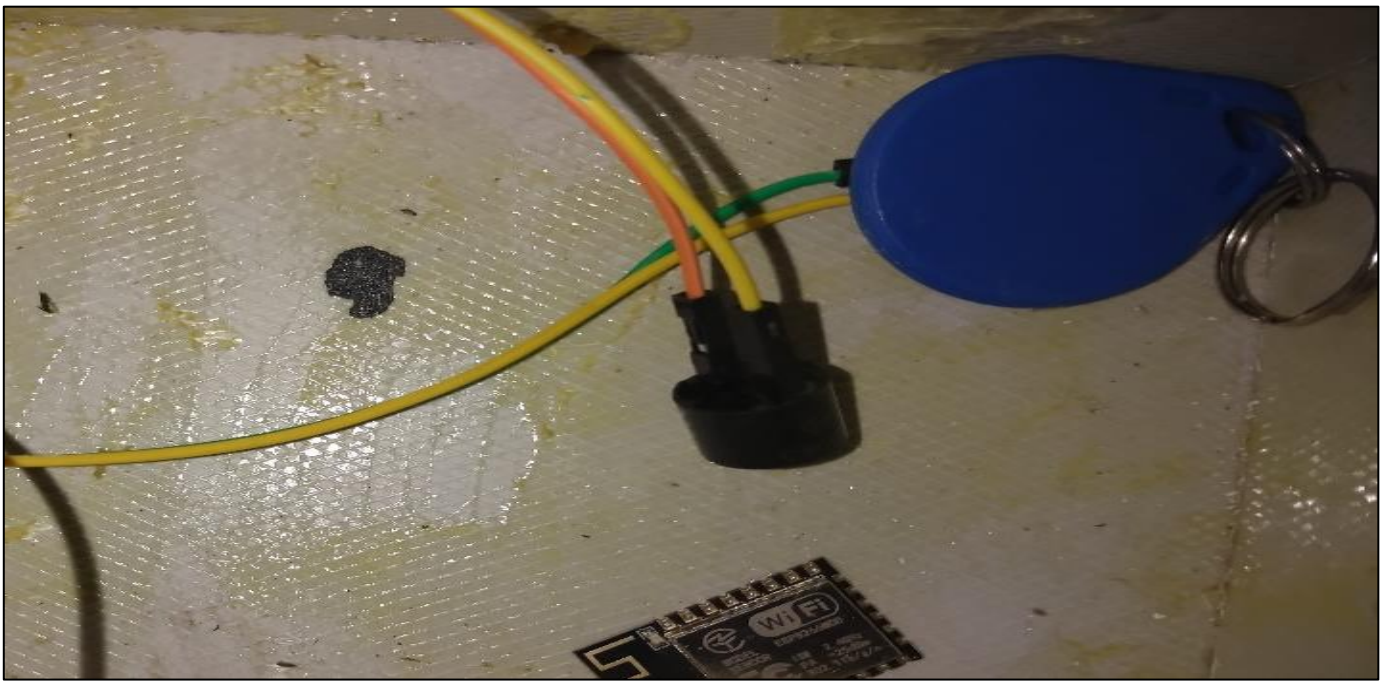

Fig 10 Buzzer

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- A 5V battery will be used to power the entire system, ensuring that the system remains operational in the event of a power outage or when used remotely.

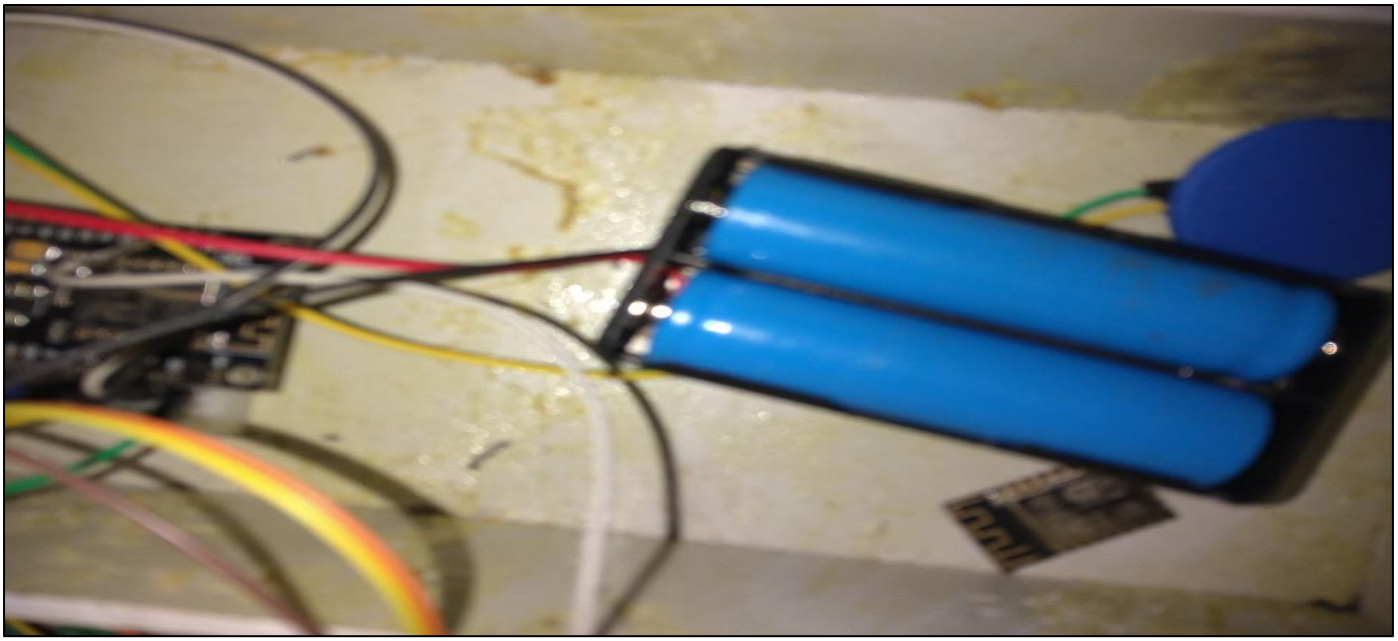

Fig 11 Battery

➢ *Software Setup*

The software setup involves configuring the NodeMCU to read RFID tags, display information on the OLED LCD, and transmit data to the MySQL database for transaction processing.

