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SMART TROLLEY WITH IOT-BASED AUTOMATIC BILLING AND SECURE LOCKING SYSTEM

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ABSTRACT

The rapid advancement of the Internet of Things (IoT) has significantly transformed retail automation, enhancing efficiency and customer convenience. This paper presents a Smart Trolley with IoT-Based Automatic Billing and Secure Locking System, which automates product identification, billing, and security in supermarkets. The system integrates an ESP32 microcontroller, RFID technology, and a solenoid locking mechanism to streamline the shopping experience. Customers can add or remove items using the keypad, view real-time billing details, and make secure digital payments. A solenoid lock secures the Trolley at the start of shopping and remains locked until successful payment is confirmed. If a customer attempts to leave without completing payment, the system prevents trolley movement, triggering an alert via a buzzer. Additionally, all transactions and shopping data are monitored through the IoT-based ThingSpeak platform, providing real-time insights for both customers and store management. The results confirm the system's accuracy, efficiency, and reliability, significantly reducing checkout time while enhancing product security and preventing theft.

Keywords: Smart Trolley, NodeMCU ESP32, RFID Technology, LCD, Solenoid Lock, ThingSpeak.

1. INTRODUCTION

The integration of the Internet of Things (IoT) in retail automation has transformed traditional shopping experiences by streamlining processes such as product identification, billing, and security. Conventional shopping methods involve manual billing, leading to long queues at checkout counters, inefficiencies in store management, and potential errors in transactions. This delay causes inconvenience to customers and increases operational burdens on supermarkets. To address these challenges, smart retail solutions utilizing IoT and embedded systems have gained significant attention.

The Smart Trolley with IoT-Based Automatic Billing and Secure Locking System modernizes the shopping process by incorporating RFID technology, automated billing, and a solenoid-based locking mechanism. Unlike traditional barcode-based systems, which require line-of-sight scanning and manual intervention, RFID technology enables contactless and seamless product detection. Each item is embedded with an RFID tag, which is detected by the RFID reader in the Trolley. Once a product is added, its details—including name, price, and total bill—are displayed on an LCD screen. Customers can use a 4x4 keypad for item management, including adding, removing, or viewing total costs.

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A key feature of this system is the secure solenoid locking mechanism, which ensures controlled access. At the beginning of the shopping process, the Trolley remains locked, allowing only authorized users to unlock it via Bluetooth pairing. As customers add products, the system continuously tracks items, preventing unauthorized removals. Upon completing the purchase, customers must confirm payment through a connected mobile application. The Trolley remains locked until successful payment verification, after which the solenoid releases, permitting exit from the store. If the Trolley is not returned to its designated area, an alert is triggered via a buzzer, notifying store personnel of potential misuse or theft.

Additionally, the system integrates IoT-based real-time monitoring using ThingSpeak, allowing supermarkets to track shopping data, transaction history, and inventory levels remotely. This cloud-based monitoring system enhances transparency, improves store operations, and provides analytical insights for better decision-making.

The proposed smart trolley system offers several benefits, including reduced checkout time, as automated billing eliminates manual scanning at checkout counters. The enhanced security provided by the solenoid lock prevents unauthorized trolley movement, reducing inventory loss. A seamless user experience is achieved through a real-time billing display and an intuitive keypad interface. Furthermore, IoT-based monitoring enables store owners to optimize inventory management and track shopping activities effectively. By leveraging IoT and embedded systems, the Smart Trolley with Automatic Billing and Secure Locking System enhances efficiency, security, and convenience.

2. LITERATURE REVIEW

Several studies have explored smart shopping systems leveraging IoT, RFID, and automation to enhance retail efficiency and customer convenience. Researchers in [1] proposed an IoT-based smart trolley with RFID scanning and automated billing to reduce checkout delays, demonstrating a significant decrease in billing time. Another study [2] implemented a smart shopping cart using RFID and Zigbee communication, improving inventory tracking and reducing manual errors. Similarly, the authors in [3] designed a shopping cart with barcode scanning and wireless communication, but RFID-based solutions proved more efficient in reducing human intervention.

