A Smart Trolley with Payment System using MoMo and Visa card for Convenient Shopping in Ghana

Isaac Adjaye Aboagye[1*], Emmanuel Asare[2], Felix Nartey[3], Francis Kwesi Nsakwa Gabriel-Wettey[4], Quartson Jerry Justice[1], Joshua Ogbogoh[1], Tariq Nasser Deen[1] and Joseph Agyiri[3]

[1]Department of Computer Engineering, University of Ghana, Legon
[2]Department of Electrical/Electronic Engineering, Koforidua Technical University
[3]Department of Computer Science, Accra Technical University
[4]Department of Educational Studies and Leadership, University of Ghana, Legon

***Corresponding author:** iaaboagye@ug.edu.gh

ABSTRACT

The advancement of automation and smart retail technologies has opened new avenues that will improve shopping experience and reduce customer waiting time. A smart trolley with an integrated payment system has been developed to revolutionize the shopping process. At the core of the smart trolley system is the ESP32 microcontroller. It processes the scanned data in real time, calculates the cumulative cost of the items in the trolley, and keeps the customer informed of his or her total expenditure. The trolley is also equipped with Radio Frequency Identification (RFID) technology that allows the automatic identification and tracking of products within the store. The system provides immediate feedback through both an audible buzzer and a visual Light-Emitting Diode (LED). A Liquid Crystal Display (LCD) mounted on the trolley provides real-time updates, enabling customers to monitor their spending as they shop. Once a customer is done with the shopping, the ESP32 will compile all items purchased, along with their respective costs, and generate a digital receipt. Payment can be made using mobile money (MoMo) or a Visa card. A machine learning-based recommendation model using content-based recommendation was integrated to provide personalized shopping suggestions. An overall recommendation accuracy of 87% was achieved. Results showed that the RFID system successfully scanned and logged 98% of items within the specified range of 5-10 cm from the RFID card reader. The LCD updated the total cost within 1.5 seconds of scanning an item. The experimental results demonstrate that the smart trolley significantly improved shopping efficiency and user satisfaction, indicating strong potential for adoption in modern retail environments. All payment requests transmitted between the mobile application and the Paystack Application Programming Interface (API) were encrypted to prevent unauthorized interception of sensitive financial information during transactions.

Keywords: Smart trolley, MoMo, RFID, Convenient shopping, Audible buzzer

1.0 INTRODUCTION

The retail landscape is undergoing a significant transformation driven by an increasing demand for enhanced customer experiences and operational efficiency (Nair, A. J., et al. 2024; Hoyer, W. D., et al., 2020). Traditional shopping methods are characterized by lengthy checkout lines and manual billing processes, often presenting challenges that can detract from the overall shopping experience (Carré, F., et al., 2020; Ghazwani, S. H. S., 2021). These challenges are especially noticeable during peak shopping times such as weekends and holidays (Schwendtner, T., 2020; Womack, J. P., & Jones, D. T., 2015). While shopping can be both a leisure activity and a practical necessity, the inherent inefficiencies of traditional methods often overshadow the enjoyment of the experience. These challenges can lead to negative customer experience and decreased operational efficiency for retailers (Verhoef, P. C., et al., 2009).

Additionally, the lack of real-time monitoring tools prevents customers from effectively managing their budgets while shopping (Pappas, A., et al., 2023). To address these issues, there is a need for a smart shopping solution that integrates advanced technologies to automate and enhance the shopping process. These inconveniences require innovation within the retail sector to address and resolve such issues effectively (Eggers, W. D., et al., 2013; Inman, J. J., et al. 2017). This research seeks to address these challenges by introducing a transformative solution using a smart trolley with an integrated payment system.

This system will revolutionize the shopping experience by automating several key aspects in the retail shop, thereby enhancing both customer satisfaction and operational efficiency. This will create a seamless, efficient, and enjoyable shopping experience for customers (Beverungen, D., et al., 2019). The concept will integrate several cutting-edge technologies, including a machine learning model. The model will analyze purchasing patterns and customer preferences to offer personalized recommendations (Mosquera, A., et al., 2017; Zimmermann, R., et al., 2023). The primary aim of this research is to develop a smart trolley with an integrated payment system that utilizes RFID technology to provide a seamless and efficient shopping experience through automatic item scanning, real-time expense tracking, and reduced checkout queues.

The LCDs on the trolley will provide customers with real-time updates on their total expenditure, enabling better financial management and overall satisfaction. This research holds the potential to significantly impact the retail industry positively. The specific objectives are to:

- Incorporate an electronic payment system within the trolley, enabling cashless transactions.
- Integrate machine learning algorithms into the system to provide item recommendations based on the customer's shopping history and preferences.
- Develop a mobile application connected to a database that allows customers to create and manage their shopping lists.

- Develop a system that utilizes RFID technology to automatically scan items as they are placed in the trolley.

Unlike previous smart trolley systems that focused primarily on RFID-based billing automation, the proposed research system integrates RFID item detection, real-time cost monitoring, Mobile Money (MoMo) and Visa card payment integration, a cloud-based database, and a machine learning-based recommendation system within a single platform. The system is specifically designed for the Ghanaian retail environment by incorporating locally accessible technologies and mobile money payment support. Additionally, the system provides personalized product recommendations and real-time synchronization between the trolley, mobile application, and backend server. The development of a smart trolley with an integrated payment system will present a transformative solution to the persistent challenges faced by customers during shopping. This will not only reduce the time spent checking out after shopping but will also eliminate human error. Some of the key features of the Smart Trolley will include purchase history, a real-time cost monitoring system, an AI-driven recommendation system, an interactive shopping experience, etc. This research paper has been divided into five sections. Section I presents an introduction to smart automation payment systems. It covers the background study of the research, presents the problem statement, outlines the objectives, scope, and emphasizes the significance of the research. Section II presents the literature review of some related articles that are relevant to the study. It further points out the strengths and limitations of the related works. Section III describes the system design and development, and the components used in the design implementation and design process of the system. It provides a holistic view of the system, its core functionality, requirements, and specifications. Section IV focuses on the physical and software design implementation of research, integration of the various components and subsystems, testing, analyses, and discussion of results. Section V is the conclusion and recommendations. It will highlight the key accomplishments of the work and possible recommendations for further research work.

2.0 LITERATURE REVIEW

In this section, a detailed literature review of related work is presented. It took into consideration areas of interest such as the advancement of automation and smart retail technologies. It provides a guide to the development of a smart trolley with a payment system. Furthermore, we highlight the strengths and limitations of the available proposed approaches. The following summary and critical examination of the available literature focuses on design procedures and the implementation of systems. (Das, T. K., et al., 2020) proposed an advanced smart trolley system that automated shopping and billing processes, allowing customers to shop without waiting in line for checkout. Their system featured an Arduino board, an RFID reader, an LCD, and ESP8266 Wi-Fi module, and a database management system. The integration of a web interface allowed centralized management of inventory and customer data. This made the system versatile for both customers and store managers. However, the study did not explore the potential of machine learning for enhancing the shopping experience. The absence of an AI-driven recommendation model based on user data from their database was a key limitation. The proposed research builds upon this work by integrating an AI-powered recommendation engine that utilizes customers' purchase history to enhance the shopping experience through personalized product suggestions.

(Rahul, R., et al., 2023) developed an automatic smart trolley system to improve customer satisfaction by minimizing waiting times at billing counters. Their system employed a Node MCU (ESP8266) microcontroller and RFID tags to automate the scanning of products. The scanned items were displayed on an OLED screen, allowing customers to view their shopping progress in real-time. By streamlining the checkout process, the system saved both time and effort for shoppers. However, a key limitation of their work was the absence of a database to store customer shopping data. Additionally, the system did not incorporate a mobile application to enhance the shopping experience by allowing users to manage shopping lists or receive personalized suggestions. The proposed research aims to address these limitations by integrating a cloud-based database for storing user data, enabling a mobile application and an AI-driven recommendation system to deliver a more personalized and interactive shopping experience.

