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IoT BASED SMART PUBLIC TOILET MANAGEMENT AND MONITORING SYSTEM

CASE STUDY: PUBLIC TOILET AT MUSANZE BUS PARKING

A dissertation submitted in partial fulfilment of requirements for the award of a Bachelor's Degree of Science in Computer Science, Option of Industrial Information Technology

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DECLARATION OF ORIGINALITY

I hereby certify that, to the best of my knowledge, the work included in this dissertation is my own. No other university or institution has ever received the same work. I so certify that this work is my own and that it partially fulfills the requirements for the INES Ruhengeri Bachelor of Science in Computer Science in Industrial Information and technology degree.

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APPROVAL

This is to certify that this dissertation work entitled “IoT based Smart Public Toilet Management and Monitoring System” is an original study conducted by Aime Parfait SIBOMANA under supervision and guidance.

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DEDICATIONS

To:

My Parent and My Family,

My supervisors,

My co-supervisors,

My lecturers,

My friends,

My Colleagues.

ACKNOWLEDGMENTS

Many people have contributed to this effort by giving of their time to assist me in conducting this study. I would like to thank my co-supervisor, Dr. Theodore HABIMANA, and my supervisor, Mrs. Console MBONIMANA, for their assistance and contributions throughout the supervision. I also want to thank my other classmates for their thoughts and support. All honour and gratitude go to the Almighty God for giving me the fortitude, bravery, and health I needed to complete my studies at INES RUHENGERI. Special thanks go out to my parents and relatives, who have given me everything they can to support my education from the time I was a little child to the present, enabling me to complete this task. At last, I would want to express my sincere appreciation, reverence, and affection to everyone who gave me moral support and unwavering encouragement over the course of the study.

ABSTRACT

Maintaining clean public toilets and promoting good hygiene are crucial for public health, especially areas like Musanze Bus Parking in Rwanda. This project suggests an innovative IoT-based Smart Public Toilet Management and Monitoring System to address sanitation concerns and enhance safety. Traditional payment methods for public toilets, which involve coins and manual operations, pose challenges in hygiene, speed, and privacy. Our system leverages modern technology, specifically the NodeMCU ESP8266 and RFID reader cards, to enable touchless access and secure payment for public toilets. The system integrates key components for seamless operation: NodeMCU ESP8266 for control and communication, RFID card readers for touchless access, servomotors for automatic door operation, LCD displays for real-time feedback, it generates alerts and notifications via Wi-Fi for efficient management. This approach ensures a cleaner, safer user experience, streamlines the payment process, enhances monitoring and management functionalities. The primary objective is to develop and implement an IoT-based system that improves hygiene, facilitates cashless payments, and optimizes resource use. The project also aims to address privacy and security concerns associated with IoT deployment, evaluate user satisfaction, and provide a sustainable model for public toilet management. The case study of Musanze Bus Parking offers practical insights and data-driven analysis on the effectiveness, efficiency, and impact of smart public toilet management systems in similar urban settings, this research has the potential to revolutionize public toilet management, significantly improving public health and hygiene standards in urban areas.

Key words: - IoT devices, Smart toilet, NodeMCU ESP8266 and RFID reader cards.

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LIST OF ABBREVIATIONS

DC: Direct Current

ESP 8266: Espressif Systems 8266

GND: Ground

I2C: Inter-Integrated Circuit

IDE: Integrated Development Environment

INES: Institut D'enseignement Supérieur

IoT: Internet of Things

LCD: Liquid Crystal Display

LED: Light Emitting Diode

MCU: Microcontroller Unit

PCB: Printed Circuit Board

RFID: Radio-Frequency Identification

RGB LED: Red, Green, Blue Light Emitting Diode

SDA: Serial Data Line

SDL: Simple Direct Media Layer

UNICEF: United Nations International Children's Emergency Fund

VCC: Voltage Common Collector

WWW: World Wide Web

LIST OF APPENDICES

CHAPTER 1: GENERAL INTRODUCTION

1.1. Background of the Study

In Rwanda, maintaining clean public toilets and promoting good hygiene are crucial for public health. As one of the cleanest countries in Africa (BBC, 2023) Rwanda is committed to upholding high sanitation standards, even during challenging times such as pandemics. To address sanitation concerns and enhance safety, we propose an innovative solution the Internet of Things (IoT) based Smart Public Toilet Management and Monitoring System in Musanze Bus Parking. This project tackles three significant issues: streamlining the payment process for public toilets, ensuring a cleaner, safer user experience, and integrating monitoring and management functionalities (UNICEF, 2021) (Bank, 2022).

Traditional methods of paying for public toilets, which involve coins and manual operations (mobile money and Airtel Money), pose challenges in hygiene, speed, and privacy. Our project leverages modern technology, specifically using the Node Microcontroller Unit Espressif Systems 8266 (NodeMCU ESP8266) and Radio Frequency Identification (RFID) reader cards, to enable touchless access to public toilets. These cards facilitate hands-free entry and provide a convenient, secure payment method. Our system surpasses traditional approaches by offering a cleaner experience, as users do not have to touch the toilet door, enhancing hygiene, it provides a faster and more efficient payment process, eliminating the need to handle coins or navigate complex payment methods. Importantly, the system ensures user privacy and as personal information is not stored on the RFID cards (John, 2023).

The IoT-based Smart Public Toilet Management and Monitoring System integrates several key components for seamless operation. The NodeMCU ESP8266 manages control and communication tasks, including connecting to a central server for data transmission. RFID card readers capture unique card identifiers, while servomotors automatically open and close the restroom door upon receiving signals from the server. Users receive real-time feedback via a Liquid Crystal Display (LCD), indicating restroom status, the system generates alerts and notifications, such as low balance or cleaning alerts, sent through Wi-Fi via the NodeMCU (Jones, 2022).

This integrated approach ensures efficient management and enhances the user experience in public toilets at Musanze Bus Parking, benefiting daily users (John, 2023).

1.2 Problem statement

Public toilets in Musanze district, especially at Musanze Bus Parking, are facing several significant issues due to outdated management practices. The current payment system relies on coins, but managers often struggle to provide change when customers pay with notes. This can cause inconvenience, potential conflict, and disrupt the user experience, handling cash transactions can lead to unsanitary conditions, as money can spread disease.

The absence of automated doors further compounds these problems. Customers sometimes forget to lock the door, leading to privacy concerns and disturbances for other users. These issues collectively result in poor hygiene, user dissatisfaction, and operational inefficiencies. To address these challenges, this project proposes the development of an IoT-based smart public toilet management system. This system will feature automated doors and a modern, contactless payment solution. By implementing these upgrades, the project aims to enhance cleanliness, streamline operations, and significantly improve the overall user experience, thereby addressing the current shortcomings and providing a more effective and user-friendly public toilet solution.

1.3. Research objective

1.3.1. General objective

The main goal of the project is to develop and implement solutions using IoT based Smart Public Toilet for management and monitoring system enhance cashless payment in public toilet at Musanze Bus Parking.

1.3.2. Specific objectives

About project on the IoT-based Smart Public Toilets Management and Monitoring system, the specific objectives might include the following:

- ❖ Collect all data and help reduce the time people spend waiting to use public toilets in busy areas implementing a smart management system.
- ❖ Design and integrate a system that allows users to access public toilets without physically touching the door, thereby improving hygiene and reducing the spread of germs.

❖ Develop a cashless payment system to facilitate easy and secure transactions, eliminating the need for physical currency and enhancing user convenience.

❖ Set up a system to monitor the status of public toilets in real-time, providing updates on occupancy, cleaning needs and other critical information via an LCD display with an I2C interface, ensuring a smooth and informed user experience.

1.4. Research questions

This project aims to investigate the potential of IoT based Smart Public Toilet Management and Monitoring System to improve the maintenance and organize clear for payment system at Public Toilet of Musanze Bus Parking. To achieve this goal, the project has developed twelve research questions that guide the investigation and address the project's objectives:

❖ How effective is the smart management system in reducing the waiting time for public toilet users in busy areas like parking lots?

❖ What are the impacts of a touchless door access system on hygiene and the spread of germs in public toilets?

❖ How does a cashless payment system improve the convenience and security of transactions for public toilet users?

❖ What are the benefits of real-time monitoring of public toilets' status (occupancy, cleaning needs, etc.) for user experience and maintenance efficiency?

1.5. Research hypotheses

The research hypotheses for the dissertation on “IoT based Smart Public Toilet Management and Monitoring System " with a case study of Musanze Bus Parking are as follows:

❖ The implementation of a smart management system is hypothesized to significantly reduce the waiting time for public toilet users in busy areas addressing the concern of congestion and improving overall user flow.

❖ The introduction of a touchless door access system is expected to lead to a measurable decrease in the spread of germs and an enhancement in hygiene standards within public toilets, thereby contributing to public health and safety.

- ❖ The integration of a cashless payment system is hypothesized to increase the convenience and security of transactions, which in turn is likely to enhance user satisfaction by offering a more seamless and efficient payment experience.
- ❖ The setup of a real-time monitoring system is anticipated to improve both user experience and maintenance efficiency by providing timely updates on the status of public toilets.

1.6. Choice of the Study

The dissertation focuses on developing an IoT-based system to improve the efficiency, user satisfaction and sustainability of public toilet facilities. The study will be conducted at Musanze Bus Parking. By integrating IoT devices to monitor and manage the toilets in real-time, the research aims to enhance operational efficiency, user satisfaction and address privacy and security concerns associated with IoT deployment. The case study will provide practical insights on the feasibility and impact of smart public toilet management systems in similar high-traffic public areas.