- NodeMCU Programming: The NodeMCU will be programmed using the Arduino IDE. The key functionalities programmed into the microcontroller are:

✓ Reading RFID tags using the MFRC522 library.
✓ Displaying the customer information and balance on the OLED LCD using the U8g2 library.
✓ Sending data (such as the customer ID and transaction amount) to the MySQL database through Wi-Fi.

- MySQL Database: The MySQL database will store customer information, including user ID, balance, and transaction history. The database will be updated in real-time each time a transaction occurs (for example, after a stadium entry or payment).
- PHP Web Interface: The PHP-based web interface will allow the stadium administrator to view and manage customer data, monitor transaction success rates, and access historical data. The web interface will include the following sections:

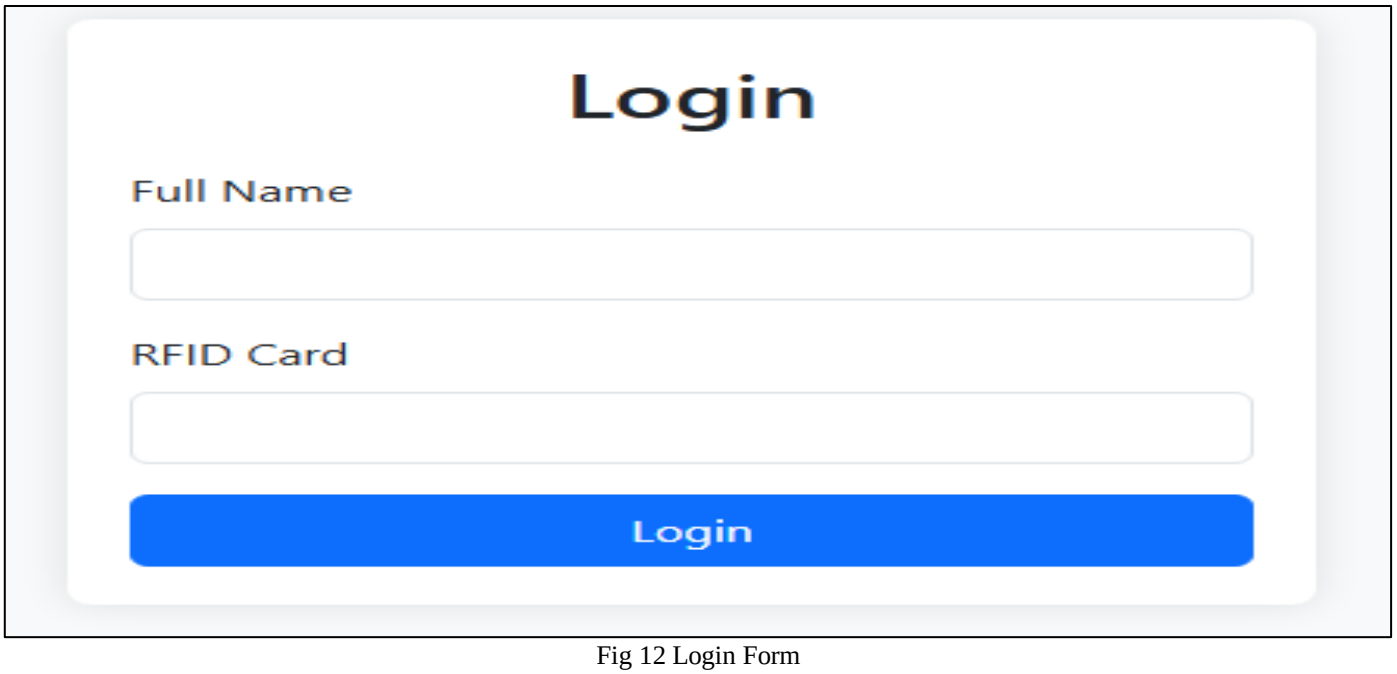

Fig 12 Login Form

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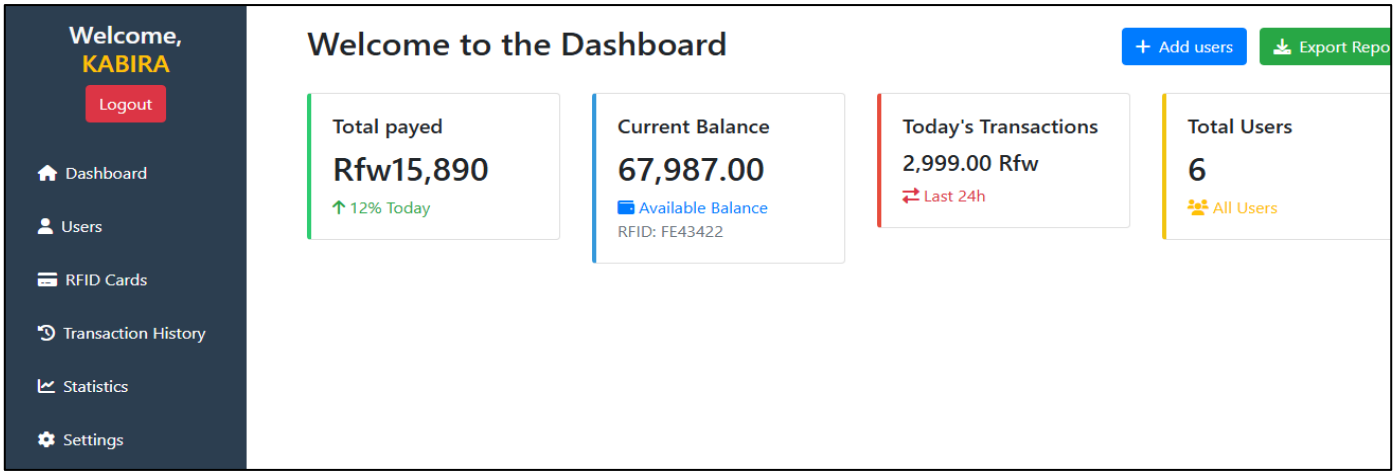