(Patil, S. R., et al., 2022) presented a smart trolley system titled "Smart Trolley with Automatic Billing System using Arduino." Their project aimed to address the inefficiencies of traditional shopping systems in large, crowded malls, particularly the time-consuming nature of barcode scanning. To overcome these challenges, they implemented an RFID-based system where each product was tagged with an RFID chip. As items were added to the trolley, an RFID reader mounted on the trolley automatically scanned the tags, eliminating the need for manual item scanning. The system was managed by an Arduino Uno microcontroller, which processed the data and displayed the total cost of the selected items on an LCD screen in real time. Although the system enhanced shopping efficiency, it lacked mobile application integration and advanced functionalities such as personalized product recommendations. The proposed research builds upon this work by integrating an AI-powered recommendation engine that utilizes customers' purchase history to enhance the shopping experience through personalized product suggestions.

(Datta, A., Riya, N. H., et al., 2023) proposed an IoT-based smart Trolley and Billing System for a Super Shop to improve the shopping experience. An innovative solution using IoT and RFID scanners is implemented in shopping trolleys. The trolley automatically scans items, announces product details, and displays prices on a screen, allowing for easier budget management. Additionally, the trolley moves on its own, and payments can be made quickly via RFID, streamlining the process and reducing physical effort, especially for elderly customers. However, the study did not consider the integration of mobile applications, personalized shopping assistance, or a machine learning-based recommendation system. This proposed research addresses these limitations by introducing mobile app support and an AI-driven recommendation system that utilizes stored customer data to deliver a more interactive and personalized shopping experience.

(Faisal, T., et al., 2021) proposed a smart cart system with multi-shopping functionalities, including integrated payment systems and virtual navigation maps embedded in shopping carts to reduce waiting times and assist customers in locating items more efficiently. This approach promotes a more autonomous shopping experience, reduces operational costs, and simplifies store management, while also encouraging a return to in-store shopping, particularly in the context of pandemic-related disruptions. However, the study did not consider the integration of mobile applications, personalized shopping assistance, an ML-based recommendation system, or an enhanced payment system. This proposed research addresses these limitations by incorporating mobile application support, a recommendation engine based on stored customer data to enable a more interactive and personalized shopping experience, and a payment module that allows users to complete transactions using credit/debit cards or Mobile Money services. Our proposed research will contribute to the development of a more efficient, scalable, and user-friendly shopping experience.

3.0 SYSTEM DESIGN AND DEVELOPMENT

This section provides a comprehensive overview of the system design, including conceptualization and development processes, system architecture, and the user interface used to build the system. The smart trolley system comprises three main components, namely the hardware system, the software system, and the backend system. The hardware system consists of the physical trolley equipped with RFID readers, an LCD, and an ESP32 microcontroller. This will manage and process data. The software system consists of the embedded software running on an ESP32 microcontroller, a machine learning model for product recommendations, and the mobile application used by customers. The backend system includes cloud-based services, a database management system, and an Application Programming Interface (API) for handling transactions and storing data. The RFID reader is used to scan products as they are added to the trolley.

Each item is equipped with an RFID tag, enabling instant identification and automatic recording of the product information. The real-time cost monitoring system features a 20x4 LCD that shows the total cost of all items in the trolley in real-time. The displayed amount updates automatically whenever items are added or removed by the customer. The e-payment integration system is integrated with the Paystack API to support cashless transactions (Al-Ammal, H. M., et al., 2020; Moon, I. T., et al., 2022). Once a customer is ready to check out, payment can be made directly through the smart trolley using either a mobile application or contactless payment options. A machine learning model is embedded within the system to provide personalized product recommendations based on the customer's shopping habits and preferences. The smart trolley is linked to a mobile application that customers can use to create shopping lists, track spending, and receive notifications about offers and discounts. The system is connected to a cloud-based database to keep track of inventory levels in real-time (Bose, R., et al., 2022). The system incorporates security mechanisms to deter theft and ensure that all scanned items are properly paid for before exiting the store. RFID tags are continuously monitored up to checkout, and any unscanned items automatically trigger alerts.

3.1. System modeling and simulation: The system was designed using multiple architectural and operational flow diagrams that illustrate the processes and interactions between the various subsystems. These include a system block diagram, as well as separate hardware and software block diagrams and flow diagrams. The overall system architecture is shown in Figure 1. The system architecture illustrates the interactions between the hardware, software, and backend components. The main server acts as the central processing unit of the backend, coordinating communication between the mobile application, hardware module, recommendation engine, payment gateway, and database. The database stores product listings, user profiles, shopping histories, and transaction records, while the machine learning server analyzes historical purchase data to generate personalized recommendations. The payment server securely processes Mobile Money and Visa card transactions through the Paystack platform.

3.2. Hardware Block Diagram: The hardware block diagram shows the internal connections within the smart trolley system, as presented in Figure 2. The RFID reader, connected to the ESP32 microcontroller, processes the scanned data from RFID tags. The microcontroller is connected to the LCD, ensuring real-time updates. The LED and buzzer provide notification when an item is scanned. The power management section shows how power is distributed from the power supply unit to the various system components, including the microcontroller, RFID reader, and display.

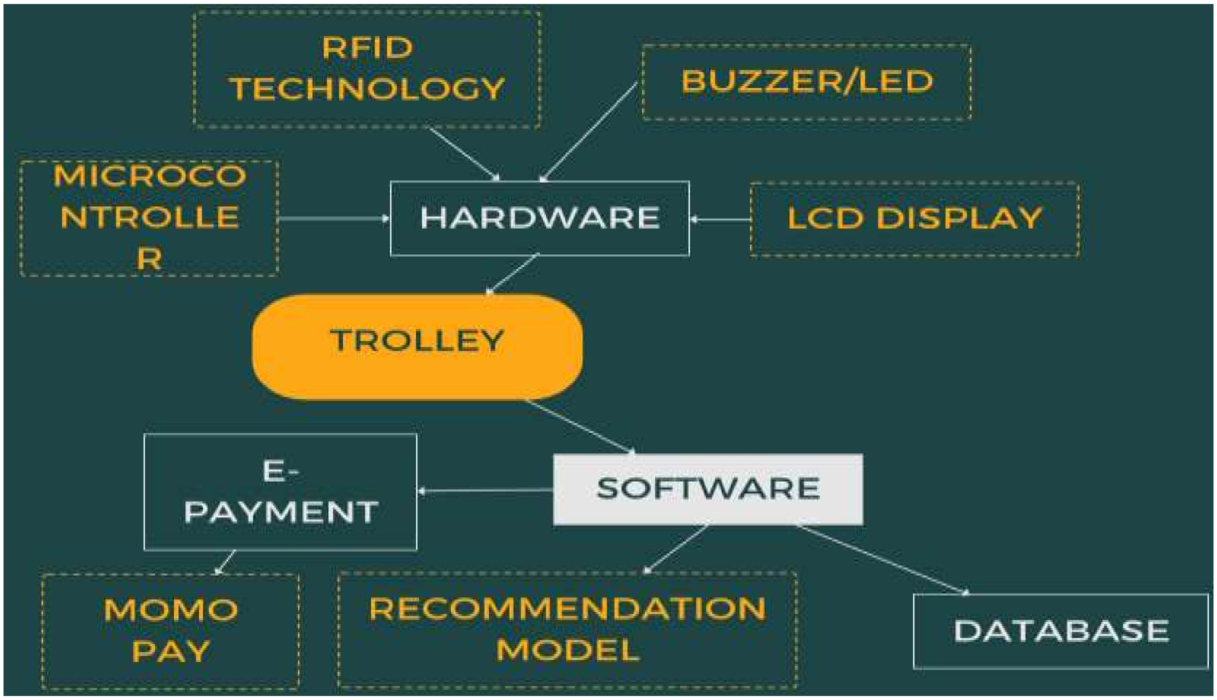

Figure 1: High-level overview of the overall system architecture and component interactions