1.7. Significance of the Study

This project focuses on developing an IoT-based Smart Public Toilet Management and Monitoring System, with Musanze Bus Parking as a case study. It addresses key challenges in urban sanitation by integrating IoT technology to enhance operational efficiency, cleanliness and user experience. The system incorporates an automatic door controlled via RFID cards, allowing secure and convenient access for users, the RFID-based payment system automates access control and transactions, ensuring a streamlined and efficient process. Real-time monitoring helps in timely cleaning and maintenance, optimizing resource use. The study is significant as it not only improves the functionality and reliability of public toilets at Musanze Bus Parking but also provides a model for similar urban areas. By reducing maintenance costs and enhancing user satisfaction, the system offers valuable insights for urban planners and policymakers. It contributes to the broader discussion on smart city technologies, aiming to revolutionize public toilet management and improve public health standards.

1.8. Delimitation of the Study

This study is specifically designed to develop and evaluate an IoT-based Smart Public Toilet Management and Monitoring System, with Musanze Bus Parking serving as the primary testing location. The research is limited to using NodeMCU ESP8266 for IoT connectivity and RFID technology for automatic door control and digital payments. The system's scope is restricted to the management and monitoring of public toilets, excluding other types of public facilities or smart city integrations, the study focuses on a single, high-traffic urban setting, which may not fully represent the needs or challenges of other environments. The project is also constrained by available budgetary resources, limiting the number of sensors and hardware components included. Consequently, advanced features or additional components beyond the basic setup are not considered within the scope of this research.

1.9. Organization of the study

The study is organized into five chapters. The first chapter is a general introduction to the study, outlining the background, problem statement, objectives, research questions, hypotheses, significance, and delimitation of the study. The second chapter provides a literature review related to the study, referencing sources of data, especially from textbooks, academic journals, reports, and previous research on IoT-based management systems, smart city initiatives, and public sanitation. The third chapter discusses the research methodology, detailing the design, data collection methods, tools technologies used and the case study approach focused on the public toilet at Musanze Bus Parking. The fourth chapter analyzes the results and provides a relevant discussion on the design, implementation and performance of the Smart Public Toilet Management and Monitoring System, including user feedback and operational efficiency metrics. Lastly, the fifth chapter describes the conclusions drawn from this study and provides recommendations for future research, policy implications, and potential improvements in public sanitation management using IoT technology.

CHAPTER 2: LITERATURE REVIEW

2.1. General Introduction

This chapter outlines the theoretical concepts and fundamental definitions used in the study, focusing on the development of IoT based Smart Public Toilet Management and Monitoring System at Musanze Bus Parking in Rwanda. It explains the necessary technologies, including IoT and RFID for user access, payment and compares related research in smart city infrastructure and public sanitation. This framework establishes the basis for understanding the study's innovative approach and its potential impact on public toilet management.

2.2. Related Works

This is the list of the work done by others in IoT based Smart Public Management and Monitoring System at Toilet:

2.2.1 Mobile App Integration for Enhanced Public Toilet Management

The related work involves integrating mobile applications to improve public toilet management, focusing on user convenience, hygiene and operational efficiency. Mobile apps provide real-time information on toilet availability, cleanliness and allow digital reservations and payments, and include a feedback mechanism for user ratings and issue reporting. Integration with mobile wallets or RFID technology facilitates cashless transactions, enhancing accessibility. IoT sensors automate maintenance alerts for real-time issue resolution. Personalized features, such as language preferences, further enhance user satisfaction. This approach streamlines operations and improves the user experience by leveraging technology to address common public toilet management challenges (Ferrer, 2010).

While IoT technology can enhance user experiences with features like real-time feedback and digital payments and several challenges need addressing. Ensuring universal access and user acceptance is crucial to avoid digital exclusion, as not all users have smartphones or reliable internet. Privacy and security concerns must be managed to protect sensitive user data and maintain trust. High initial setup costs and ongoing maintenance expenses pose financial challenges, requiring secured funding for sustainability. Integrating IoT systems with existing infrastructure presents logistical hurdles, needing careful planning and coordination to ensure smooth deployment and operation.

2.2.2 Smart Public Facilities Management and Monitoring

The Smart Public Facilities Management and Monitoring approach integrates IoT technologies to enhance oversight and efficiency of public amenities. IoT sensors in facilities like toilets, parks and community centres collect real-time data on occupancy, cleanliness and resource use. Cloud computing and data analytics process this data for actionable insights, improving operational efficiency through predictive maintenance. Benefits include enhanced user experience with mobile app feedback, optimized resource use for sustainability and proactive public infrastructure management promoting urban development (Doe, 2022).

While innovative in enhancing public infrastructure oversight through IoT, the project faces criticisms. It may exclude those without smartphones or internet access. Data privacy and security concerns arise due to sensitive data collection. Financial sustainability challenges include high initial costs and ongoing expenses. Integrating IoT with existing infrastructure poses technical and operational hurdles. Environmental impacts like e-waste and energy use need mitigation. Addressing these issues through risk management and stakeholder engagement is crucial for project effectiveness and sustainability.

2.2.3 Usability and User Experience of Coin-Operated Public Toilets

Niemeyer and Barnard in 2016 studied coin-operated public toilets in South Africa, highlighting issues such as hygiene concerns from handling coins, inconvenience due to exact change requirements, and privacy issues in public settings. They recommended exploring alternative, user-friendly payment methods to improve satisfaction and ensure equitable access to sanitation facilities. Their findings underscore the need for innovative approaches in public health infrastructure to address these operational challenges. (Niemeyer&Barnard, 2016).

While evaluation of coin-operated public toilets highlighted issues with traditional payment systems, prompting a call for digital alternatives. Concerns included hygiene risks from handling coins. The study focused primarily on payment system issues and lacked a comprehensive exploration of broader sanitation management aspects. Recommendations for alternative payment methods lacked comparative analysis with existing systems, potentially limiting practicality. Implementation barriers and socio-economic disparities affecting access to improved sanitation infrastructure were not adequately addressed.

2.3. Definition of key terms

This is the list of key terms used in the project development:

2.3.1 Internet of Things (IoT)

The Internet of Things (IoT) refers to the network of physical objects embedded with sensors, software and other technologies to connect and exchange data with other devices and systems over the internet. These "things" can be anything from everyday household items to sophisticated industrial tools (Khosrow-Pour, 2018).

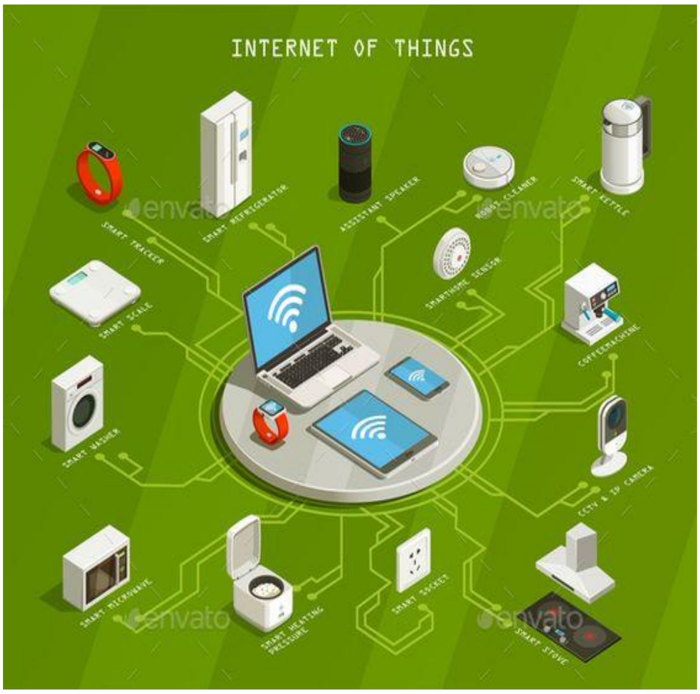

Figure 1: Internet of Things (Khosrow-Pour, 2018)

2.3.2 Smart Management System

Integrates IoT technologies to monitor and optimize public facilities like toilets and parks. It uses IoT sensors to gather real-time data on occupancy, usage patterns, cleanliness, and resource consumption. This data is analyzed via cloud computing and advanced analytics to inform proactive decision-making, such as predictive maintenance and resource allocation, aiming to enhance operational efficiency, user experience, and sustainability (Madisetti, 2014).

2.3.3 Monitoring System

A system designed to observe and track activities, processes, or conditions in real-time, often using sensors and data analytics with a dashboard in the context of our project refers to a centralized platform that collects and displays real-time data from IoT sensors and other sources within the public facilities. This system provides stakeholders, such as facility managers and administrators, with a visual representation of key metrics like occupancy rates, cleanliness status, resource usage and maintenance alerts. The dashboard allows for easy monitoring and management of various aspects of public infrastructure, enabling proactive decision-making and efficient allocation of resources (Madisetti, 2014).

2.3.4 Public Toilets

In the context project, "public toilets" refer to facilities provided for use by the general public, typically located in public spaces such as parks, transportation hub, and commercial areas. These facilities are designed to provide sanitation and hygiene services, including toilets, sinks, and sometimes showers, to individuals who are away from their homes or workplaces. The aim is to ensure that basic sanitation needs are met for all individuals, contributing to public health and comfort in urban and communal settings (Griffiths, 2019).

2.3.5 Real-time

Refers to the capability of processing and responding to data as it is generated, without any noticeable delay. It ensures that information is updated and actions are taken immediately as events occur, ensuring users receive current and accurate data at all times. For instance, in the context of monitoring public toilet occupancy, sensors continuously collect data and transmit it instantly to a central system for immediate access and action. This capability is pivotal for enhancing operational efficiency, delivering timely feedback to users and enabling proactive maintenance in IoT-based smart public management and monitoring systems (Johns, 2022).

2.3.6 Devices

A device is a tool, either electronic or mechanical, created to carry out a particular task or function efficiently. It can range from simple gadgets to complex systems that automate processes and improve functionality.