Fig 13 Cashier Home Page

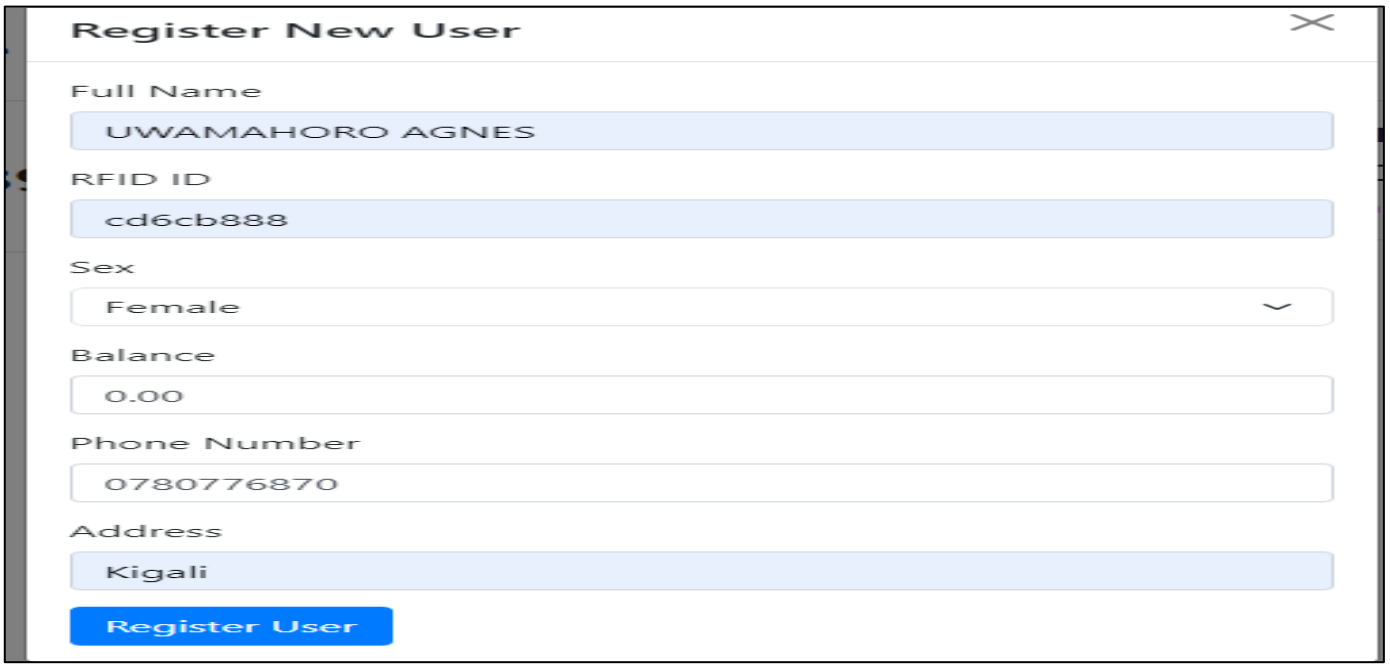

Fig14 Users Registration Form

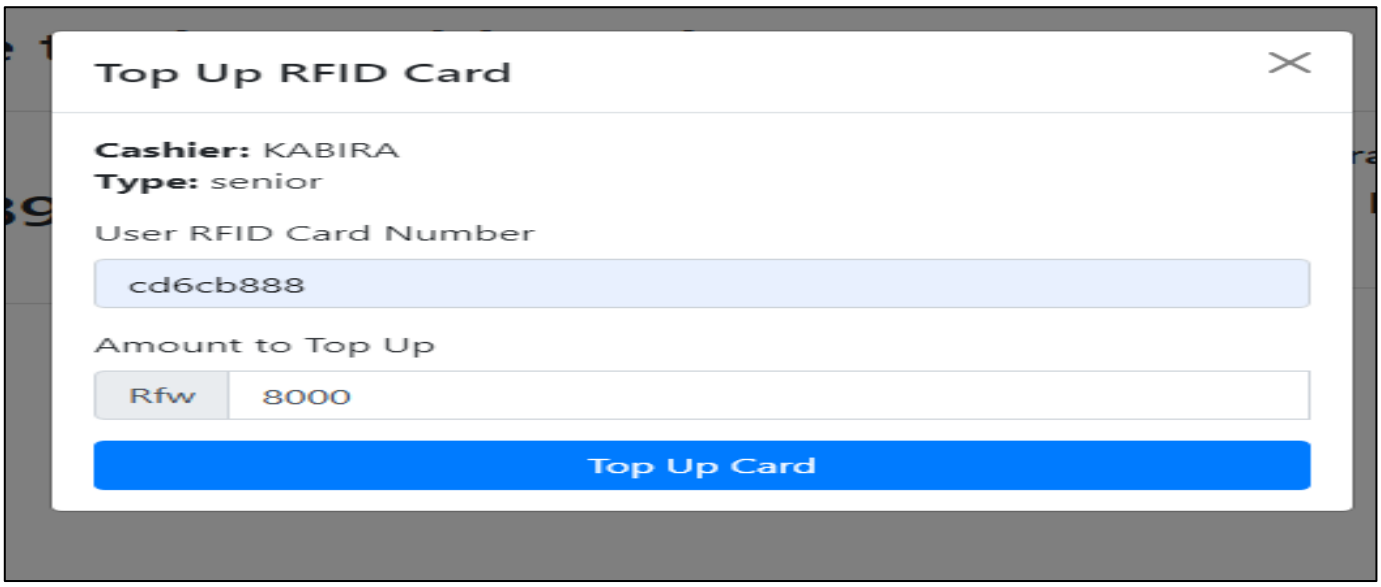

Fig 15 Users Top-up form

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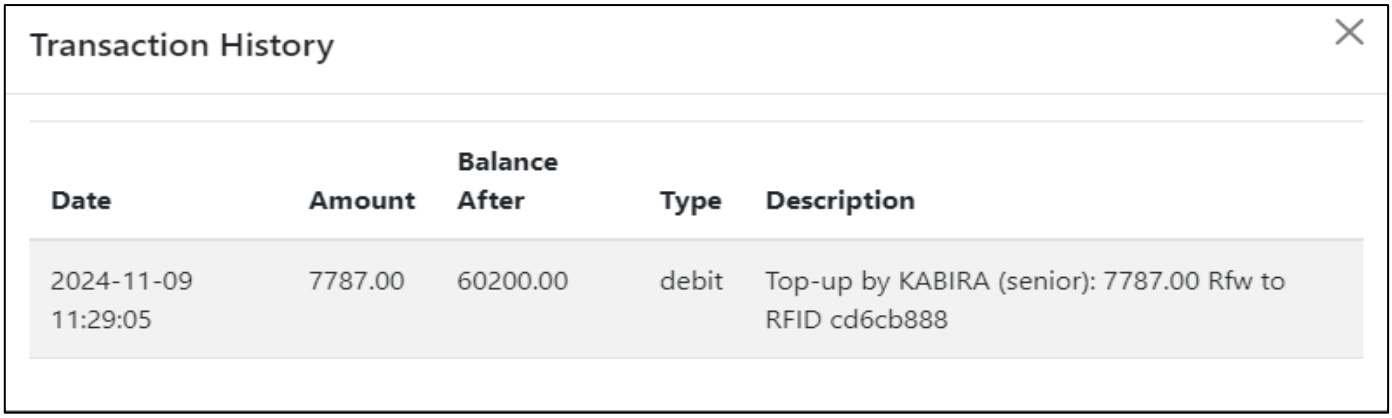