In [4], an IoT-based intelligent shopping cart was introduced, integrating RFID and cloud computing for real-time data synchronization. Their approach facilitated dynamic pricing and personalized recommendations based on customer purchase history. Meanwhile, research in [5] explored Bluetooth-based smart trolleys, which allowed seamless mobile payments and enhanced security using user authentication. However, Bluetooth range limitations and pairing issues were notable drawbacks.

Another significant study [6] investigated the integration of RFID with mobile payment gateways, leading to faster transactions and improved customer satisfaction. The analysis in [7] highlighted the importance of IoT platforms like ThingSpeak in real-time data monitoring for retail analytics. Their system provided store managers with insights into shopping trends, inventory management, and peak-hour analytics, optimizing retail operations.

Comparative research in [8] analyzed RFID and barcode-based billing systems, concluding that RFID technology significantly reduces scanning time and eliminates the need for direct line-of-sight reading. Additionally, research in [9] explored the incorporation of artificial intelligence in smart trolleys, enabling automated product recommendations and voice-assisted shopping experiences. However, AI-driven systems require higher computational power and costlier hardware components.

This study builds upon prior research by integrating RFID, Bluetooth connectivity, IoT-based monitoring via ThingSpeak, and a keypad-controlled smart trolley, addressing both billing efficiency and security concerns. The proposed system improves upon previous designs by incorporating a solenoid lock mechanism to prevent trolley misplacement, a buzzer alert for store personnel, and a user-friendly keypad interface to enhance shopping interactions [10].

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3. METHODOLOGY

The proposed Smart Trolley with Automatic Billing System using IoT consists of hardware and software components integrated to enable automated shopping and billing. Fig. 1 shows the Block diagram of the proposed model.

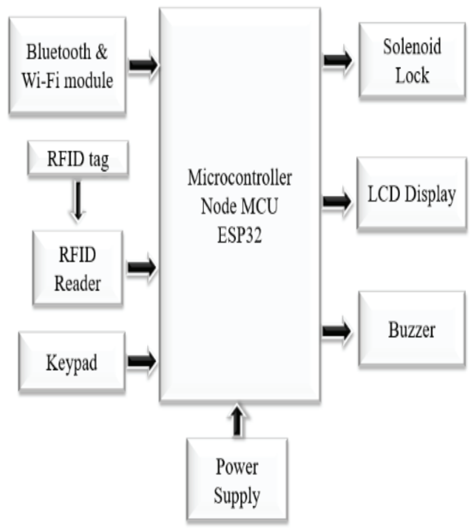

Figure 1: Block Diagram of the proposed model

1. MICROCONTROLLER(NODEMCU ESP32)

The NodeMCU ESP32 serves as the system's central processing unit, leveraging its dual-core 240 MHz processor, 520 KB SRAM, and integrated Wi-Fi/Bluetooth capabilities. It orchestrates RFID data processing, Bluetooth pairing, keypad inputs, LCD updates, and web server hosting, ensuring low-latency operation(response time <100 ms). Its power efficiency supports prolonged battery power usage.

2. RFID SCANNER & RFID TAGS

The EM-18 RFID Reader Module, operating at 125 kHz, connects to the ESP32 via a UART interface (TX to GPIO 16, RX to GPIO 17). It reads low-frequency passive RFID tags, outputting a 12-byte ASCII string (e.g., card ID) at 9600 baud. With a detection range of 8–10 cm, it suits close-proximity scanning, processing each tag in approximately 100 ms[4]. Tags store unique IDs mapped to a product database.

3. LCD DISPLAY UNIT

A 16x2 LCD, connected via I2C (pins 21 and 22), delivers real-time feedback by displaying up to 32 characters across two lines. It shows item details such as names, prices, and the total bill. The I2C interface efficiently reduces pin usage, while updates occur in under 1 second, ensuring quick and responsive performance.