2.3.7 RFID Read Card

Radio Frequency Identification (RFID) is a technology that uses electromagnetic fields to automatically identify and track tags attached to objects. These tags contain electronically stored information, typically a unique identifier that can be read remotely by RFID readers. RFID systems consist of tags (or transponders) and readers (or interrogators), which communicate wirelessly to transmit data. This technology finds applications in various industries for tracking and managing inventory, controlling access, and facilitating contactless transactions (Finkenzeller, 2010).

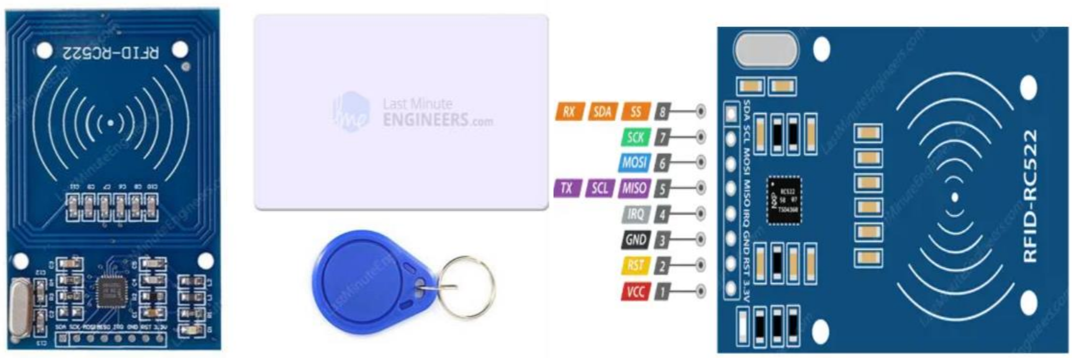

Figure 2: RFID Read Card (Finkenzeller, 2010)

2.3.8 Liquid Crystal Display with an I2C interface

LCD, or Liquid Crystal Display is a type of flat panel display technology widely used in electronic devices such as televisions, computer monitors, smartphones, and calculators (Lenovo, 2020).

Figure 3: Liquid Crystal Display with an I2C interface (Arduino, 2023)

2.8.9 Direct Current (DC) Servo motor

Direct Current (DC) servomotor is a type of rotary actuator that uses a closed-loop control system to maintain precise angular position or speed. It operates on direct current (DC) and is commonly used in applications requiring accurate positioning, such as robotics, CNC machines, and automated systems (Siemens, 2023).

Figure 4: DC Servo motor (Siemens, 2023)

2.8.10 Light Emitting Diode (LED)

A Light-Emitting Diode (LED) is a semiconductor device that emits light when an electric current flows through it. When current passes through an LED, the electrons recombine with holes emitting light in the process. LEDs allow the current to flow in the forward direction and blocks the current in the reverse direction. LEDs are widely applied in indicating or display circuits (Craford, 2009).

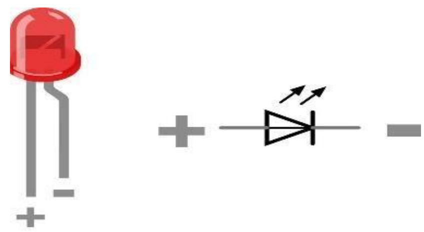

Figure 5: Light Emitting Diode (Craford, 2009)

2.8.11 Jumper Wires

Jumper wires serve as essential connectors, facilitating the seamless integration of different electronic modules and components. They enable easy prototyping and testing by allowing quick and temporary connections between various parts of the circuit.

Jumper wires also play a vital role in troubleshooting and debugging, as they can be used to isolate specific components or sections of the system for analysis (Digest, 2022).

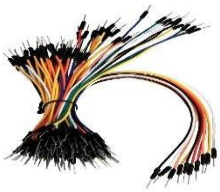

Figure 6: Jumper Wires (Digest, 2022)

2.8.12 Resistors

Resistors are essential for voltage scaling, current limiting, and signal conditioning. They protect components from damage due to excessive current, and establish reliable logic levels for accurate data transmission. Without resistors, the electronic circuits could malfunction, leading to component failures, and compromised system performance (Smith J. &., 2020).

Figure 7: Resistors (Green, 2021)

2.8.13 Printed Circuit Board (PCB)

A Printed Circuit Board (PCB) is the board base for physically supporting and wiring the surface mounted and socketed components in most electronics. Simply, the connecting wires are used to connect two points of components on the board (Applications P. C., 2010).

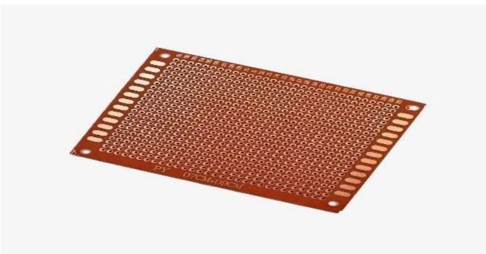

Figure 8: Printed Circuit Board (PCB) (Ferrer A. , 2010)

2.8.14 Soldering Wires

Soldering wires involves joining two or more electrical, this process creates a strong and permanent electrical connection, ensuring reliable conductivity in electronic circuits or projects (Components, 2018).

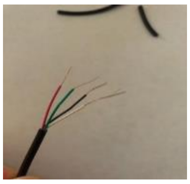

Figure 9: Soldering Wires (Chow, 2018)

2.8.15 Universal Serial Bus (USB) cable

The Universal Serial Bus (USB). USB cable assemblies are some of the most popular cable types available, used mostly to connect computers to peripheral devices refer (USB.org, 2010)**.**

Figure 10: USB cable Type A (USB,2010)

2.8.16 Node-MCU ESP8266

NodeMCU ESP8266 is a low-cost Wi-Fi module based on the ESP8266 chip, widely used for IoT projects. It integrates a microcontroller unit (MCU) with Wi-Fi capability, making it easy to connect to the internet and control devices remotely. NodeMCU supports Lau scripting language and Arduino IDE for programming, offering flexibility in developing IoT applications. It features GPIO pins for interfacing with sensors and actuators, making it ideal for prototyping and DIY electronics projects (Applications N. E., 2012).

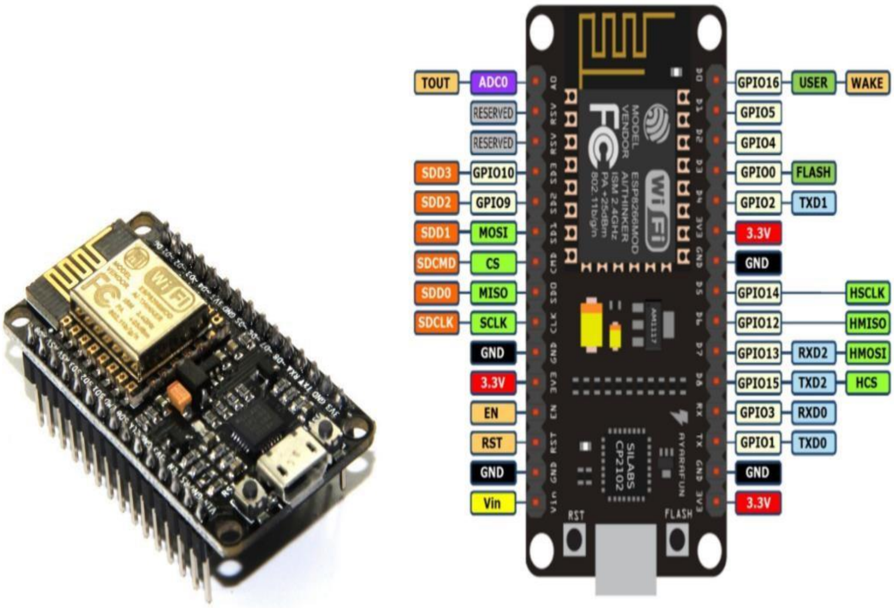

Figure 11: Node-MCU ESP8266 (Applications N. E,2012)

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

Research methodology use to develop the IoT-based Smart Public Management and Monitoring system. It covers the research design, data collection methods, and tools and equipment used, it describes the data analysis techniques and the system implementation process, ensuring the study's reproducibility and the methodology could properly refer to the theoretical analysis of the methods appropriate to a field of study or the body of methods and principles particular to a branch of knowledge.

3.2 Case Study (Musanze Bus Parking at Public Toilet)

The study of this project was conducted in the Rwanda country in Musanze District, Muhoza Sector in Musanze Bus Parking at Public Toilet, the aim of this study is develop an IoT-based smart management and monitoring system. This project seeks to improve sanitation facilities by implementing real-time monitoring of usage for payment, automated door for close and open after pay, cleanliness and maintenance needs. By employing IoT technology, the system aims to enhance public health standards and optimize the management of public toilet facilities in Musanze District. Through continuous monitoring and automated door alerts, the system ensures timely maintenance and improved user experience for residents and visitors like.

Figure 12: Case study in Musanze Bus Park at Public Toilet

3.3 Technique of data collection

Data collection methods in this project involve using IoT to monitor occupancy, payment usage patterns, cleanliness, and maintenance needs public toilets. These methods real-time data collection for effective management and enhancement of public facilities.

3.3.1 Observation

Observation involved direct monitoring of payment, automated door, occupancy, cleanliness, and maintenance status in public toilets using IoT. In this project, sensors were deployed to observe and record real-time data on facility usage and conditions. This technique allowed for continuous monitoring and immediate alerts to management personnel or maintenance teams in case of issues. By observing the real-time data collected from the sensors, the system aimed to ensure proactive management and enhanced usability of public facilities.

3.3.2 Documentation

Documentation involved gathering and analysing existing records and reports related to Musanze bus parking and public toilets, including usage statistics, maintenance logs, and user feedback. In this project, the researcher reviewed municipal reports, maintenance records, and feedback from users to gather qualitative data on facility usage and maintenance needs. Documentation of the IoT system design, installation process, and operational phases was maintained to ensure a comprehensive understanding of project implementation. This approach provided valuable insights into current challenges and operational effectiveness, guiding improvements in the management and maintenance of public facilities.