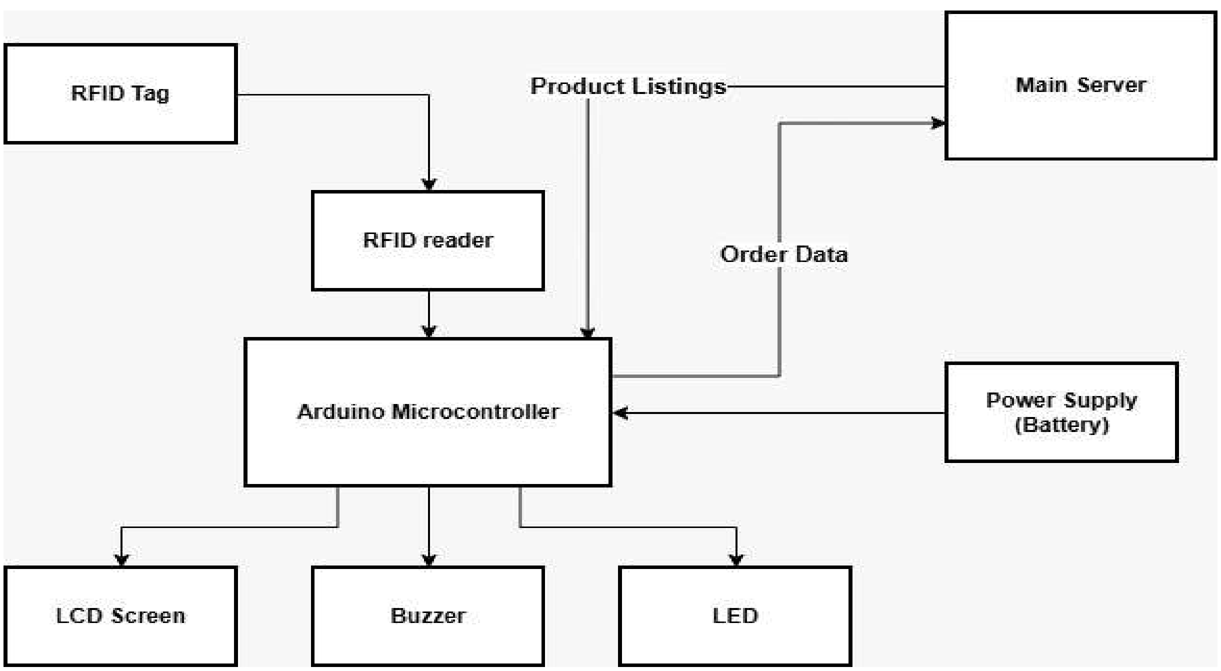

Figure 2: Hardware block diagram showing system components and their connections.

3.3. Hardware operational flow diagram: The hardware operational flow diagram shown in Figure 3 details the step-by-step process involved from when a shopper enters the shopping mall to the completion of shopping and preparation for payment. The system initializes when the trolley is powered on. The user authenticates using a personal card to start shopping, ensuring secure communication between the hardware and the mobile application during checkout and payment. As an item is placed in the trolley, the RFID reader scans the tag. The ESP32 microcontroller processes the scanned data and checks if the item has been previously scanned. The total cost is updated on the LCD, and the item is added to the list of purchased items. The system continues to scan new items until the user initiates checkout. Once the shopper has finished shopping, a trolley tag is used to initiate the checkout process. Once the checkout process is initiated, the shopping details are sent to the mobile app for authentication and payment.

3.4. Software Architecture Diagram: The software architecture is represented in a block diagram as shown in Figure 4. The embedded software on the ESP32 microcontroller handles item scanning, cost calculation, and communication with the mobile app. The mobile application communicates with the trolley to synchronize data and provide user functionalities like shopping lists and payment processing. The machine learning server shows how the machine learning model interacts with the cloud backend to provide product recommendations. The hardware module communicates the shopping data from the microcontroller unit to the main server. The payment server facilitates transaction processing, while the admin panel is used to manage and update product data, as well as to ensure the consistent and reliable operation of the system.

The user starts by creating a shopping list on the mobile app or by directly placing items in the smart trolley. As items are added, the system provides real-time cost updates and recommendations. The user can add or remove items, with the system adjusting the total cost and recommendations accordingly. The user initiates checkout, leading to the payment process. After payment, the system updates inventory, provides a receipt, and the user completes the shopping session.