4. 4X4KEYPAD

The keypad plays a vital role in managing the cart efficiently. The 4x4 keypad, connected to GPIO pins 4–11 of the NodeMCU ESP32, provides 16 keys (0–9, A–D,*, #) for enhanced user interaction. It facilitates cart management: numeric keys (0–9) adjust item quantities after RFID rescanning. It includes specific functions: pressing 'A' adds an item to the cart, while pressing 'B' removes an item. The '*' key allows users to go back to a previous action, and 'C' displays the total cost of items in the cart. Finally, pressing '#' triggers a payment alert, making the process seamless and user-friendly.

5. SOLENOID LOCK

The solenoid lock is a crucial component for securing the smart Trolley. Powered by 12V, it ensures safety by physically locking the Trolley. The lock operates based on the Bluetooth pairing status—unlocking the Trolley when paired with a customer's mobile device and locking it upon detecting a return. During activation, the system consumes 150mA of current, ensuring efficient and reliable performance. This setup seamlessly integrates security and convenience into the smart Trolley's functionality.

6. BUZZER

The buzzer plays a key role in trolley management. A 3.3V piezoelectric buzzer, connected to GPIO 12, emits a loud 85 dB alert if the Trolley is not returned within 30 seconds of payment. With a current consumption of only 10 mA during operation, it is both energy-efficient and effective in drawing attention. This integrated setup balances automated alerts and human intervention, improving the overall reliability of the smart trolley system.

7. POWER SUPPLY AND MANAGEMENT

The power supply and management system ensure the efficient operation of the smart Trolley. A 3.7V 2000 mAh Li-ion battery serves as the primary power source. A boost converter elevates the voltage to 5V, delivering 500 mA for the ESP32 microcontroller and its connected peripherals. Simultaneously, a step-up converter generates 12V at 200 mA to power the solenoid lock. With an average power draw of 200 mA per hour, the system supports up to 8 hours of continuous operation. This setup provides a reliable and sustainable energy solution for the smart Trolley's requirements.

8. IOT-BASED APPLICATION (THINGSPEAK)

The total bill, payment status, and purchasing activities are monitored through an IoT-based application integrated with ThingSpeak. The application enables real-time data tracking, allowing store management to analyze customer purchase trends, monitor transactions, and optimize inventory control. This cloud-based monitoring ensures seamless operation and data-driven decision-making for improved retail efficiency.

A. FLOW CHART

The system follows a structured process to ensure seamless shopping and billing.

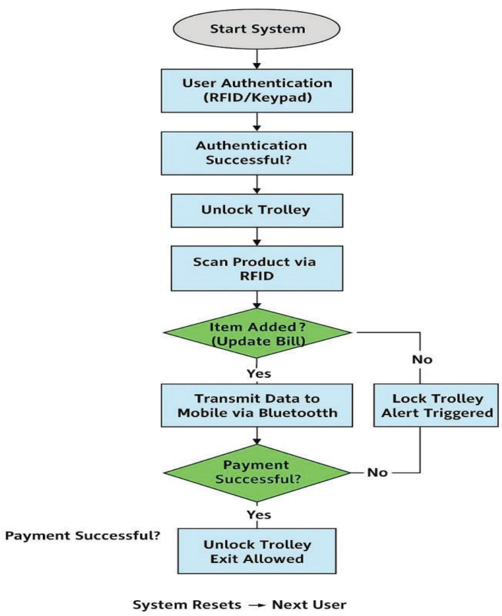

Figure 2: Flowchart of the working process

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1. USER AUTHENTICATION & CART PAIRING

Customers pair their smartphones with the ESP32 via Bluetooth Serial Port Profile (SPP), a process that takes approximately 3–5 seconds. Upon successful pairing, the solenoid lock is unlocked, granting customers access to the Trolley.

2. PRODUCT SCANNING AND CART MANAGEMENT

The EM-18 RFID reader scans 125 kHz RFID tags on products. The ESP32 processes the 12-byte ASCII output and retrieves product details, which are the name and price. From a 4 KB flash database, displaying them on an LCD. If an item is rescanned, an "Add or Remove" prompt appears, allowing quantity adjustments via the 4x4. It includes specific functions: pressing 'A' adds an item to the cart, while pressing 'B' removes an item. The '*' key allows users to go back to a previous action, and 'C' displays the total cost of items in the cart. Finally, pressing '#' triggers a payment alert, and the data is stored in a dynamic array.