3.3.3 Interview

Interviews were conducted with the manager, cleaner, and five users of the smart toilets system. The manager discussed issues with the automated payment system and door mechanisms, highlighting their effects on facility management and income generation. The cleaner mentioned difficulties related to these automated features and how they impact maintenance tasks. Users reported problems with payment processing and door functionality. This information is essential for understanding and addressing shortcomings in the system to improve its overall performance and efficiency.

3.3.4 Usage Logs

Usage logs were collected through the IoT platform to monitor the performance of the smart toilets system, specifically focusing on the automated payment system, door mechanisms, and management of incomes. These logs provided detailed, continuous data on payment transactions, door operation frequencies, and the impact on revenue generation. By analysing these logs, we were able to identify recurring issues such as payment failures or door malfunctions and assess their effects on overall management. This method offered accurate and objective insights into system performance, enabling us to pinpoint problems and make informed improvements to enhance both functionality and income management.

3.4 Data analysis

The collected data underwent a combination of qualitative and quantitative analysis:

3.4.1 Quantitative Analysis

The focus was on examining the usage of the Musanze bus parking and public toilets. This included collecting real-time data on how frequently these facilities were used, tracking user patterns over time. The study compared various payment methods, including the use of RFID technology, to evaluate their efficiency and ease of use. Cleanliness and maintenance metrics were also quantified, with data collected on cleanliness levels, how often maintenance was required, and the time taken to address these needs. the effectiveness of the current management methods was compared to the new IoT-based system, with the data demonstrating significant improvements in user safety, payment processes, security, and overall management efficiency.

3.4.2 Qualitative Analysis

User satisfaction was assessed through feedback collected via observation, documentation, and interviews, providing insights into how users perceived both the current and proposed systems. Observational insights were also gathered to identify issues related to cleanliness, maintenance, and accessibility that might not have been captured by quantitative data. Interviews and documentation offered valuable feedback from client, highlighting the challenges faced in maintaining the facilities and how the new IoT-based system could address these issues. The analysis also compared user experiences between the existing system and the new IoT system, showing significant improvements in cleanliness, accessibility, management, and monitoring.

3.5 System requirements

Meeting user needs was help us create an effective IoT-based system for managing Musanze bus parking at public toilets. This system monitor usage and maintenance in real-time, providing alerts to staff when needed, and ensuring efficient facility management.

3.5.1 Functional requirements

Functional requirements specify what the system should do or the features it should have to fulfill its intended purpose, functional requirements for our project on Musanze bus parking and public toilets:

- **RFID Payment Integration:** The system should support RFID technology for automated payment processing at bus parking facilities and public toilets.
- **Automated Door Control**: It should include automated doors that open and close based on RFID authentication, ensuring secure access for users.
- **Real-time Alerts:** The system should send immediate alerts to management personnel for payment verification and maintenance needs.
- **Usage Monitoring:** It should monitor usage statistics and provide real-time data on occupancy, payment transactions, and door access events.
- **Maintenance Tracking:** It should track maintenance needs and scheduling to ensure efficient facility upkeep.

3.5.2 Non-functional requirements

Non-functional requirements define criteria that specify how a system should behave, rather than what it should do, are some non-functional requirements for my project on Musanze bus parking at public toilets:

- **Performance**: The system should handle peak loads efficiently, processing RFID transactions and door operations promptly.
- **Reliability**: It should operate reliably without frequent downtime, ensuring continuous availability of payment and door control functionalities.
- **Security**: The system should provide secure RFID authentication and encrypted communication to protect user data and prevent unauthorized access.

- **Scalability**: It should be scalable to accommodate future expansion of public toilet facilities in Musanze District.
- **Usability**: The system interface should be intuitive and user-friendly for both management personnel and facility users.
- **Maintainability**: It should be easy to maintain and update, with clear documentation and support for troubleshooting and upgrades.

3.6 System development methodology

System development methodology is a structured approach used to requirement analysis, system design, coding, testing, deployment and implement systems effectively. It provides a framework called Agile methodology for managing the development process to ensure project success and alignment with user requirements.

3.6.1 Agile methodology

Agile model is a combination of iterative and incremental process models with a focus on process adaptability and customer satisfaction by rapid delivery of working software products. Agile Methods break the product into small incremental builds. Each iteration typically lasts from about one to three weeks. The iterative approach is taken and the working software build is delivered after each iteration.

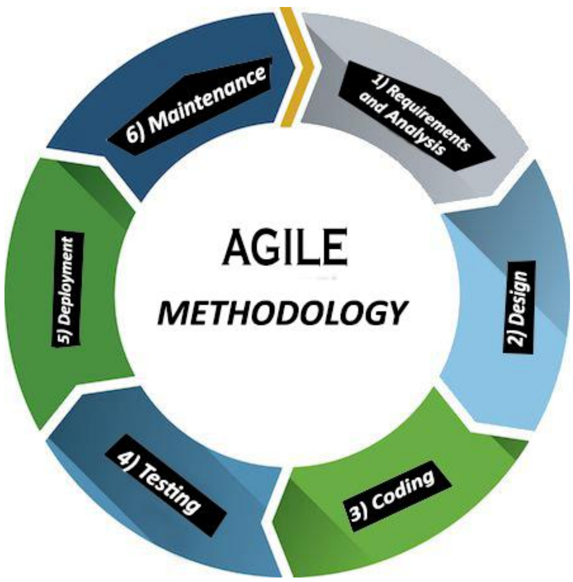

Figure 13: Agile Methodology (Agile, n.d.)

a) Requirements and analysis

In the Requirements and Analysis phase, the initial task involved the identification and meticulous documentation of the precise requirements necessary for the implementation of the IoT-based Smart Public Toilets Management and Monitoring system. This involved understanding the needs of the manager, cleaner, and client, determining the necessary features of RFID, and defining the system's overall functionality. Key activities included conducting interviews with workers of Musanze bus parking at the public toilet, observing payment processes, and analysing user feedback on management and monitoring needs, real-time notification requirements, and safety features of the system.

b) System Design

Following the requirements gathering, the System Design phase involved creating a detailed plan for the Smart Public Toilets Management and Monitoring system. This included designing the system architecture, selecting appropriate hardware components (such as RFID readers and LCDs), and defining the software functionalities (such as monitoring algorithms, notification mechanisms, and user interfaces). The design process also included creating prototypes and developing initial designs for the system's physical and digital interfaces. Simulation tools were used to test and validate the design, ensuring the system met performance and reliability standards before deployment.

c**) Coding**

In Coding phase focused implementation, the actual IoT-Based Smart Public Toilets Management and Monitoring system was developed by coding software and integrating it with hardware components such as NodeMCU ESP8266, RFID readers, LCD, and notification modules. The software handled data collection from RFID, RFID-based payments, real-time notifications, and automated door control systems for toilet functions. These elements were combined to create a functioning prototype, followed by thorough testing and debugging to ensure proper operation and adherence to requirements.

d) Testing

After coding, implementation, the Testing phase ensured that the Smart Public Toilets Management and Monitoring system met the defined requirements and operated flawlessly. This included thorough testing procedures, such as unit testing for individual components, integration testing for the entire system, and user acceptance testing to confirm its performance in real-world scenarios. The objective was to detect and address any issues related to functionality, performance, safety, ensuring that the system functioned reliably and met user expectations.

e) Deployment

Up on successful testing, the system proceeded to the Deployment phase. This involved setting up the IoT-based Smart Public Toilets Management and Monitoring system at Musanze bus parking and public toilets in Muhoza sector, Musanze district, Rwanda. Infrastructure installation and staff training ensued to ensure efficient system operation. Initial performance monitoring and user feedback guided adjustments for optimal functionality.

f) Maintenance

The Maintenance phase involved ongoing support and updates for the IoT-based Smart Public Toilets Management and Monitoring system. This stage included monitoring the system's performance, addressing any issues that arose, and providing regular updates to improve functionality and address emerging needs. Maintenance ensured that the system remained effective, reliable, and secure over time.

3.7 Software Requirements

This system runs on a different version of software and other programming languages. these requirements describe what the software should do, how it should behave, and what capabilities it should provide to support the system include the followings:

- Arduino IDE
- Visual Code Studio Software
- Circuit.io

3.8 Hardware Requirements

This system runs on a different requirements describe what the hardware should do, how it should behave and what capabilities it should provide to support the system include the following:

- RFID Read Card
- Liquid crystal display with an I2C interface
- DC Servo motor
- Light Emitting Diode
- Jumper Wires
- Resistors
- Printed Circuit Board (PCB)
- Soldering Wires
- USB cable
- Node-MCU ESP8266

CHAPTER 4: DESIGN AND IMPLEMENTATION

4.1 Introduction

This chapter presents the design, implementation, and analysis of the IoT-based smart public toilet access management system. It includes the flowchart, circuit diagram, hardware setup, web interface services, and challenges encountered during the development process.

4.2 System Design Architecture

System design Architecture refers in IoT-based smart public toilet access management system integrates various components to enhance functionality and user experience. Key elements include an RFID Read Card, LCD with I2C interface, DC Servo Motor, LED, Jumper Wires, Resistors, PCB, Soldering Wires, USB Cable, and NodeMCU ESP8266. The system is powered by a reliable Power Supply. The RFID Reader identifies user cards and sends data to the NodeMCU ESP8266, which then communicates with a web server for user validation and controls the door lock mechanism via a servo motor. An LCD Display provides real-time user information. The system includes a Web Server and Database to manage user credentials and access rights, with the NodeMCU connecting to the internet for secure and efficient management. This setup ensures a hygienic, efficient, and user-friendly public toilet experience using modern IoT technology.