Fig 16 Transaction History for Cashiers

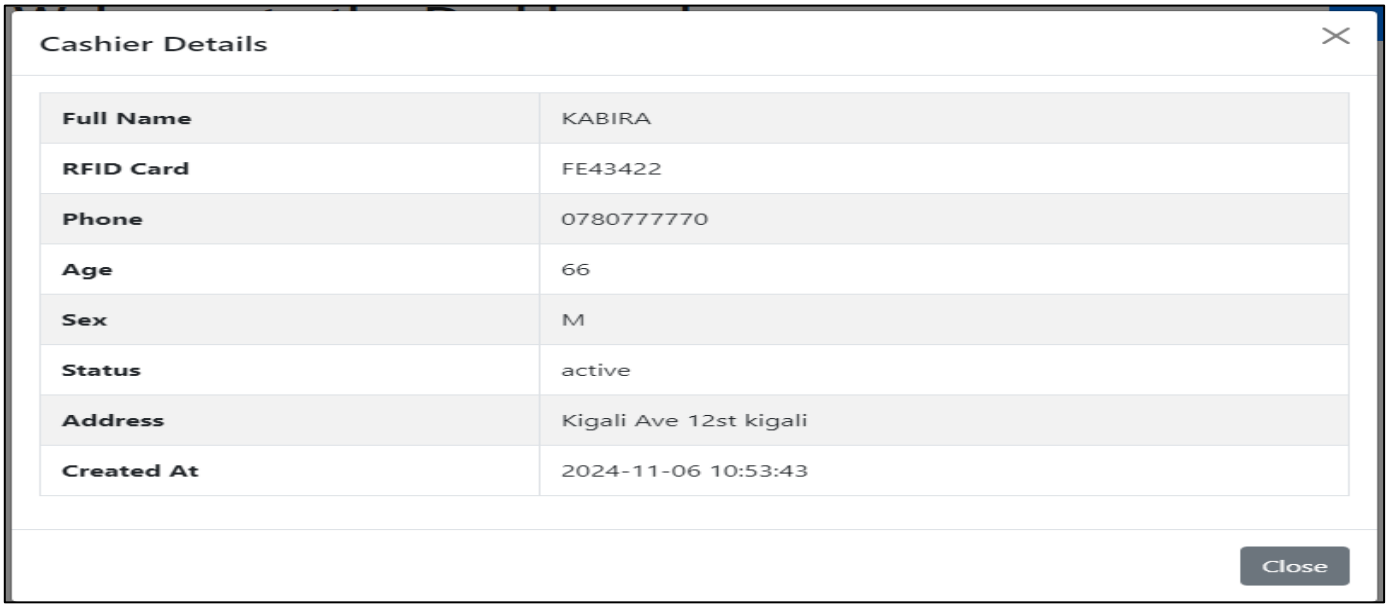

Fig 17 Cashiers Detail account

- Dashboard: Provides an overview of Admin activities and transaction status.