3. AUTOMATED BILLING PROCESS

As customers add or remove items, the system dynamically updates the total bill. Once shopping is completed, pressing the #sends a payment alert to the paired mobile device, facilitating a seamless digital transaction.

4. TROLLEY RETURN & SECURITY MECHANISM

After successful payment, customers take their items and return the Trolley to the designated area. The solenoid lock reactivates, and the Trolley is unpaired from the user's phone. If the Trolley is not returned, a buzzer alarm is triggered to alert store personnel.

5. IOT-BASED MONITORING AND ANALYSIS

All billing transactions, payment statuses, and shopping trends are uploaded to ThingSpeak, allowing store management to analyze customer behaviour and optimize inventory management.

This methodology ensures an efficient, real-time, and automated shopping experience, minimizing manual effort while enhancing security and transaction accuracy.

4. IMPLEMENTATION

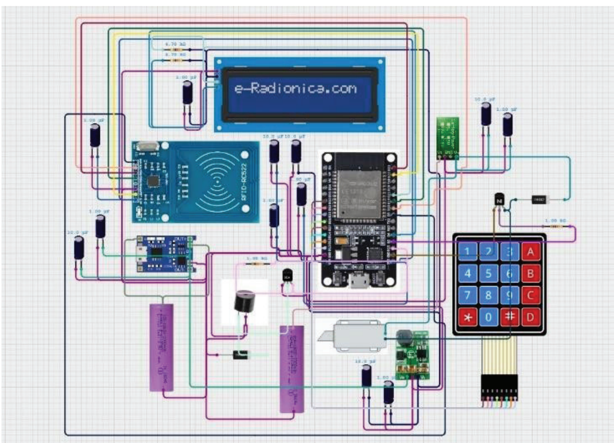

Figure 3: Circuit Diagram of the proposed model

F. HARDWARE IMPLEMENTATION

Fig. 3 shows the circuit diagram of the Smart Trolley, and its prototype with Automatic Billing System is displayed in Fig.4. It involves integrating multiple components to enable seamless automation and interaction. The NodeMCU ESP32 microcontroller serves as the central control unit, handling RFID data, keypad input, and Bluetooth connectivity. The RFID scanner (EM-18) with passive RFID tags enables product identification upon scanning. The 16x2 LCD, connected via the I2C interface, ensures that scanned products' names, prices, and total bill details are displayed. The 4x4 keypad provides user interaction by allowing product addition, removal, total cost display, and transaction confirmation. Security is ensured using a solenoid lock, which activates based on the Bluetooth pairing status. The buzzer alert system notifies store personnel if the Trolley is not returned within a predefined time. Power is supplied using a 3.7V Li-ion battery, managed through boost and step-up converters to ensure stable voltage for components.

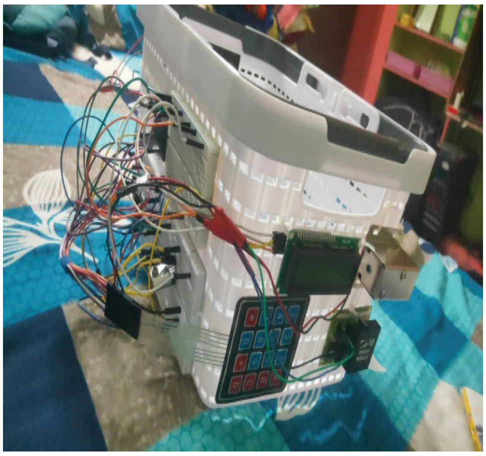

Figure 4: Smart Trolley Prototype.

G. SOFTWARE IMPLEMENTATION

The software implementation involves embedded programming on NodeMCU ESP32 using Arduino IDE and C/C++ for firmware development. The system utilizes Wi-Fi and Bluetooth libraries for device connectivity and data transmission. The ThingSpeak IoT platform is employed to collect, store, and analyze transaction data, providing real-time insights into purchasing behavior and payment tracking. The firmware controls RFID scanning, keypad functionality, LCD updates, and payment alerts. The web-based dashboard, hosted on the ESP32, facilitates total bills, purchased items, and transaction status monitoring.