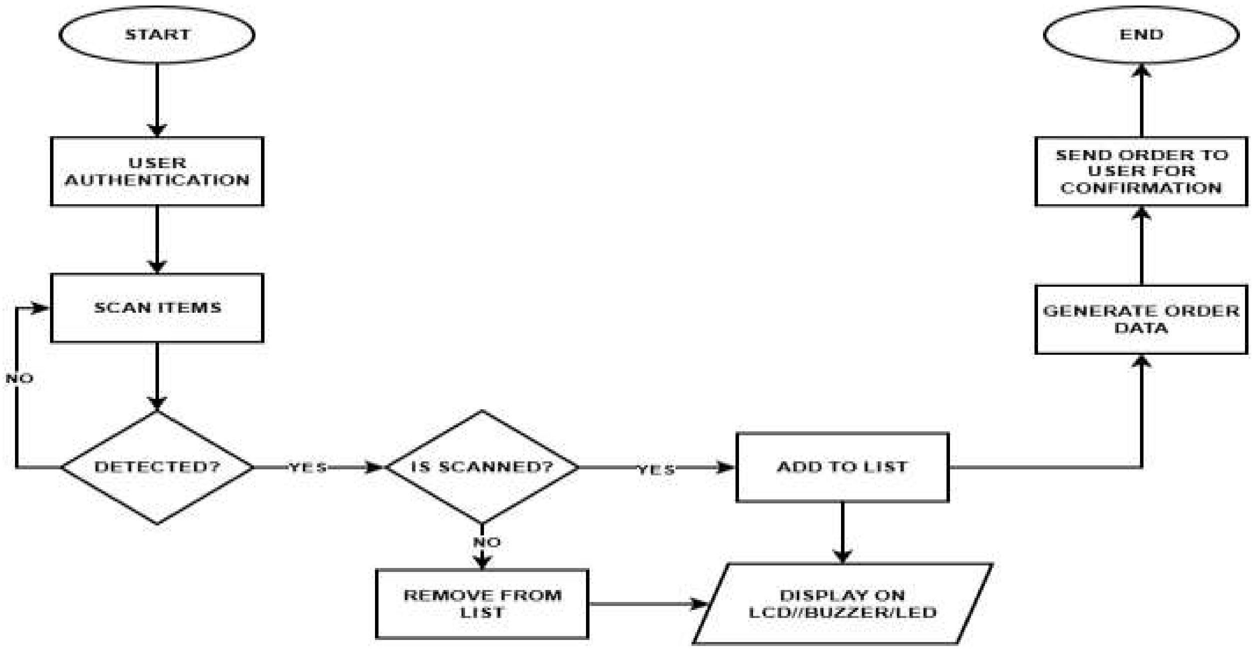

Figure 3: Hardware operation flow diagram and data processing

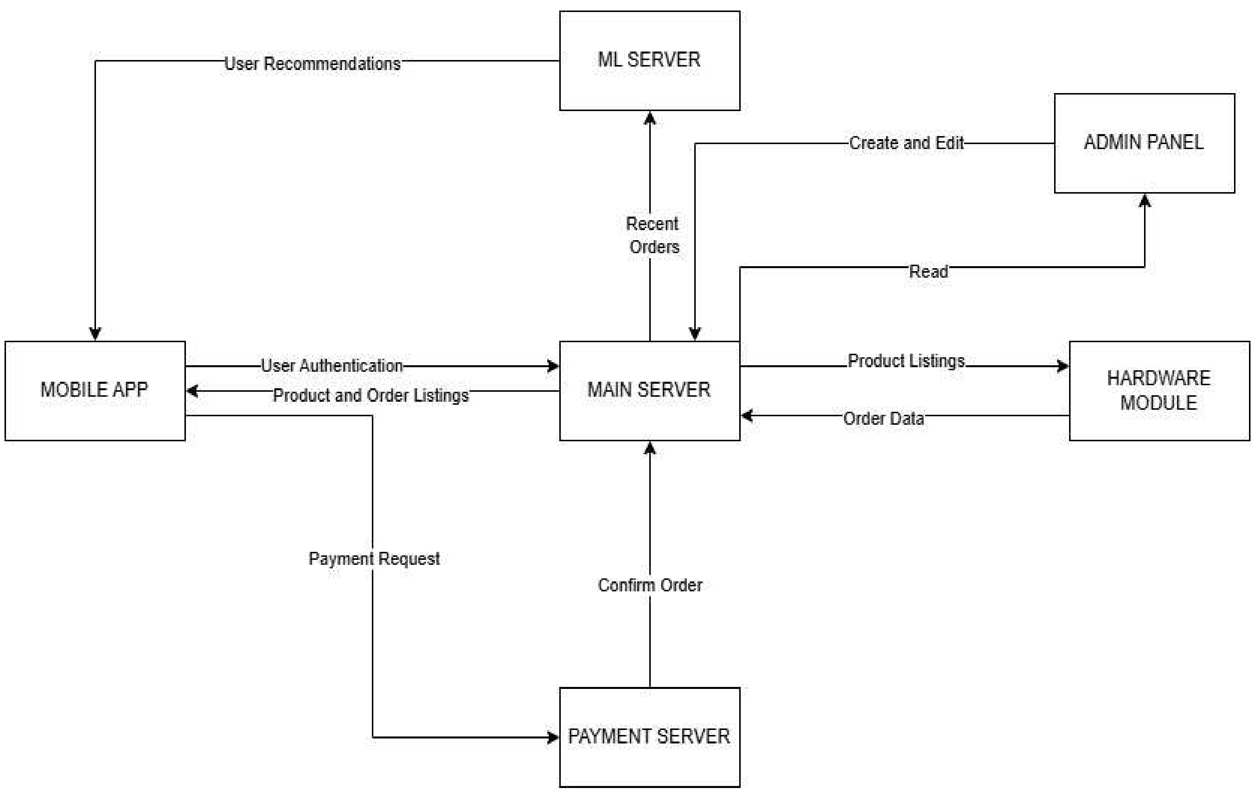

Figure 4: Software block diagram and its functional relationships

3.5 System Software Flow Diagram: The software flow diagram in Figure 5 outlines the process involved in using the mobile application. It also shows how the various interfaces of the app interact, as well as communication with the server. The user selects the payment option on the mobile application or directly via the trolley. The system cross-checks all scanned items to ensure they are accounted for. The payment request is sent to the Paystack API. Upon successful payment, the system updates the inventory and displays a confirmation message on the LCD. The transaction is completed, and the user can exit the store.

The onboarding and registration interfaces shown in Figure 6 serve as the user's first interaction with the application, setting the tone for the entire experience. The user interface (UI) is designed to welcome new users and guide them through the application's key core features. The registration screen enables new users to create an account. Like the login screen, it is user-friendly, with fields for the user's name, email, password, and phone number. Each field is labeled clearly, and any form of validation, such as password strength or email format, is indicated in real-time to enhance user experience and guide the user through the process.