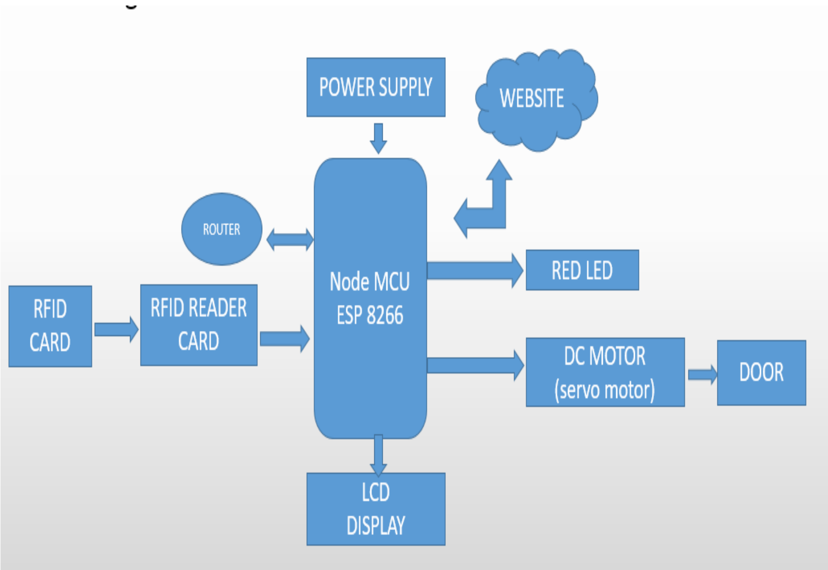

Figure 14: System Design Architecture

4.2.1 Physical Use Case Diagram

The Use Case Diagram for the IoT Smart Public Toilet Management and monitoring System illustrates the interaction between various components. The Power Supply provides electricity to all parts of the system. The RFID Reader detects and reads data from RFID tags in user cards, transmitting the unique ID to the NodeMCU ESP8266. This microcontroller board is programmed to read the RFID data, communicate with a web server to validate user access, and control the door lock mechanism via a servo motor based on the validation. The LCD Display shows relevant information to users, such as stall availability. The system includes a Web Server and Database for managing user credentials, access rights, and maintaining system logs. The NodeMCU connects to the internet to facilitate communication with the server, ensuring secure and efficient access management.

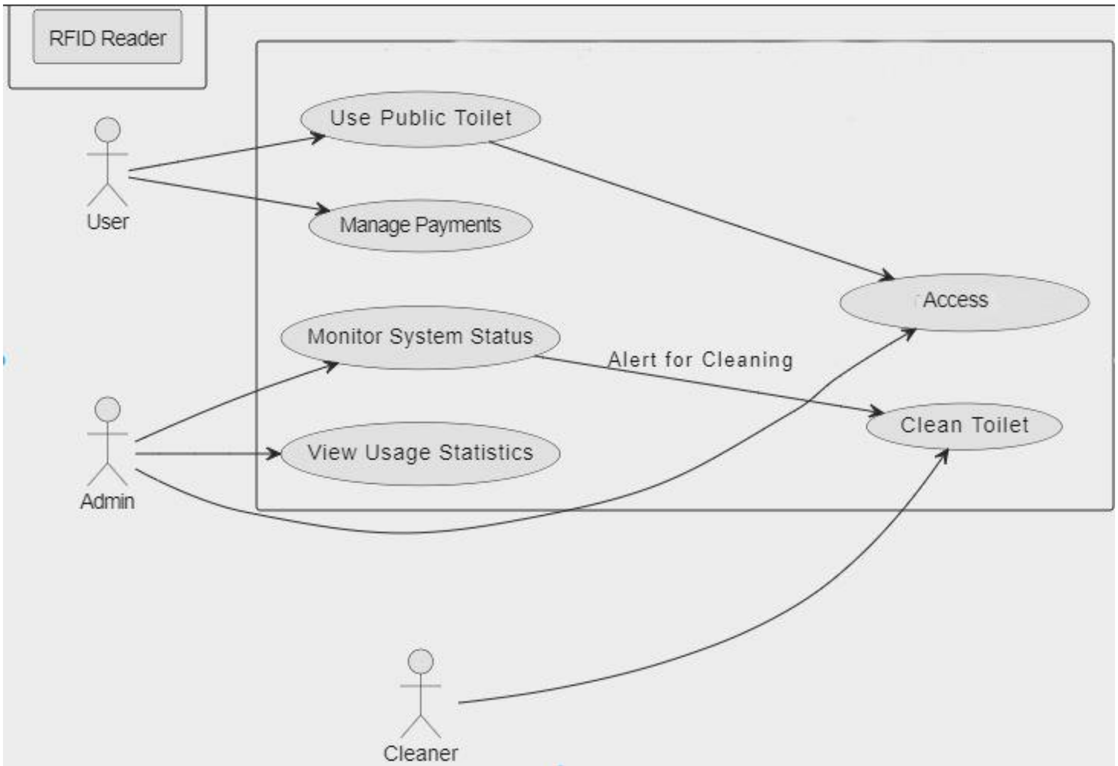

Figure 15: Use Case Diagram

4.2.2 Flow Chart

The flowchart outlines the process of the IoT-based smart public toilet access management system. The user approaches the toilet entrance, and the system checks if the user is new. New users need to purchase an RFID card. Existing users tap their RFID card on the reader, and the system reads the card to identify its type: customer, admin, or cleaner. Admin and cleaner cards grant immediate access for maintenance tasks. For customer cards, the system checks the balance. If sufficient, it deducts the service cost, unlocks the door using a servo motor, and turns on a green LED to indicate availability. Insufficient balance triggers a red LED, signaling the need to recharge the card via the dashboard platform. An LCD display with an I2C interface provides real-time information such as balance status and access messages. The NodeMCU microcontroller reads the RFID data, controls the servo motor, and communicates with the database for user validation and balance updates. The process ends when the user either enters the toilet or leaves after being notified of insufficient balance. This structured approach ensures a seamless, hygienic, and efficient user experience for public toilet access, leveraging modern IoT technology.

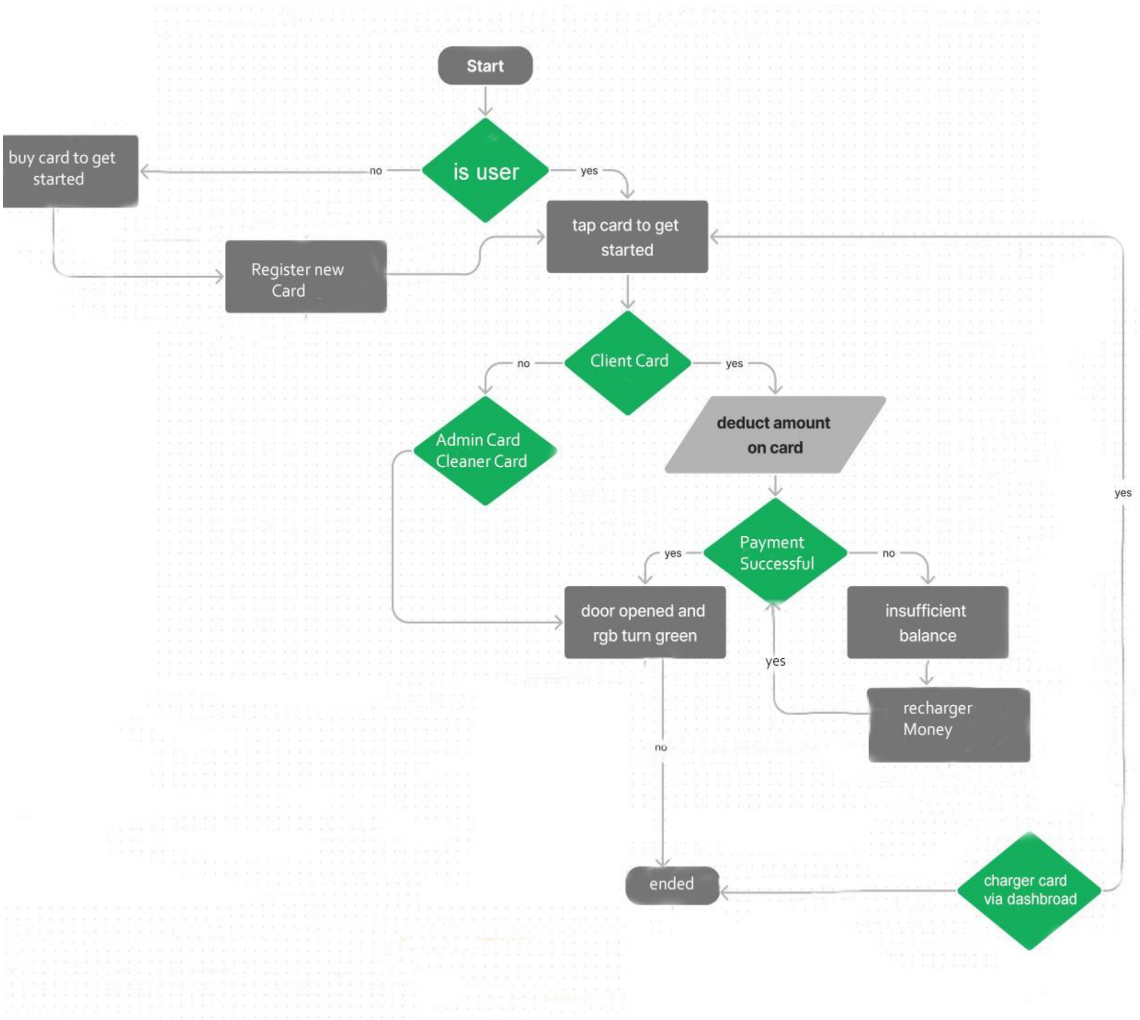

Figure 16: Flow chart

4.2.3 Circuit Diagram

The IoT-based IoT smart public toilet management and monitoring system employs various components connected to the NodeMCU ESP8266 microcontroller for automated access and payment management. The RFID-RC522 reader, I2C LCD display, RGB LED, and servo motor are connected to the NodeMCU ESP8266. The RFID-RC522 reader connects with its VCC to the 3.3V pin, RST to D3, MISO to D6, MOSI to D7, SCK to D8, SDA to RX, and GND to the GND pin on the NodeMCU ESP8266. The I2C LCD display connects its VCC to the Vin pin, GND to GND, SDA to D2, and SCL to D1 on the NodeMCU. The RGB LED has its common cathode connected to GND on the NodeMCU, and the red anode pin is connected to D0. The servo motor connects its signal pin to D4, VCC to 3.3V, and ground to GND. When powered on, the LCD display shows the public toilet status. The RFID-RC522 reads the card's serial number and sends this data to the NodeMCU. The NodeMCU sends a GET request to the web platform to check the card type and balance. Admin and cleaner cards unlock the door directly. For customer cards, the web platform deducts the service fee and sends a JSON response back to the NodeMCU. Sufficient balance unlocks the door and turns the RGB LED green. Low balance keeps the door locked and turns the RGB LED red. External alerts indicate toilet occupancy. To exit, the user taps their card again to relock the door. The system also sends email notifications to cleaners and tracks users and fees via a dashboard.