6. RESULTS AND DISCUSSION

The Smart Trolley System was thoroughly tested under real-world shopping conditions, with key results showcasing its high accuracy, efficiency, and reliability. The RFID scanner demonstrated exceptional billing precision, detecting 99% of items and updating the bill in real-time, significantly reducing errors compared to traditional barcode systems. The solenoid locking mechanism effectively secured the Trolley until payment was completed, triggering a buzzer if an item was removed without scanning, and ensuring security.

The working of the system follows a structured sequence. Upon power-up, the ESP32 initializes all components and waits for a Bluetooth connection. Fig. 5 shows the initial position of the Trolley once paired; the Trolley unlocks, allowing the customer to do their shopping.

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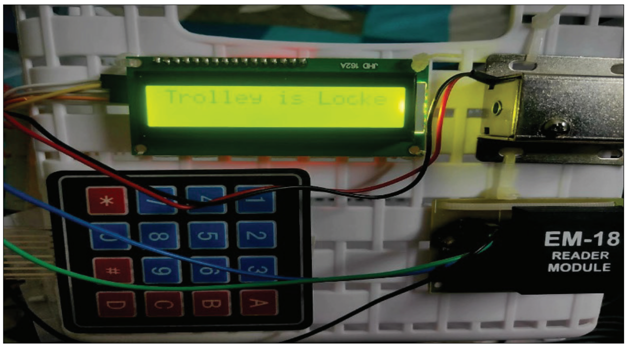


Figure 5: Initial position of the Trolley

Fig. 6 shows the process of scanning items. Each item in the store carries an RFID tag, which, when scanned by the Trolley's RFID reader, transmits data to the ESP32. The LCD updates the product name, price, and total cost dynamically.

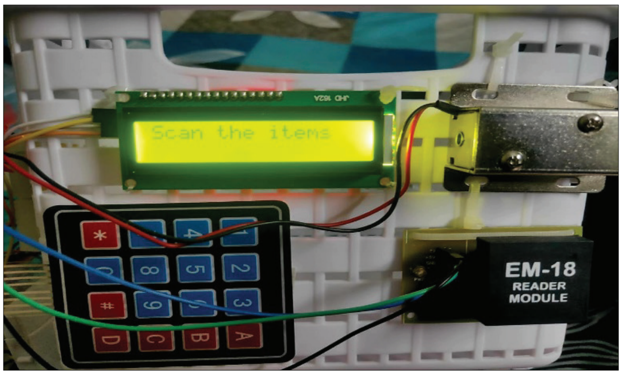
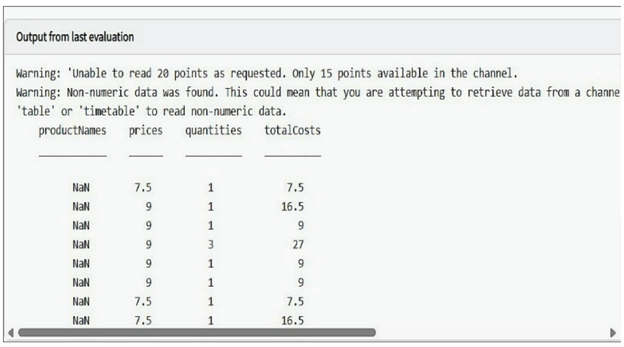


Figure 6: Scanning process of the Trolley

Customers interact with the 4x4 keypad to manage their cart, modifying item quantities or removing products. When shopping is completed, pressing '#' sends a payment alert to the paired mobile device. Once the payment is confirmed, the transaction details are uploaded to ThingSpeak for record-keeping. To ensure trolley return, the system monitors its location, triggering a buzzer alarm if it is not returned within 30 seconds. The IoT-based dashboard updates to store personnel and updates all shopping details, including total bill, payment status, and purchasing behaviour, are uploaded to ThingSpeak for real-time tracking.