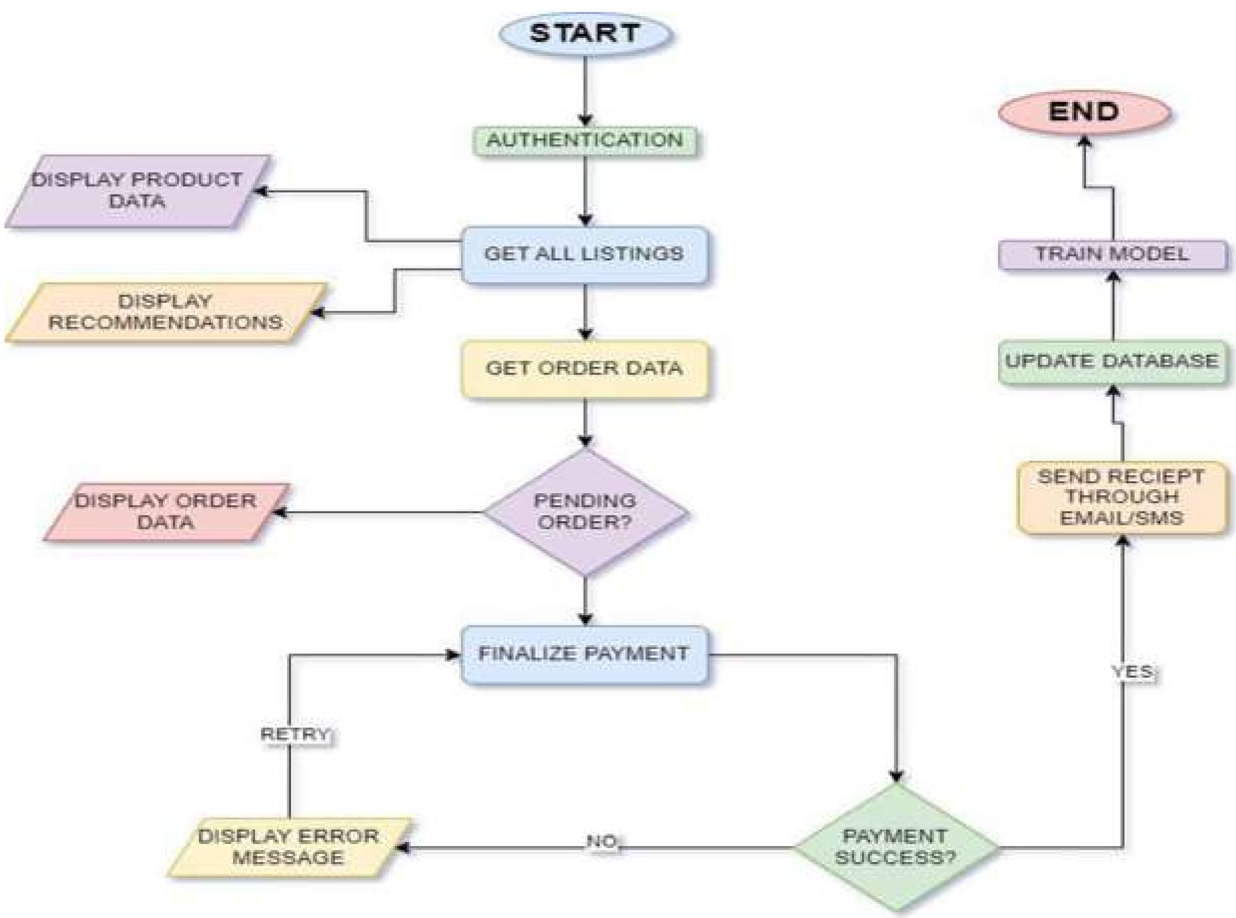

Figure 5: Software flow diagram showing the sequence of program execution

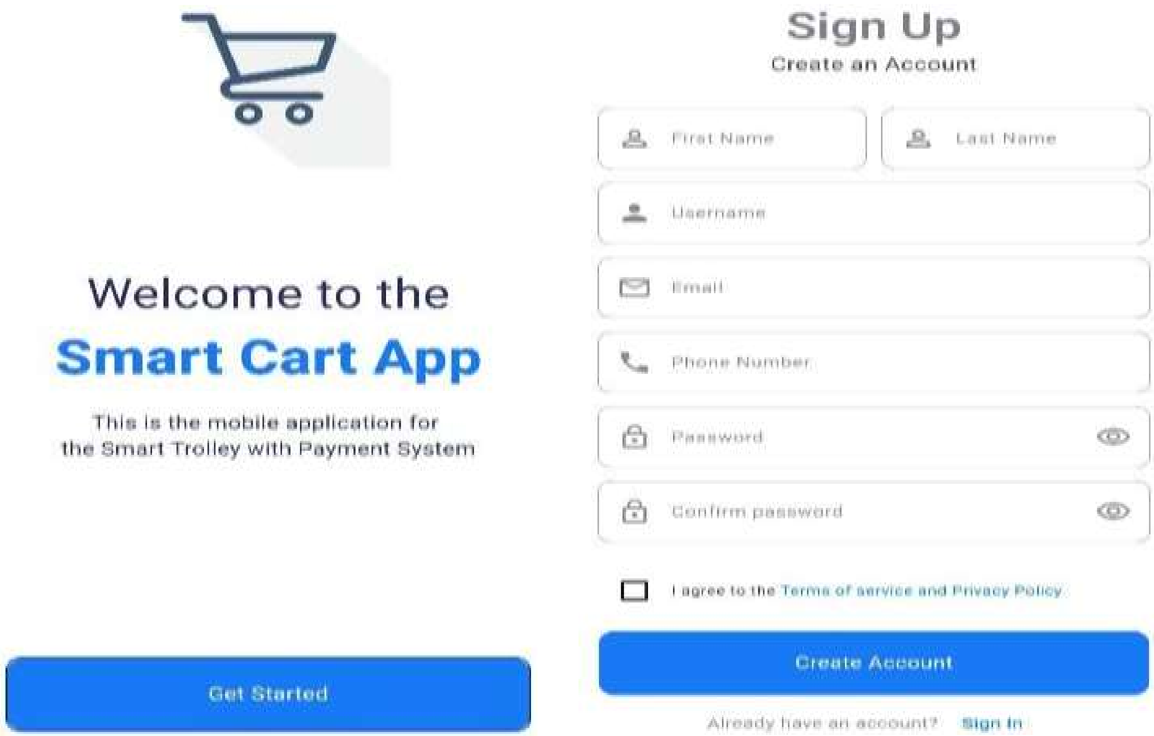

Figure 6: Account registration screen for new users

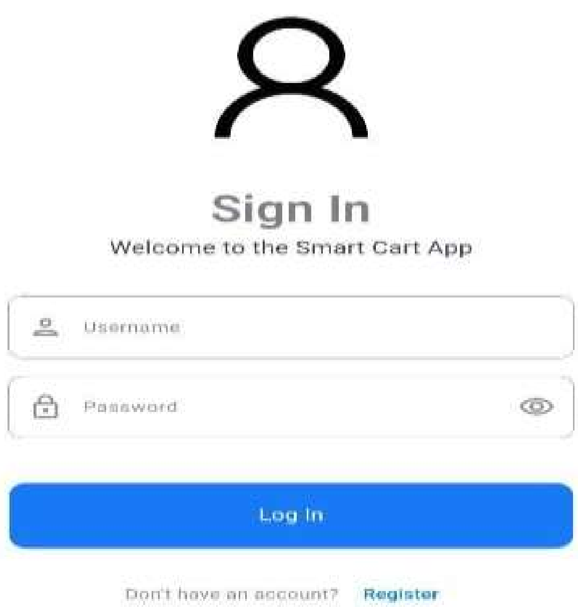

Figure 7: User authentication login screen

The login screen is designed with a focus on simplicity and functionality to enhance user convenience. It features a minimal layout with two input fields for the user's email or username and password. Each field is clearly labeled, and placeholder text is provided to guide users on the required input.

The administrative dashboard shown in Figure 8 serves as the central hub for system management and monitoring. It gives administrators quick access to key functions, including user management, product management, order monitoring, and system analytics. It is visually organized, typically structured using a grid or list layout for clarity. Each section represents a different function, such as viewing products, recommendations, and recent orders. The order list screen provides users with an organized view of all their current and past orders. The UI is structured as a scrollable list, where each order is presented as a card or a row. Each card or row contains brief but essential information about the order, including the order number, date, status ("Pending," or "Completed"), the products purchased, and total amount. The order confirmation screen provides a detailed overview of a specific order. The UI is designed for clarity, presenting all necessary details in a format. At the top of the screen, the order number and status are prominently displayed, followed by a list of the items included in the order. Each item is listed with its name, quantity, price, and a small thumbnail image for easy identification. The administration dashboard serves as the central hub where administrators can access and manage various aspects of the system. The UI of this screen is clean and functional, prioritizing clarity and organization. At the top of the dashboard, a navigation bar or sidebar provides quick access to essential features, including user management, content creation, data analytics, and system settings. Each section is represented by icons paired with descriptive labels for easy identification.

The create page is where administrators can add new records, such as users, products, articles, etc., depending on the system's purpose. The edit page is intended to allow administrators to modify or delete existing records. Its structure closely mirrors the create page, ensuring consistent user experience. At the top of the page, the title typically reads something like "Update Item," followed by the name or identifier of the specific record being edited. This ensures that the administrator is fully aware of which record they are modifying.

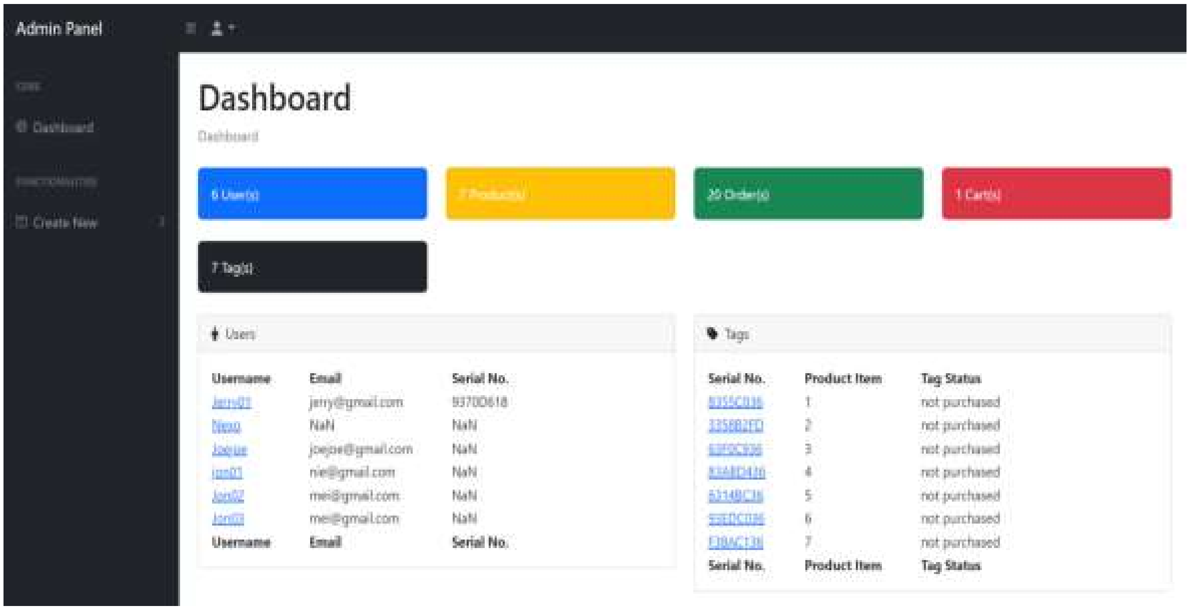

Figure 8: Administrative dashboard showing key metrics and management controls

4. 0 SYSTEM IMPLEMENTATION AND TESTING

This section provides a comprehensive overview of the design framework used in implementing the smart trolley. The implementation followed a structured process, testing, and deployment. The ESP32 Microcontroller, which is the central unit responsible for controlling the system, was integrated with other peripherals, such as the RFID reader and LCD, buzzer, etc. The RFID reader was mounted on the trolley in an optimal position to easily scan tags as items were placed in or removed from the smart trolley. RFID tags were attached to products. The LCD was connected to the ESP32 microcontroller using the I2C interface, allowing it to show real-time cost updates. A battery-powered supply was integrated into the trolley, ensuring stable power for continuous operation. The power supply system was designed to be efficient and rechargeable for long-term use. The buzzer and LED indicators were connected to provide feedback to users, signaling successful scans or errors during item detection. Figures 9a and 9b show the initial component assembly and component assembly and testing, respectively.