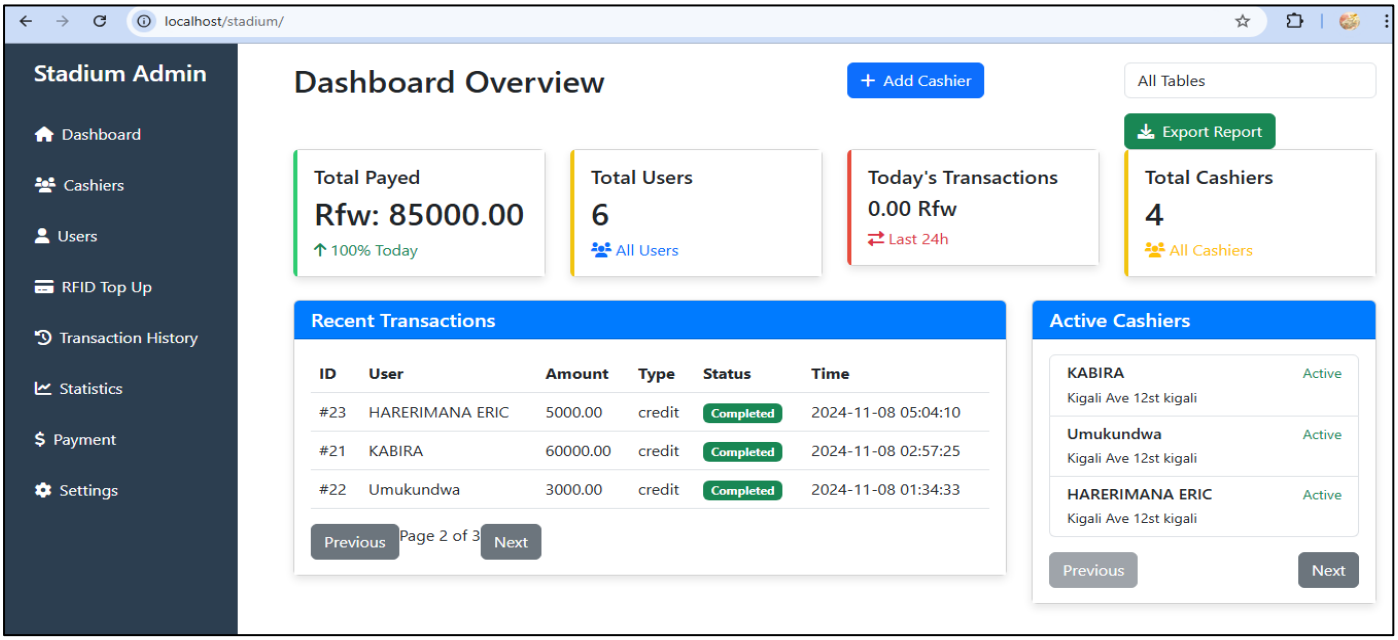

Fig 18 Admin Dashboard

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- Manage Cashiers: Allows the admin to add, edit, or delete cashier's records.