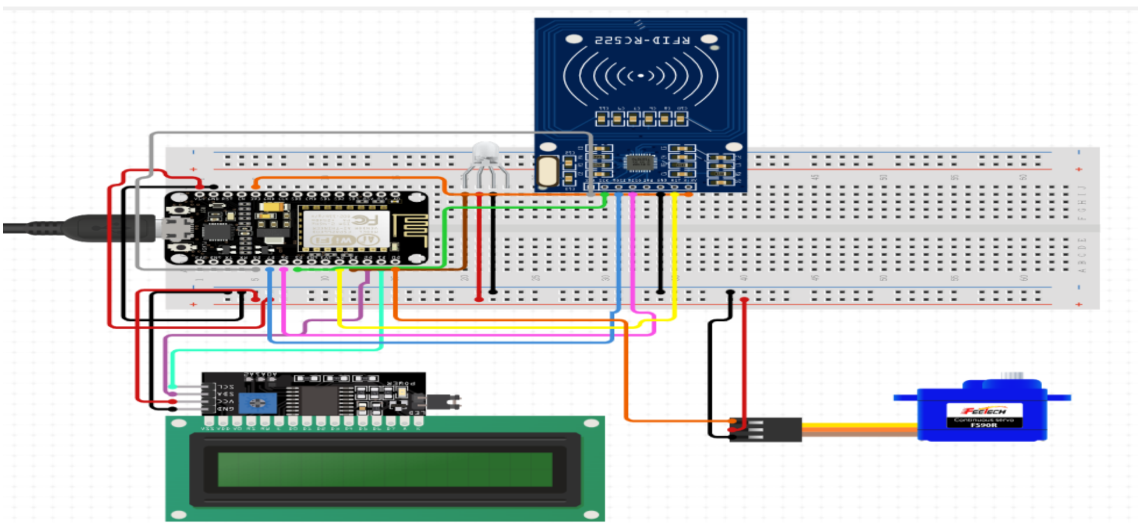

Figure 17: Circuit diagram

4.3.1 Discussion of Results About Hardware Device

In the discussion of results, the performance of hardware devices like NodeMCU ESP8266, servomotor and RFID readers is evaluated based on their reliability, efficiency and integration within the IoT-based system. These devices are crucial in achieving seamless automation and real-time monitoring in public toilet management.

4.3.2 When Admin and Cleaner access allowed

In the hardware setup, various components worked together to achieve the desired functional. When a new card is tapped on the RFID reader, the system first checks the card type. Admin and cleaner cards show "Admin Card" but admin have access for enter every time even the restroom is occupied by client so about “Cleaner Card" on the LCD, followed by "Access Allowed." but not have access when restroom is occupied by client explain well in the following figure:

Figure 18: Admin and Cleaner access allowed

4.3.3 When Low Found Balance on card

The servo motor activates, opening the door. For customer cards, insufficient balance displays "Low Found Balance," and the red LED of the RGB light turns on. The servo motor remains inactive, and the door does not open explain well in the following figure:

Figure 19: Low Found Balance on card

4.3.4 When The restroom toilet occupied

Sufficient balance deducts 50 Rwf, and the servo motor opens the door. After three seconds, the servo motor closes the door. If a new card is tapped while the toilet is occupied the LCD displays "The restroom toilet occupied" and LED of the RGB light turns on explain well used following picture:

Figure 20: The restroom toilet occupied

4.3.5 Client must pay 50 Rwf for enter and Pay 50 Rwf for exit

Client Must pay 50 Rwf for enter and pay for exit, the system deducts 50 Rwf again, and the servo motor opens the door, closing after three seconds.

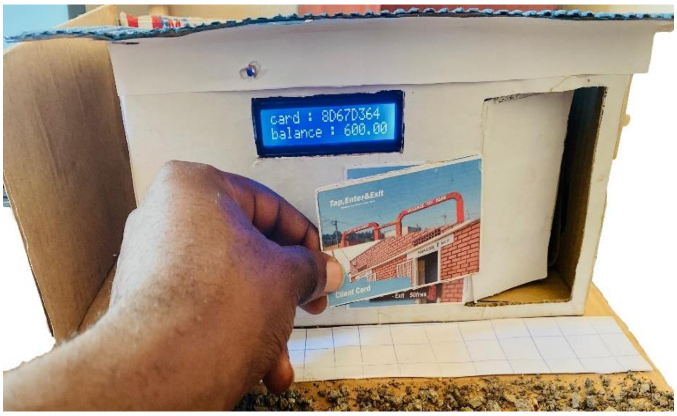

Figure 21: Pay 50 Rwf for enter and Pay 50 Rwf for exit

4.4 Discussion of Results About Web Interface Services

The web interface services, particularly the dashboard, allow for real-time monitoring and management of public toilets. It provides an intuitive display of usage statistics, alerts and control features enabling efficient decision-making and system oversight.

4.4.1 Dashboard Interface

The dashboard provides a comprehensive overview of key metrics:

The dashboard provides key metrics for effective management of public toilets. It displays the Number of Users which reflects the total count of individuals who have accessed the facilities updating in real-time. The Number of Toilets indicates the total count of facilities managed by the system. it tracks the Amount of Money Made Per Day, showing the daily revenue generated from public toilet usage. These metrics collectively offer a comprehensive overview of the system's performance and financial impact. This setup provides valuable insights into usage patterns and financial performance, aiding in better decision-making and resource allocation.

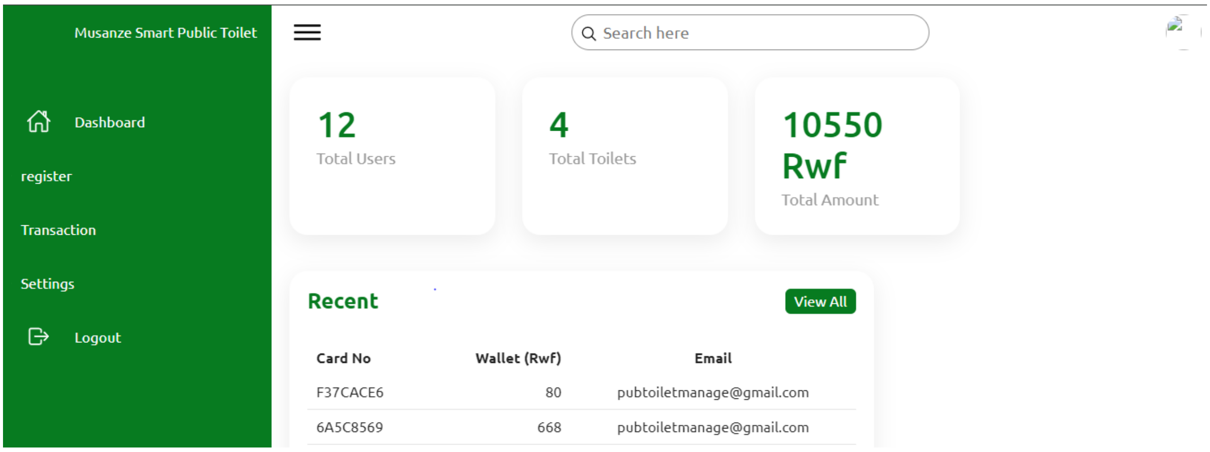

Figure 22: Dashboard interface

4.4.2 Registration Interface New Card

The registration interface facilitates easy registration of new RFID cards. When a new RFID card is tapped, the system reads the card's unique ID number, displayed on the LCD screen and serial monitor. The user enters this ID number into the registration interface and clicks "Register" to store the ID number in the database, creating a new user profile.

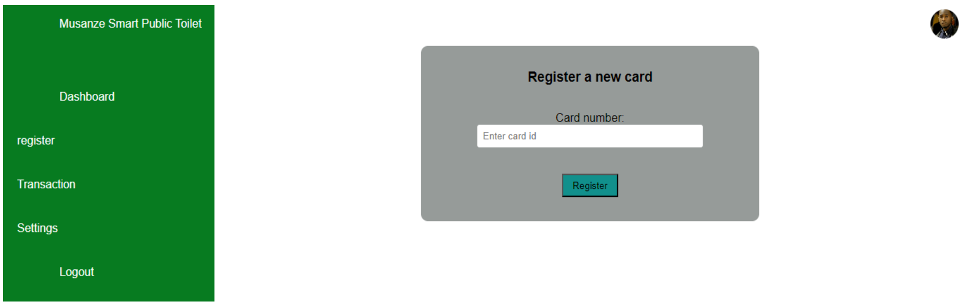

Figure 23: Registration interface

4.4.3 Recharge Card Interface (Put money card)

The Recharge Card interface allows users to add money to their RFID cards. Users select the card ID, enter the desired amount, and click "Send" to update the card's balance in the database. This process ensures real-time updates and confirmation, making recharging efficient.