The software development phase focused on writing the embedded code, developing the mobile application, and integrating backend services to ensure the smart trolley operated seamlessly. The ESP32 microcontroller was programmed using the Arduino Integrated Development Environment (IDE) to handle RFID scanning, communication with the LCD, and interaction with the cloud backend. A code was developed to read RFID tags, process the data, and update the product list and total cost in real time. A code was written to calculate and display the total cost on the LCD screen as items were added or removed. The system was optimized to minimize power consumption by reducing processing power during idle periods. A mobile application was developed using Visual Studio Code. This provided users with a platform to interact with the smart trolley. The application allows users to create shopping lists, view product recommendations, track their spending, and make cashless payments. The mobile application was designed to synchronize with the trolley via Wi-Fi, ensuring real-time updates and data consistency. A cloud-based Structured Query Language (SQL) database was set up to store product information, user profiles, transaction records, and inventory data. The system continuously updates the database whenever an item is scanned, maintaining accurate records of purchased items and related shopping information.

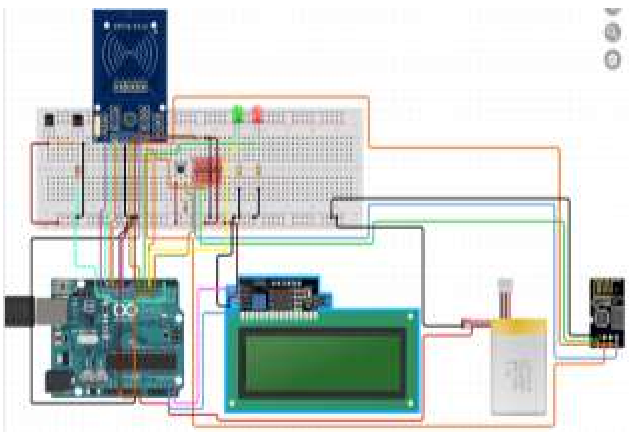

Figure 9a: Initial component assembly

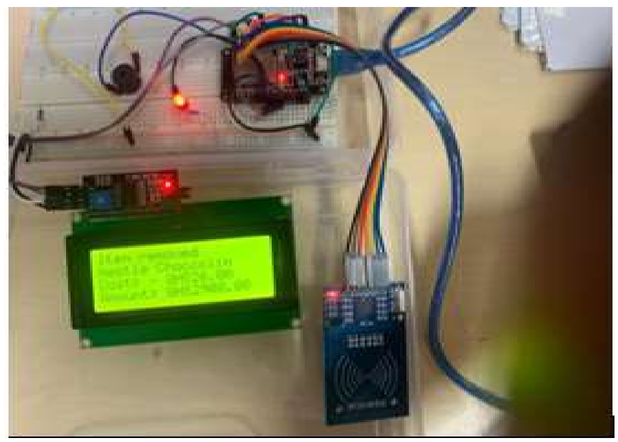

Figure 9b: Component assembly and testing

Figure 10: Fully assembled hardware system mounted on the trolley

4.1. Testing and Results: The system was subjected to several tests to assess its performance, reliability, and ease of use. The testing procedure evaluated the functionality of individual components, the integration between hardware and software, and the overall user experience. To assess the accuracy and efficiency of the RFID reader in detecting and recording items within the system, several products were fitted with RFID tags. The RFID reader was installed on the trolley to facilitate the testing process. Various distances and angles were evaluated to replicate real-world operating conditions. Items were individually placed into the trolley, allowing the RFID reader to scan each tag. One hundred (100) products were tagged with RFID cards. The RFID reader was mounted on the Smart Trolley in an optimized position to facilitate reliable tag detection during shopping activities. To simulate realistic operational conditions, RFID performance testing was conducted across varying scanning distances ranging from 5 cm to 10 cm. Products were placed into the trolley individually, allowing the RFID subsystem to scan and register each tagged item while the ESP32 microcontroller processed and logged the corresponding product information. To evaluate detection reliability, each tagged product was scanned repeatedly at every 1 cm interval within the specified operating range (5 cm, 6 cm, 7 cm, 8 cm, 9 cm, and 10 cm). Multiple scan attempts were conducted at each distance, resulting in a total of 500 RFID scan attempts across all tagged products. Out of the 500 scans performed, 490 scans were successfully detected and logged by the system, yielding an RFID detection accuracy of 98%.

$$RFID\ Accuracy = \frac{Successf\ ul\ Reads}{Total\ Scan\ Attempts} \times 100$$

$$RFID\ Accuracy = \frac{490}{500} \times 100\ = 98\%$$

The scanned information was processed by the ESP32 microcontroller, which updated the LCD and recorded the product details. Items were also removed from the trolley to verify that the system accurately detected and reflected the changes.

The results showed that the RFID system successfully scanned and logged 98% of items within the specified range (5 cm to 10 cm). Some difficulties were encountered with items placed beyond the 10 cm range or at extreme angles. Signal interference remained low, with only a few missed scans occurring when multiple items were scanned at once. Further improvements in accuracy could be achieved by adjusting the RFID reader's sensitivity and optimizing its placement on the trolley.

Figure 11: RFID module testing setup for tag detection

Table 1: Quantitative Evaluation of the RFID Subsystem

Parameter	Value
Number of RFID-Tagged Products Tested	100
Total RFID Scan Attempts	500
Successful RFID Scans	490
Failed RFID Scans	10
RFID Detection Range	5 cm to 10 cm
Experimental Duration	5 days
Average RFID Response Time	1.2 seconds
RFID Accuracy	98%

4.2. Real-Time Cost Monitoring and E-Payment Test: Ten products with different prices were selected and tagged for the experiment. The LCD was connected to the ESP32 microcontroller to update the total cost as items were scanned. Products were added and removed from the trolley in sequence. The cumulative cost was monitored on the LCD to verify consistency and accuracy, while the display update time was recorded to evaluate system responsiveness. The system accurately calculated and displayed the total cost of all items in the trolley. No discrepancies were noted in the pricing. The display updated the total cost within 1.5 seconds of scanning an item. This is acceptable for real-time operation. Further optimization of the microcontroller code could slightly reduce the update time to make the system even more responsive. To evaluate the performance of the integrated electronic payment system, a controlled experiment was conducted over a period of seven days using the Paystack payment gateway. A total of 50 users participated in the experiment and performed a combined total of 150 payment transactions using Mobile Money (MoMo) and Visa/debit cards through the mobile application connected to the trolley via Wi-Fi. During each transaction, users selected the “Checkout” option on the mobile application, after which the system verified all scanned items and transmitted the payment request securely to the Paystack Application Programming Interface (API). The experiment monitored transaction success rate, payment processing time, payment confirmation response, and synchronization with the inventory database. The results showed that all 150 transactions were completed successfully without transaction failure. Users received payment confirmation notifications on both the mobile application and the Liquid Crystal Display within an average response time of 2 to 3 seconds. Transaction data was securely encrypted during communication with the payment gateway, ensuring transaction confidentiality and compliance with payment security standards.