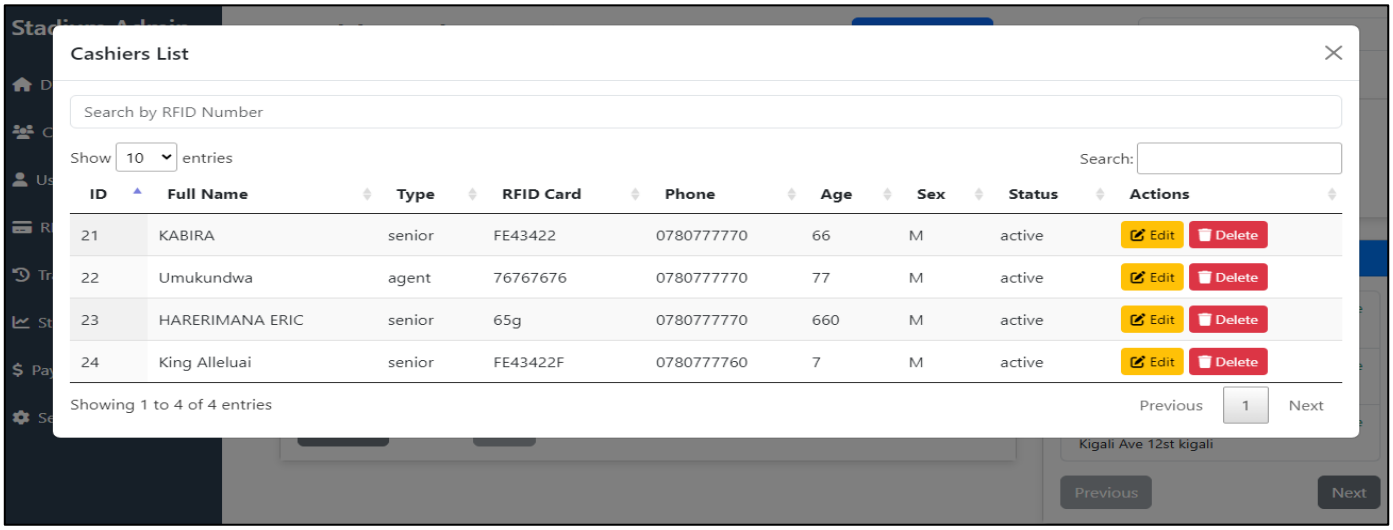

Fig 19 Managing Cashiers

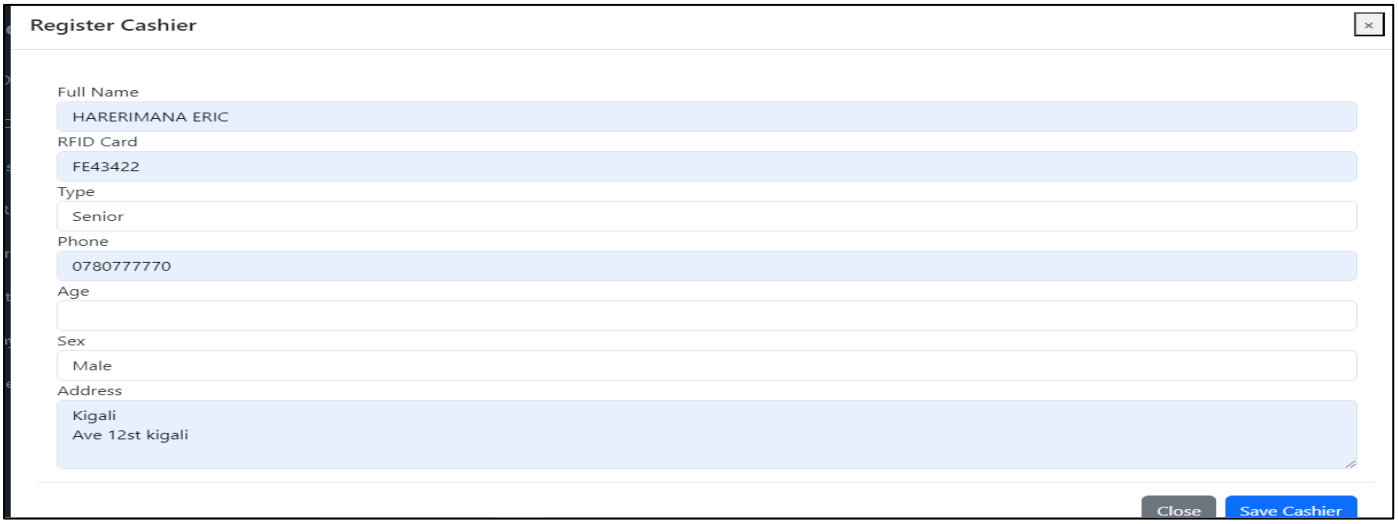

Fig 20 Register Cashiers Form

Fig 21 Top-Up Money to Agents (Cashiers)

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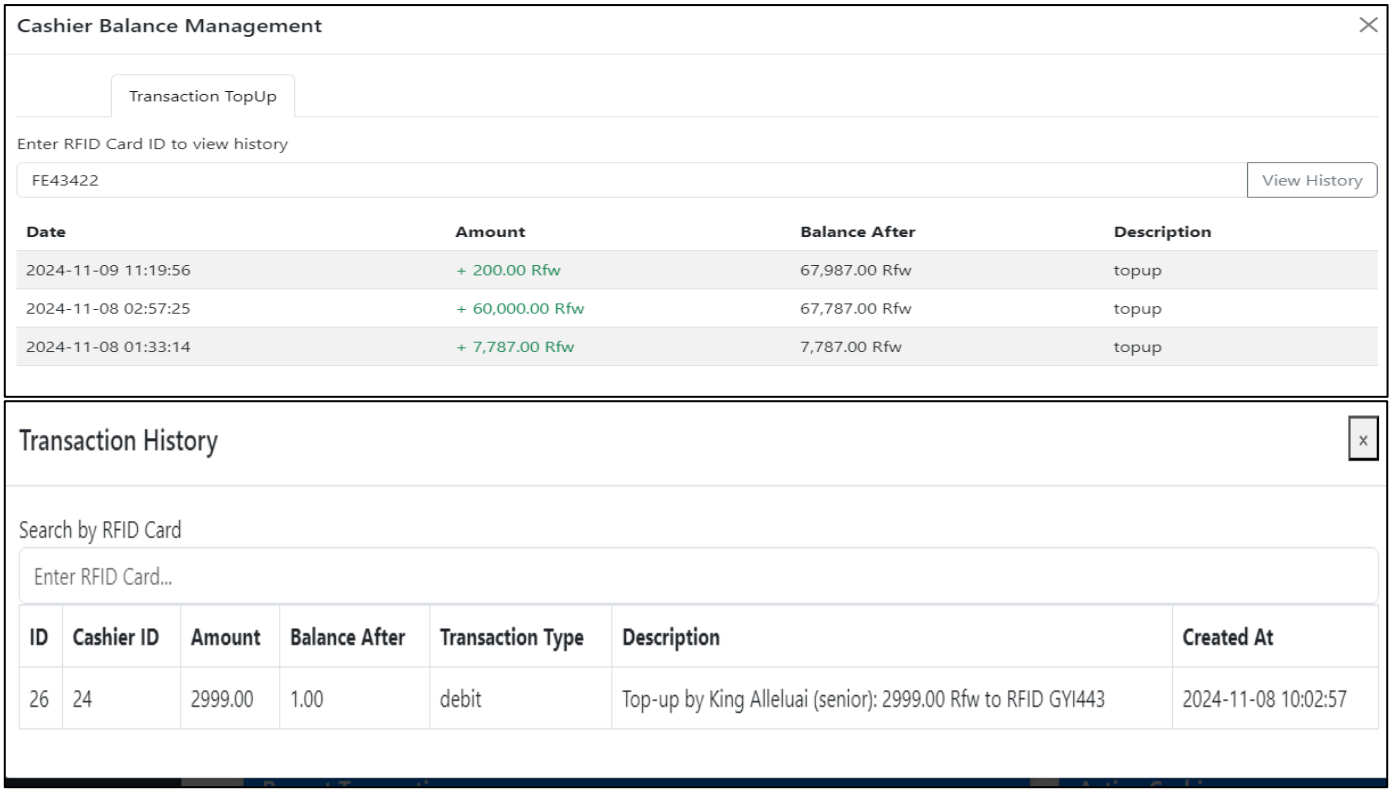