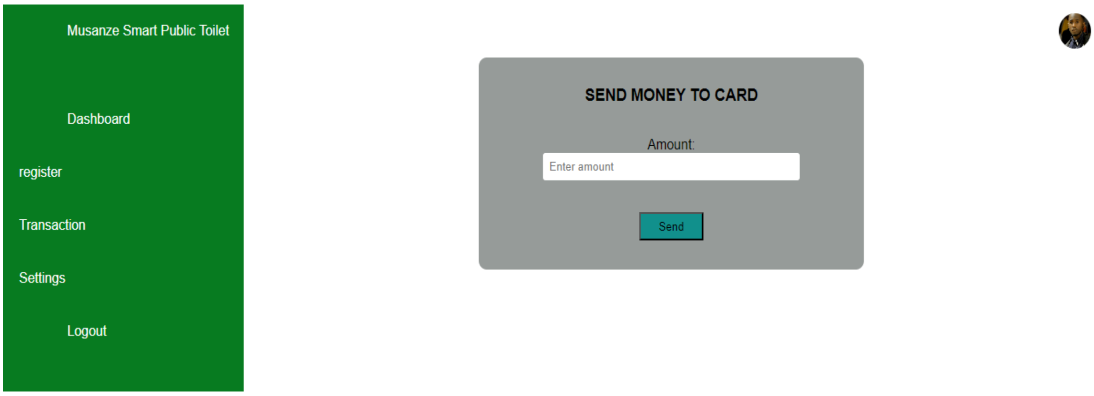

Figure 24: Recharging interface

4.5 Challenges and Solutions

Initially, use used an Arduino Uno with a GSM SIM800L module, but it failed to establish a reliable internet connection. when switched to the NodeMCU ESP8266, which successfully connected our system to the internet, enabling seamless interaction between hardware and database. This change allowed us to achieve our project goals and ensure the system functioned as intended technologies to further enhance functionality and efficiency and focus to additional system of get loan to client.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project focuses on the implementation of an IoT-based smart public toilet management and monitoring system. By using several physical devices such as NodeMCU ESP8266, which helps to prototype and build IoT products and includes firmware that runs on the ESP8266 Wi-Fi module, the system ensures efficient and reliable internet connectivity. The RFID-RC522 reader is employed to detect and read RFID tags, enabling user identification and access control. A servo motor is used to drive allowing for automated door opening and closing. An RGB LED functions as an indicator, signalling low balance on a user's card, while an LCD display with I2C interface provides real-time information to users, the system operates by having users tap their RFID cards to gain access. If the card belongs to an admin or cleaner, the door opens immediately. For customers, the system checks the card balance and either allows access by deducting the required amount or indicates insufficient funds through the RGB LED. The system also provides alerts for occupied toilets and notifies cleaners after a set number of uses. Data on users, toilet usage, and financial transactions are managed and displayed through a web-based dashboard, ensuring comprehensive monitoring and efficient management. The developed system is cost-effective, secure, and efficient, providing a modern solution to smart public toilet management and monitoring. It enhances user convenience, ensures hygienic conditions and facilitates maintenance, making it a valuable addition to public infrastructure.

5.2 Recommendations

Based on the produced system, has recommendations on different sectors IoT-based Smart Public Toilet Management and Monitoring System, several recommendations will propose and The Rwandan government should consider implementing this system across public toilets to support effective like management, monitoring and real world digital.

5.2.1 Recommendations to Public Toilets Manager

Based on the produced system we recommend the manager of Public Toilets in Musanze Bus Parking about our project accept and use our project this Use IoT Smart Systems Install the IoT-based monitoring system to manage public toilets more effectively. This system will help in keeping the toilets clean, reduce blockages, and provide better service to the public. Train the Staff Make sure the team knows how to operate and maintain the system. Regular check-ups will keep everything running smoothly. Gather User Feedback Set up a simple way for users to give feedback. This will help in making improvements based on real user experiences.

5.2.2 Recommendations to Next Researchers

For those attempting to replicate or build up on this project, we recommend focusing on robust and reliable hardware integration. While the NodeMCU ESP8266 provides excellent connectivity and control, consider using higher precision components such as industrial-grade RFID readers and more durable servo motors to enhance system longevity and performance. Regular maintenance and calibration of these components are crucial for consistent operation, enhancing the user interface with a higher resolution LCD display and audio feedback can significantly improve user experience, making the system more accessible and user-friendly. Integrating data analytics and machine learning algorithms can predict maintenance needs and optimize system performance by analyzing usage patterns and system data. Upgrading to more advanced communication modules like the ESP32-S2 or ESP32-C3 can improve connectivity and security, ensuring reliable and secure data transmission.

Incorporating solar-powered energy sources can make the system more sustainable, reducing operational costs and ensuring continuous operation during power outages. To alleviate financial burdens on students working on final-year projects, it is recommended to extend project deadlines to allow for thorough research and refinement, and ensure extended lab access for hands-on practice. These measures will enhance the quality and feasibility of student projects.

REFERENCES

Applications, N. E. (2012). Retrieved from https://www.nodemcu.com/index_en.html

Applications, P. C. (2010). Retrieved from https://www.electronics-tutorials.ws/pcb/pcb_1.html

Arduino. (n.d.). Retrieved from https://www.arduino.cc/en/Guide/Introduction

Arduino. (2023). San Francisco: Arduino Pres.

Bank, W. (2022). *Sanitation and Hygiene in Africa: Challenges and Solutions.* Washington, D.C.: World Bank Group.

BBC. (2023). *Rwanda: The Cleanest Country in Africa.* Londom: BBC News.

Circuits, O. P. (n.d.). Retrieved from circuit.io: https://www.circuit.io/

Code, V. S. (2024, july 17). *Microsoft*. Retrieved from https://code.visualstudio.com/

Components, S. T. (2018). Retrieved from https://www.electronics-tutorials.ws/soldering/soldering.html

Craford, M. G. (2009). *Light-emitting diodes.* Cambridge: UK: Cambridge University Press.

Digest, C. (2022). Jumper wires and their applications in electronics. New York: TechBooks Publishing. Retrieved from https://circuitdigest.com/tutorial/jumper-wires-their-types-and-uses

Doe, J. (2022). IoT Innovations in Public Facilities Management. In *IoT Innovations in Public Facilities Management* (p. 210). New York: TechPublishers Inc.

Ferrer, A. (2010). Integrating Mobile Applications for Public Toilet Management. In A. Ferrer, *Advances in Public Hygiene Management* (pp. 123-145). New York: TechBooks Publishing.

Finkenzeller, K. (2010). RFID Handbook: Applications, Technology, Security, and Privacy. In 3. Edition, *RFID Handbook: Fundamentals and Applications in Contactless Smart Cards, Radio Frequency Identification and Near-Field Communication.* Hoboken: Wiley.

Griffiths, K. (2019). *Public Sanitation and Hygiene.* New York: Urban Health Press.

John, S. (2023). *Modern Payment Solutions for Public Facilities.* New York: Tech Innovations Publishing.

Johns. (2022). Real-Time Data Processing in IoT Systems. New York: Tech Press.

Jones. (2022). IoT-based Smart Public Toilet Management and Monitoring System. In J. Jones, *Tech Innovations Publishing* (pp. 45-67). New York: Tech Innovations Publishing.

Khosrow-Pour. (2018). *Handbook of research on the Internet of Things applications and services (in italics and sentence case).* IGI Global.

Lenovo. (2020). *LCD technology*. *Lenovo*. Retrieved from https://www.lenovo.com/lcd-technology

Madisetti, V. K. (2014). Internet of Things: A Hands-On-Approach. In *Digital Signal Processing Handbook.* Boca Raton: CRC Press.

MongoDB. (n.d.). Retrieved from https://www.mongodb.com/what-is-mongodb

Niemeyer&Barnard. (2016). Coin-operated public toilets in South Africa: Addressing hygiene, convenience, and privacy issues. In *Innovative Approaches in Public Health Infrastructure* (pp. 45-62). Cape Town: Health and Sanitation Press.

Node.js. (n.d.). *Introduction to Node.js*. Retrieved from Retrieved from : https://nodejs.org/en/docs/guides/getting-started-guide/

Siemens. (2023). Direct Current (DC) Servo Motor. In *Understanding Servo Motors* (pp. 45-47). New York: Siemens ABB.

Smith. (2020). *Understanding soldering.* TechPress.

Smith, J. &. (2020). *Understanding Electronics.* New York: Tech Publishers. Retrieved from www.electronicshub.com

Smith, J. A. (2020). *RFID systems for smart public toilets: Enhancing efficiency and user satisfaction.* TechPub.

UNICEF. (2021). *Improving Sanitation and Hygiene Practices in Sub-Saharan Africa.* New York: United Nations Children's Fund (UNICEF).