$$Payment\ Success\ Rate = \frac{Successf\ ul\ Transactions}{Total\ Transactions} \times 100$$

$$Payment\ Success\ Rate = \frac{150}{150} \times 100 \ = 100\%$$

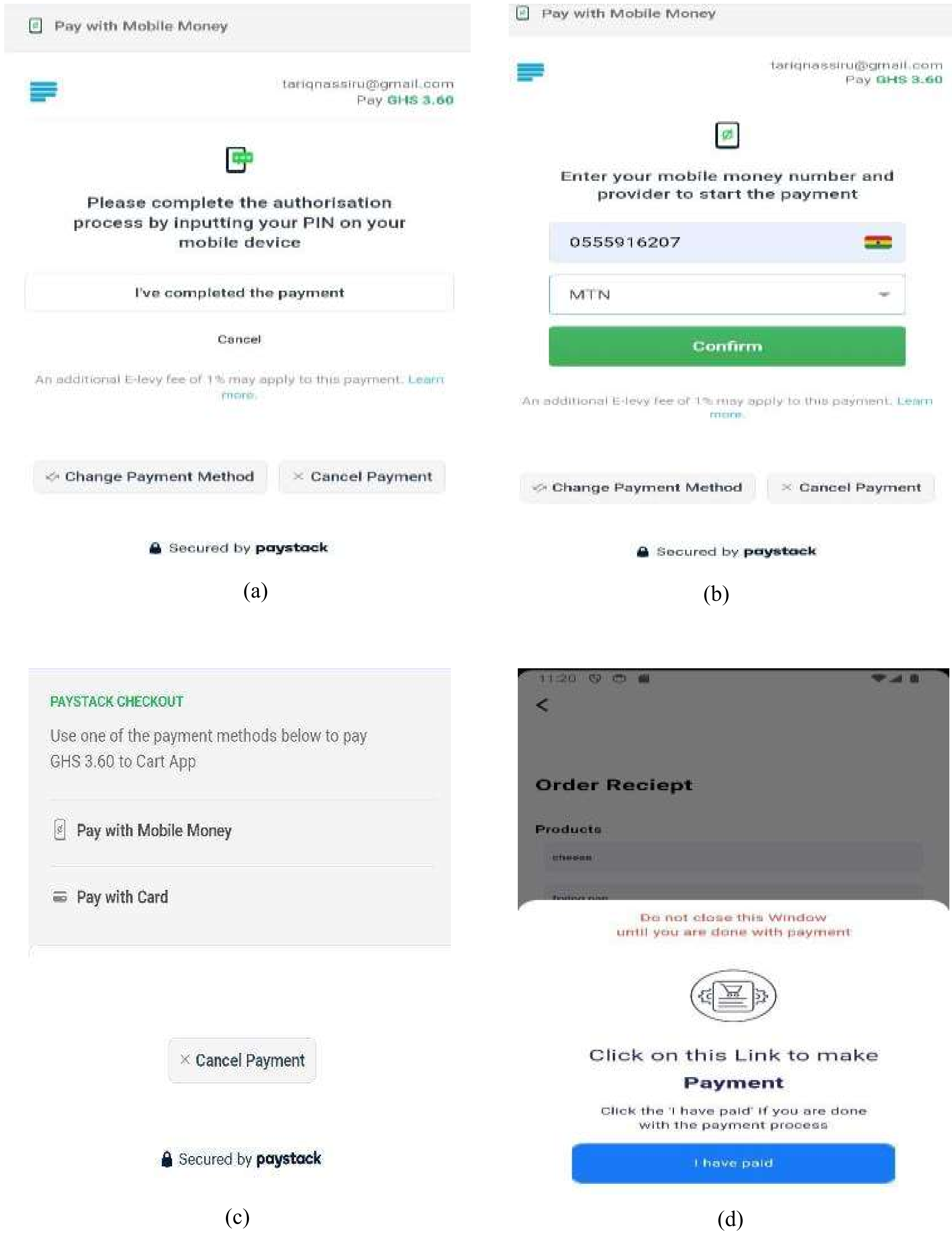

Figure 12 (a, b, c, and d): Payment system showing transaction process and validation

Table 2: Quantitative Evaluation of the E-Payment System

Parameter	Value
Sample Size	50 participants
Number of Transactions Tested	150
Successful Transactions	150
Failed Transactions	0
Payment Methods Tested	Mobile Money (MoMo), Visa/Debit Card
Experimental Duration	7 days
Average Processing Time	2.4 seconds
Minimum Processing Time	1.8 seconds
Maximum Processing Time	3.1 seconds
Payment Success Rate	100%

4.3. Machine Learning-Based Recommendation System Test: To assess the performance of the machine learning model, a dataset of historical purchase data was used to train the machine learning model. The model was deployed on the cloud backend and connected to the mobile application. Test users were assigned different shopping histories and then instructed to place items into the trolley. The model generated product recommendations, which were displayed in real-time. The relevance and accuracy of the recommendations were evaluated based on the user's preferences. The recommendation engine employed a content-based filtering approach trained on historical purchase records. Model performance was validated by comparing the recommendations generated with user purchasing preferences and complementary product relationships. A total of 20 test users with varying shopping patterns were assigned different purchase histories to replicate realistic retail purchasing scenarios. The evaluation consisted of 300 recommendation instances generated across the test users. Recommendation accuracy was assessed by comparing generated recommendations against user purchase preferences and complementary product relationships. A recommendation was considered successful when the suggested item matched the user's historical purchasing patterns or demonstrated logical purchasing relevance to products already present in the trolley. Out of the 300 recommendation instances evaluated, 261 recommendations were identified as relevant, resulting in an overall recommendation accuracy of

87%. The remaining 13% of recommendation inaccuracies primarily occurred when users had limited purchase history, highly diverse shopping behavior, or insufficient historical patterns for reliable personalization.

$$Recommendation\ Accuracy = \frac{Correct\ Recommendations}{Total\ Recommendation\ Instances} \times 100$$

$$Recommendation\ Accuracy = \frac{261}{300} \times 100 = 87\%$$

The machine learning model provided accurate recommendations for 87% of users. Products suggested were often related to or complementary to items in the user's trolley. Recommendations were generated within 1-2 seconds after an item was scanned, ensuring a smooth shopping experience. Expanding the dataset and refining the model's training process could further improve the accuracy of recommendations.

Table 3: Quantitative Evaluation of the Machine Learning Recommendation System

Parameter	**Value**
Number of Users Involved	30
Dataset Size	1,200 purchase records
Total Recommendation Tests Conducted	300
Correct Recommendations	261
Incorrect Recommendations	39
Experimental Duration	7 days
Average Recommendation Response Time	1.6 seconds
Recommendation Accuracy	87%

```python
if is_present:
    column_name = 'lemmatized_concatenated'
    word_count, matching_rows = count_word_occurrences(df_lemmed[column_name], unique_word_to_check)
    print(f"\n'{unique_word_to_check}' appears {word_count} times in the '{column_name}' column.")

    print("\nRandom 10 lemmatized values containing the unique word:")
    random_sample = random.sample(matching_rows, min(9, len(matching_rows)))
    recommended_titles = df_lemmed[df_lemmed[column_name].isin(random_sample)]['Product Name'].values

    print("\nThe first 10 recommendations are:")
    for i, title in enumerate(recommended_titles, start=1):
        print(f"{i}: {title}")
```

```
'Toys' appears 6735 times in the 'lemmatized_concatenated' column.

Random 10 lemmatized values containing the unique word:

The first 10 recommendations are:
1: Nino Percussion NINO-NS355 14-Inch Cymbal with Holding Straps, Nickel Silver
2: Thames & Kosmos Biology Genetics and DNA
3: Revell 1/25 '85 Oldsmobile 442/FE3-X Show Car Plastic Model Kit
4: Everest Toys Flexi-Forts Set
5: PLAYMOBIL 9473 Spielzeug-Schneetroll mit Schlitten, Unisex-Kinder & 9474 Spielzeug-Schlitten mit Königspaar, Unisex-Kinder
6: Toy Story Buzz Lightyear, Bandai Cinema-Rise Standard
7: C&D Visionary DC Comics Originals Batman Logo 6 cm Embossed Metal Emblem Sticker
8: Winning Moves Games Pay Day, The Classic Edition
9: Small World Toys Gertie Sport - Bumpin' Around 6'' Ball (Colors Vary)
```

Figure 13: Machine learning recommendation model and evaluation workflow

A usability evaluation was conducted to assess user satisfaction, ease of use, and the overall effectiveness of the smart trolley system in a real-world shopping scenario. The study involved the same 50 participants who participated in the payment and system functionality tests. The evaluation was conducted over a period of seven days in a simulated retail environment. After completing the tasks, participants completed a usability questionnaire based on a 5-point Likert scale, where 1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, and 5 = Excellent. The questionnaire evaluated the following usability metrics: Ease of use, System responsiveness, Payment convenience, Recommendation usefulness, and Overall satisfaction.