Fig 22 Cashier Balance

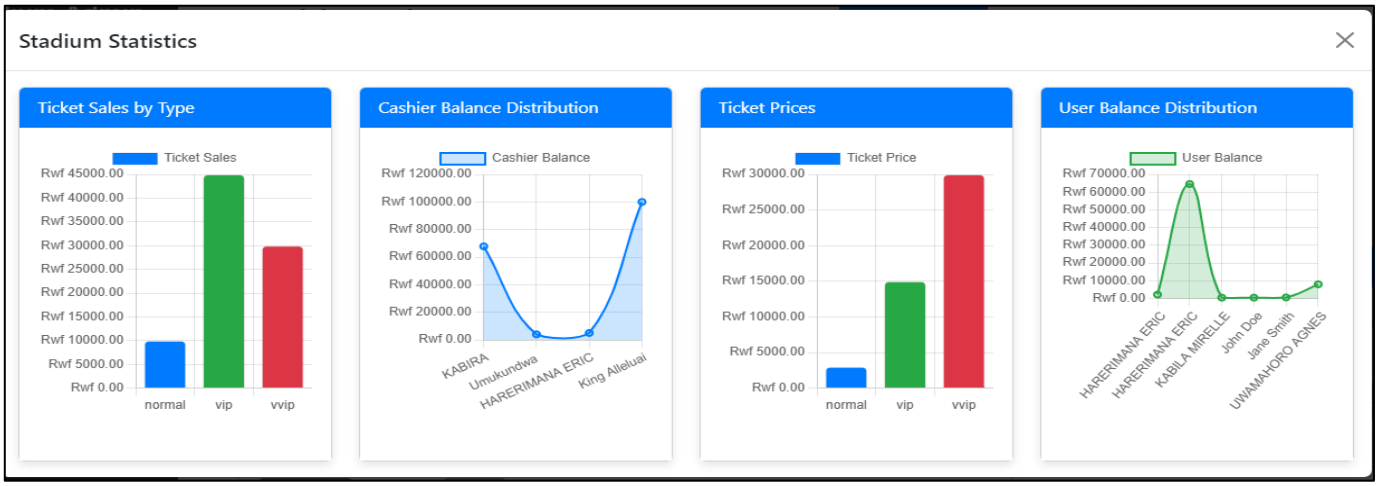

Fig 23 Stadium Statistics

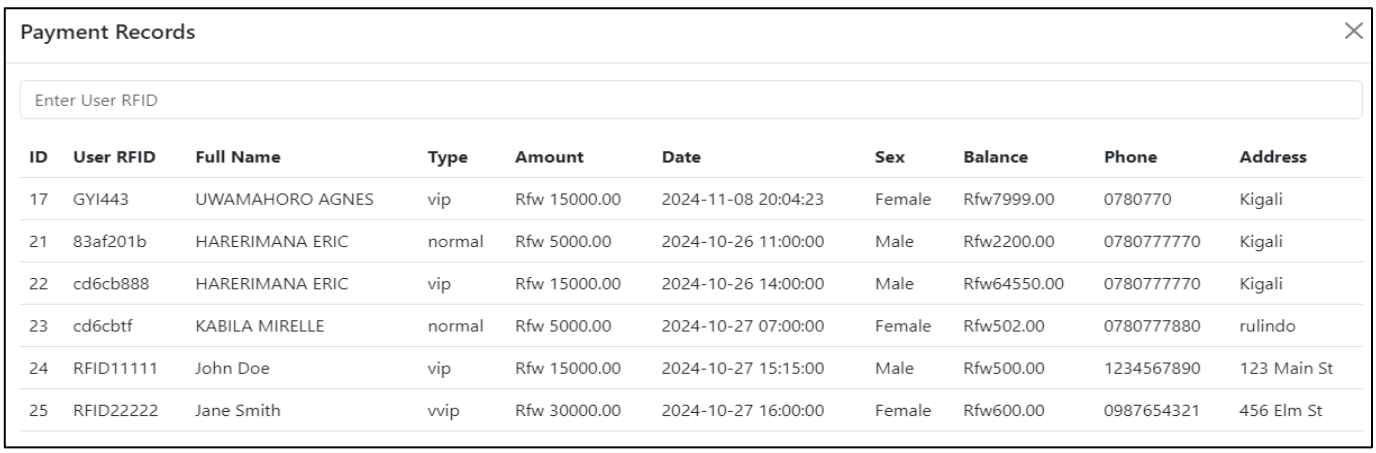

Fig 24 Payment Records History

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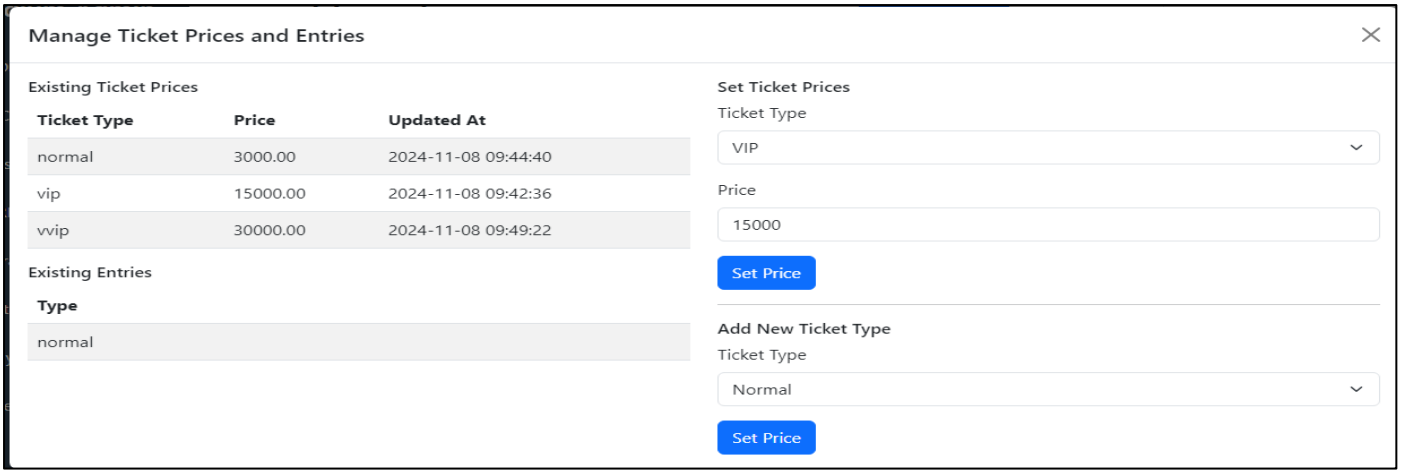