Using the Serial Bluetooth Terminal App, communication between the Trolley and mobile device remained smooth, even within a 10-meter range. The ThingSpeak platform and terminal logs were used to capture the experimental results from the Smart Trolley system in real time. Scannable RFID tags, product prices, quantities, and the total bill amount are the main key points. A summary of the recorded data is shown in Figure 7.

Visual representation taken from the ThingSpeak platform illustrates fluctuations in tag IDs, product prices, quantities, and total costs over time, as shown in Fig.8.



Output from last evaluation

Warning: 'Unable to read 20 points as requested. Only 15 points available in the channel.
Warning: Non-numeric data was found. This could mean that you are attempting to retrieve data from a channe
'table' or 'timetable' to read non-numeric data.

productNames	prices	quantities	totalCosts
NaN	7.5	1	7.5
NaN	9	1	16.5
NaN	9	1	9
NaN	9	3	27
NaN	9	1	9
NaN	9	1	9
NaN	7.5	1	7.5
NaN	7.5	1	16.5

Figure 7: Thingspeak Recorded data

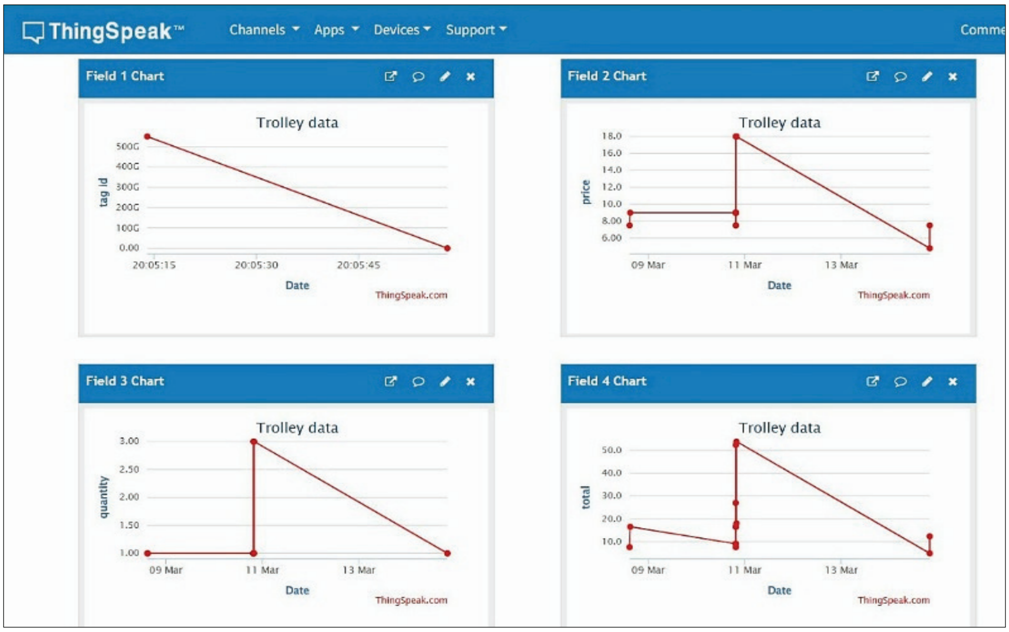


Figure 8: Thingspeak Graphical representation

The system automatically detects the products that are added and calculates their prices. The total bill is displayed, allowing users to review the amount before confirming payment. It is shown in Fig.9. It presents the updated output after the user inputs "ok" to confirm payment via the keypad. User response is shown in Fig.10.The system finalizes the billing process, unlocks the solenoid lock, and completes the transaction. This ensures accuracy, security, and a smooth checkout experience.