Table 4: User Usability Evaluation Results

Evaluation Metric	**Average Rating (Out of 5)**
Ease of Use	4.5
System Responsiveness	4.3
Payment Convenience	4.6
Recommendation Usefulness	4.1
Overall User Satisfaction	4.4

The overall user satisfaction score was calculated using:

$$Average\ Rating = \frac{\sum_{i=1}^{n} x_i}{n}$$

Where:

- x represents each participant's rating
- n represents the total number of participants involved in the usability evaluation.

All payment requests transmitted between the mobile application and the Paystack Application Programming Interface (API) were encrypted to prevent unauthorized interception of sensitive financial information during transactions. User authentication was implemented using RFID-based identification and mobile application login credentials. Each user was required to authenticate using a registered RFID card before accessing the trolley system. This ensured that shopping activities, payment records, and recommendation data were associated only with authorized users. Sensitive user information, such as payment details and shopping records, was not stored directly on the trolley hardware, reducing the risk of data exposure in the event of device compromise. To ensure transaction confidentiality and integrity, the system verified all scanned items before payment processing and generated confirmation notifications only after successful payment authorization. The cloud database was configured with restricted administrative access to minimize unauthorized modification of inventory and transaction records.

5.0 CONCLUSION AND RECOMMENDATION

The smart trolley with an integrated payment system offers an innovative solution to the ongoing challenges customers encounter during shopping.

This will reduce the time spent on checkout and eliminate human error during shopping. One of the key features of the Smart Trolley is its real-time cost monitoring system. This feature helps shoppers to manage their budgets effectively and avoid insufficient funds at checkout. The system incorporates advanced machine learning algorithms that offer personalized product recommendations based on the customer's shopping history and preferences. Through the mobile application, users can create and organize their shopping lists, which the trolley can recognize as they move through the store. The integration of e-payment systems into the smart trolley promotes the adoption of cashless transactions, which is particularly beneficial in the global push towards digital economies. This research demonstrated the potential to revolutionize the traditional shopping experience by reducing waiting times, improving efficiency, and providing personalized services to customers. It is recommended that a more robust power source be supplied. Future developments should consider the use of Ultra High Frequency (UHF) RFID technology to enhance the system's ability to read multiple tags simultaneously over a longer distance. Deploying a localized server will reduce latency and ensure that the smart trolley operates efficiently, especially in high-traffic scenarios. There was an issue with compatibility with IOS devices. Future research should tackle this issue. This research provides significant contributions to the field of smart retail technologies. The results of the tests affirmed the readiness of the smart trolley system for deployment. Features such as personalized item recommendation and payment make the smart trolley more applicable in our current age of digitization compared to the traditional trolley.

REFERENCES

Nair, A. J., & Manohar, S. (2024). Green Service Consumption: Unlocking Customer Expectations on Technological Transformations Enhancing Purchase Experience in Retail Stores. International Journal of Information Management Data Insights, 4(2), 100277.

Hoyer, W. D., Kroschke, M., Schmitt, B., Kraume, K., & Shankar, V. (2020). Transforming the customer experience through new technologies. Journal of interactive marketing, 51(1), 57-71.

Carré, F., Tilly, C., Benner, C., & Mason, S. (2020). Change and uncertainty, not apocalypse: Technological change and store-based retail.

Ghazwani, S. H. S. (2021). The impact of AI-Enabled checkouts on shoppers' attitudes and purchase intent in Saudi Arabia (Doctoral dissertation, Auckland University of Technology).

Schwendtner, T. (2020). The COVID-19 crisis and its effects on in-store operations and marketing in grocery retailing/Author Teresa Schwendtner.

Womack, J. P., & Jones, D. T. (2015). Lean solutions: how companies and customers can create value and wealth together.

Simon and Schuster.

Verhoef, P. C., Lemon, K. N., Parasuraman, A., Roggeveen, A., Tsiros, M., & Schlesinger, L. A. (2009). Customer experience creation: Determinants, dynamics and management strategies. Journal of Retailing, 85(1), 31-41.

Pappas, A., Fumagalli, E., Rouziou, M., & Bolander, W. (2023). More than Machines: The Role of the Future Retail Salesperson in Enhancing the Customer Experience. Journal of Retailing, 99(4), 518-531.

Eggers, W. D., & Macmillan, P. (2013). The solution revolution: How business, government, and social enterprises are teaming up to solve society's toughest problems. Harvard Business Press.

Inman, J. J., & Nikolova, H. (2017). Shopper-facing retail technology: A retailer adoption decision framework incorporating shopper attitudes and privacy concerns. Journal of Retailing, 93(1), 7-28.

Beverungen, D., et al. (2019). Conceptualizing smart service systems. Electronic Markets, 29, 7-18.

Zimmermann, R., et al. (2023). Enhancing brick-and-mortar store shopping experience with an augmented reality shopping assistant application using personalized recommendations and explainable artificial intelligence. Journal of Research in Interactive Marketing, 17(2), 273-298.

Das, T. K., Tripathy, A. K., & Srinivasan, K. (2020). A Smart Trolley for Smart Shopping. In the 2020 International Conference on System Computation Automation and Networking (ICSCAN), Pondicherry, India (pp. 1-5).

Rahul, R., Krishnamoorthy, R., & Murugesan, A. (2023). Automated Smart Trolley System using RFID Technology. In 2023 2nd International Conference on Advancements in Electrical, Electronics, Communication, Computing, and Automation (ICAECA), Coimbatore, India 1-4

Patil, S. R., Mathad, S. N., Gandhad, S. S., & Ellemmi, M. C. (2022). Smart Trolley with Automatic Billing System using Arduino. IAES International Journal of Artificial Intelligence (IJ-AI), 2(2), 2268-2273.

Datta, A., Riya, N. H., Bhowmik, J., Anik, M. S., & Alam, M. T. (2023). Design and Implementation of an IoT-Based Smart Trolley and Billing System for Super Shop (Doctoral dissertation, Faculty of Engineering, American International University–Bangladesh).

Faisal, T., et al. (2021). Smart Cart with Multi-shopping Solutions. Int. J. Interact. Mob. Technol., 15(24), 77-93.

Al-Ammal, H. M., et al. (2020). A novel design of a fully seamless e-payment experience. In 2020 International Conference on Innovation and Intelligence for Informatics, Computing and Technologies (3ICT), 1-6.

Moon, I. T., Shamsuzzaman, M., Mridha, M. M. R., & Rahaman, A. S. M. M. (2022). Towards the advancement of cashless transactions: A security analysis of electronic payment systems. Journal of Computer and Communications, 10(7), 103-129.

Bose, R., Mondal, H., Sarkar, I., & Roy, S. (2022). Design of a smart inventory management system for the construction sector based on IoT and cloud computing. e-Prime-Advances in Electrical Engineering, Electronics and Energy, 2, 100051.