USB.org. (2010). *to industry standards and technical specifications on USB technology (.*

APPENDICES

Appendix A: Code of Arduino

```
#include <SPI.h>                  // Library for SPI communication
#include <MFRC522.h>              // Library for RFID reader
#include <Wire.h>                 // Library for I2C communication
#include <LiquidCrystal_I2C.h>    // Library for LCD with I2C
#include <Arduino.h>              // Main Arduino library
#include <ESP8266WiFi.h>          // Library for ESP8266 Wi-Fi
#include <ESP8266WiFiMulti.h>     // Library to manage multiple Wi-Fi connections
#include <ESP8266HTTPClient.h>    // Library for making HTTP requests
#include <WiFiClient.h>           // Library for Wi-Fi client
#include <ArduinoJson.h>          // Library for handling JSON
#include <Servo.h>                // Library for controlling servo motors
#define SS_PIN D8                 // SS (Slave Select) pin connected to D8
#define RST_PIN D3                // RST (Reset) pin connected to D3
#define RED D0                    // Red LED connected to D0
Bool taped = false;               // Flag to check if the RFID card has been tapped
ESP8266WiFiMulti WiFiMulti;       // Object to manage multiple Wi-Fi connections
MFRC522 mfrc522 (SS_PIN, RST_PIN); // Create MFRC522 instance for RFID
reader
LiquidCrystal_I2C led(0x27, 16, 2); // Set up LCD at I2C address 0x27 with 16
columns and 2 rows
byte cardUID[7];                  // Array to store card UID
char previousCard[32];            // Array to store the previous card UID
int wallet = 200:                 // Initialize wallet balance
byte specificUUID[4] = { 0x1D, 0x0C, 0x09, 0x6C };  // UUID for a specific user
```

```
byte cleaner[4] = { 0xC1, 0x56, 0xF3, 0x24 };      // UUID for a cleaner

void setup() {

  Serial.begin(115200);          // Start serial communication at 115200 baud rate

  myservo.attach(D4);            // Attach the servo to pin D4

  myservo.write(0);              // Set initial servo position to 0 degrees

  delay(2000);                   // Wait for 2 seconds

  for (uint8_t t = 4; t > 0; t--) {

    Serial.printf("[SETUP] WAIT %d...\n", t);  // Print countdown to the serial monitor

    Serial.flush();            // Ensure all data is sent before delaying

    Delay (1000);              // Wait for 1 second

  }

  WiFi.mode(WIFI_STA);           // Set Wi-Fi mode to Station (connect to an AP)

  WiFiMulti.addAP("iPhone", "12345678"); // Add a Wi-Fi network to connect to

  // Initialize RFID reader

  SPI.begin();                   // Start SPI communication

  mfrc522.PCD_Init();            // Initialize the RFID reader

  Serial.println("Scan a MIFARE Classic card");

  lcd.begin();                   // Initialize the LCD

  lcd.backlight();               // Turn on the LCD backlight

  pinMode(RED, OUTPUT);          // Set RED LED pin as output

  digitalWrite(RED, 0);          // Turn off the RED LED

}

void loop() {

  lcd.setCursor(0, 0);           // Set cursor to the first row, first column
```

```
  lcd.print("Musanze Public");    // Display text on the first row
  lcd.setCursor(0, 1);            // Set cursor to the second row, first column
  lcd.print("Toilet System");     // Display text on the second row
  if (!mfrc522.PICC_IsNewCardPresent()) {
    return;                       // If no card is present, return to the start of the loop
  }
  if (!mfrc522.PICC_ReadCardSerial()) {
    return;                       // If unable to read the card, return to the start of the loop
  }
  for (byte i = 0; i < mfrc522.uid.size; i++) {
    cardUID[i] = mfrc522.uid.uidByte[i];
  }

  lcd.clear();                    // Clear the LCD screen
  lcd.setCursor(0, 0);            // Set cursor to the first row, first column
  lcd.print("Card:");
  for (byte i = 0; i < mfrc522.uid.size; i++) {
    lcd.print(cardUID[i] < 0x10 ? "0" : ""); // Add leading zero if the value is less than
0x10
    lcd.print(cardUID[i], HEX);  // Print the UID in hexadecimal format
  }
  delay(300);                     // Delay for 300 milliseconds
  if (memcmp(cardUID, specificUUID, sizeof(specificUUID)) == 0 && wallet > 0) {
    lcd.setCursor(0, 1);          // Set cursor to the second row
    lcd.print("balance : ");
```

```
    lcd.print(wallet);          // Display the wallet balance
  } else if (memcmp(cardUID, cleaner, sizeof(cleaner)) == 0) {
    lcd.setCursor(0, 1);
    lcd.print("processing......");
  } else {
    lcd.setCursor(0, 1);
    lcd.print("processing......");
    int uidLength = mfrc522.uid.size;
    char cardUIDString[uidLength * 3 + 1]; // Buffer for UID string
    sprintf(cardUIDString, "%02X", cardUID[0]); // Start conversion with the first byte
    for (int i = 1; i < uidLength; i++) {
      sprintf(&cardUIDString[strlen(cardUIDString)], "%02X", cardUID[i]); // Append
bytes
    }
    Serial.print("original Card: ");
    Serial.println(cardUIDString); // Print UID to serial monitor

    getData(cardUIDString);      // Call function to get data based on the UID
  }
}
void postData(char* prefix) {
  Serial.print("prefix : ");
  Serial.print(prefix);
  if ((WiFiMulti.run() == WL_CONNECTED)) {
    WiFiClient client;
```

```
    HTTPClient http;
    Serial.print("[HTTP] begin...\n");
    if (prefix[strlen(prefix) - 1] != '\0') {
      prefix[strlen(prefix) - 1] = '\0';
    }
    lcd.clear();                   // Clear the LCD screen
    lcd.setCursor(0, 0);           // Set cursor to the first row, first column
    lcd.print("Registering Card");  // Display "Registering Card"
    lcd.setCursor(0, 1);           // Set cursor to the second row, first column
    lcd.print("Processing.....");   // Display "Processing....."
    char url[256];
    snprintf(url, sizeof(url), "http://172.20.10.6:4000/signup/?username=%s", prefix);
    if (http.begin(client, url)) {  // Start HTTP connection
      Serial.print("[HTTP] POST...\n");
      int httpCode = http.POST("");  // Send the POST request
        Serial.printf("[HTTP] POST... failed, error: %s\n",
  http.errorToString(httpCode).c_str());
        lcd.print(http.errorToString(httpCode).c_str());  // Display error on LCD
        return;
      }
      http.end();  // End HTTP connection
    } else {
      Serial.println("[HTTP] Unable to connect");
    }
  }
```

```
}

        Serial.printf("[HTTP] PATCH... failed, error: %s\n", http.errorToString(httpCode).c_str());  // Print the error message
        lcd.print(http.errorToString(httpCode).c_str());  // Display the error message on the LCD
        return;  // Exit the function if the PATCH request fails
      }
      http.end();  // End the HTTP connection
    } else {
      Serial.println("[HTTP] Unable to connect");  // Print an error message if the connection fails
    }
  }
}
```

Appendix B: Code for Dashboard

```
<!DOCTYPE html>
<html lang="en">
  <head>
    <meta charset="UTF-8" />
    <meta http-equiv="X-UA-Compatible" content="IE=edge" />
    <meta name="viewport" content="width=device-width, initial-scale=1" />
    <title>Responsive Admin Dashboard</title>
    <!-- ======= Styles ====== -->
    <!-- <link rel="stylesheet" href="./assets/css/style.css"> -->
    <link rel="stylesheet" href="./assets/css/style.css" />
  </head>
  <body>
    <!-- =============== Navigation ================ -->
    <div class="container">
      <div class="navigation">
        <ul>
          <li>
            <a href="#">
              <span class="icon">
                <ion-icon name="logo-"></ion-icon>
              </span>
              <span class="title">Musanze Smart Public Toilet </span>
            </a>
```

```
</li>


<li>
  <a href="index.html">
    <span class="icon">
      <ion-icon name="home-outline"></ion-icon>
    </span>
    <span class="title">Dashboard</span>
  </a>
</li>
<li>
  <a href="register.html">
    <span class="title">register</span>
  </a>
</li>
<li>
  <a href="transaction.html">
    <span class="title">Transaction</span>
  </a>
</li>
<li>
  </a>
</li>
<li>
```

```
      <a href="Settings.html">
        <span class="title">Settings</span>
      </a>
    </li>
    <li>
      <a href="login.html">
        <span class="icon">
          <ion-icon name="log-out-outline"></ion-icon>
        </span>
        <span class="title">Logout</span>
      </a>
    </li>
  </ul>
</div>
<!-- ======================== Main ==================== -->
<div class="main">
  <div class="topbar">
    <div class="toggle">
      <ion-icon name="menu-outline"></ion-icon>
    </div>
    <div class="search">
      <label>
        <input type="text" placeholder="Search here" />
        <ion-icon name="search-outline"></ion-icon>
```

```
      </label>
    </div>
    <div class="user">
      <img src="assets/imgs/customer01.jpg" alt="" />
    </div>
  </div>
  <!-- ====================== Cards ================== -->
  <div class="cardBox">
    <div class="card">
      <div>
        <div id="users">0</div>
        <div class="cardName">Total Users</div>
      </div>
    </div>
    <div class="card">
      <div>
        <div class="numbers">4</div>
        <div class="cardName">Total Toilets</div>
      </div>
    </div>
    <div class="card">
      <div>
        <div id="numbers">0</div>
        <div class="cardName">Total Amount</div>
```

```html
      </div>
    </div>
  </div>
  <!-- ================ Order Details List ================= -->
  <div class="details">
    <div class="recentOrders">
      <div class="cardHeader">
        <h2>Recent</h2>
        <a href="#" class="btn">View All</a>
      </div>
      <table>
        <thead>
          <tr>
            <td>Card No</td>
            <td>Wallet (Rwf)</td>
            <td>Email</td>
            <!-- <td>Role</td> -->
          </tr>
        </thead>
        <tbody></tbody>
      </table>
    </div>
  </div>
</div>
```

```
    </div>


    <!-- =========== Scripts =========  -->
    <script src="assets/js/main.js"></script>
<!-- ====== ionicons ======= -->
    <script
      type="module"
      src="https://unpkg.com/ionicons@5.5.2/dist/ionicons/ionicons.esm.js"
    ></script>
    <script
      nomodule
      src="https://unpkg.com/ionicons@5.5.2/dist/ionicons/ionicons.js"
    ></script>
  </body>
</html>
```