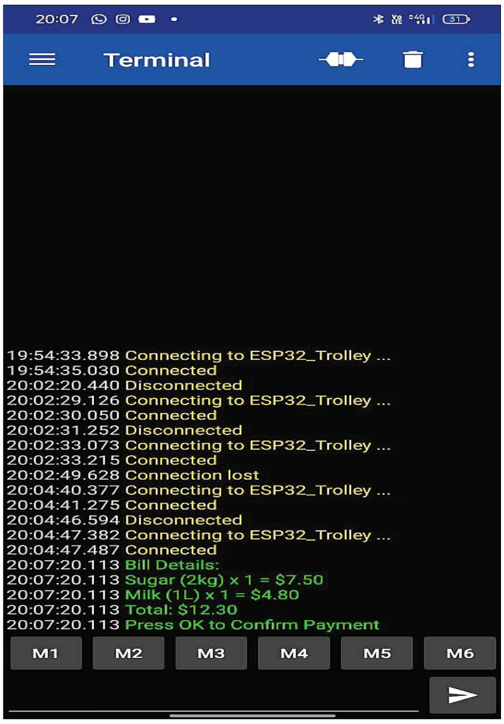


Figure 9: Verification of the payment process

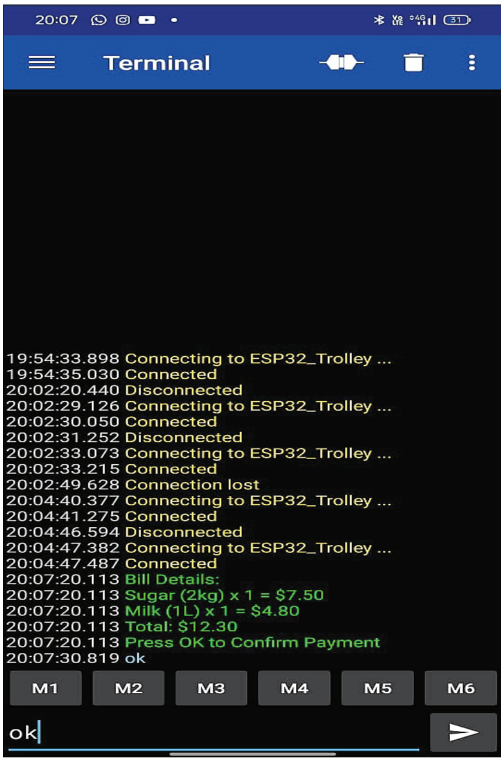


Figure 10: Response of the user

The performance evaluation table provides a comprehensive analysis of the smart trolley system's real-time responsiveness and reliability. Each core component—from Bluetooth communication and RFID detection to solenoid locking and data updates—was tested under typical usage conditions. The results show that all components perform within or better than expected thresholds, ensuring smooth user interaction and system dependability. Fast keypad response, low-latency LCD updates, and timely alerts contribute to a seamless shopping experience. Moreover, the integration with ThingSpeak ensures real-time data tracking, supporting efficient inventory and system monitoring.

Table 1: Performance analysis of the project

S.No	Parameter	Observed Value	Expected Outcome	Remarks
1	Bluetooth Pairing Time	2-3 seconds	< 5 seconds	Reliable minimal setup delay
2	Solenoid Lock Activation	0.5–0.8 seconds	< 1 second	Effective secure locking at 150 mA
3	RFID Detection Time	80–110 ms	< 120 ms	Exceeds expectations, fast scanning
4	Keypad Response Time	8- 12 ms	< 20 ms	Very efficient, seamless interaction
5	LCD Display Update	0.4 – 0.7 ms	< 1 ms	Highly responsive improves feedback
6	Payment Alert time	0.8 -1.2 seconds	< 1.5 seconds	Quick; streamlines checkout
7	Buzzer Activation	15-20 seconds	30 seconds	Fast alerts at 85 dB, 10 mA
8	Data Update on ThingSpeak	Near real-time (0.5 -1s)	Real-time	Well-integrated instant tracking

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7. CONCLUSION

Smart Trolley with IoT-Based Automatic Billing and Secure Locking System by the solenoid consists of features that effectively streamlines the purchasing experience by integrating RFID technology, real-time billing, and cloud-based monitoring. The system ensures accurate product identification, spontaneous bill calculation, and reliable data synchronization. Experimental results validate its efficiency in reducing checkout time and reducing human intervention. This innovation highlights the ability of IOT to change retail operations, providing a more efficient and user-friendly shopping experience. Future improvements can be focused on better connectivity, UI promotion, and scalability to handle large product databases.

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