Fig 25 Managing Tickets

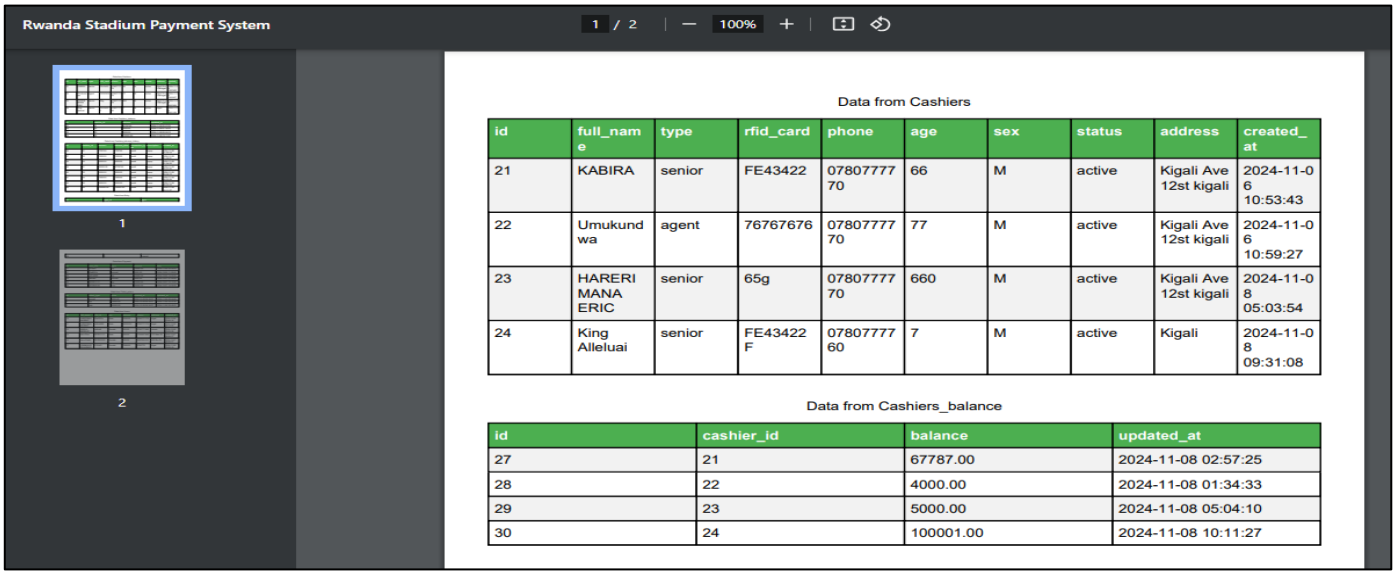

Fig 26 Exported Data.

V. CONCLUSION

The implementation of the Extended Model of Internet of Things-based Rwanda Stadium Payment System has proven to be an effective solution to address the challenges faced by stadium-goers, particularly related to long queues and manual ticketing processes. By leveraging RFID technology, the system offers a seamless, efficient, and modern way for customers to pay for their entry into the stadium.

The introduction of this system has successfully achieved the goal of enhancing operational efficiency and improving user experience at Pere Stadium. The system significantly reduces waiting times by enabling quick and easy payment processing through RFID cards. Customers simply tap their cards at the entry gate, which is scanned and validated by the RFID reader, eliminating the need for cash handling or manual ticket checks. This process is not only faster but also more accurate, ensuring that payments are processed in real time.

One of the notable features of the system is the LCD display, which shows the customer's card details and balance, allowing customers to track their payment status and avoid confusion. This transparency helps enhance the customer's confidence in the system and reduces the potential for disputes at the entry points.

The system's reliance on RFID technology provides a secure and reliable solution, ensuring that only registered customers with valid RFID cards are permitted entry. This improves security at the stadium and ensures accountability, as all transactions are logged and stored in the central database.

Overall, the system proves to be a cost-effective solution for the stadium, reducing the need for manual ticketing and processing while increasing operational efficiency. The system's implementation has the potential to be scaled to other stadiums and large venues in Rwanda, contributing to the modernization of payment processes across the country.

RECOMMENDATIONS

- Based on the findings of this research, the following recommendations are made for the successful

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implementation and future development of the Rwanda Stadium Payment System:

- Wider Implementation: The system should be extended to other major stadiums and venues across Rwanda to help streamline the payment process and improve customer experience in various settings. A nationwide rollout would help standardize entry processes, leading to a more uniform experience for customers.
- System Enhancement: Further research should be conducted to incorporate mobile payments or integrate with existing mobile money platforms in Rwanda. This would allow users to top-up their RFID cards via mobile phones, offering greater flexibility in how users load money onto their cards. Mobile payment options could enhance user accessibility and convenience.
- Continuous Training for Stadium Agents: Staff responsible for managing customer recharges and card issuance should undergo continuous training to ensure they are fully proficient in handling the system's operation and troubleshooting issues. Well-trained staff can improve the user experience by resolving issues quickly and efficiently.
- Periodic System Updates: Regular updates to the system's software and database management will be essential to ensure that it remains secure, efficient, and up-to-date with technological advancements. Keeping the system current will also help in addressing any emerging vulnerabilities or system bugs.

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