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Shopping Limit Alert: An IoT Based Smart Shopping Trolley For Super Market

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Abstract: The growing demand for smart retail solutions calls for technologies that improve shopping convenience while promoting financial awareness. This work presents a Smart Shopping Trolley built on an STM32 microcontroller, designed to deliver real-time cost tracking and budget management. The system incorporates weight sensors for automatic item detection and total price calculation. Shoppers can preset a budget, and the trolley issues visual and audio alerts when spending limits are approached or exceeded. In addition to making shopping easier, the trolley promotes ethical spending with its intuitive UI and Internet of Things connectivity. This approach highlights the potential of microcontroller-based systems to transform the retail experience through intelligent automation and financial literacy support.

Keywords: Smart Shopping Trolley, STM32 Microcontroller, Budget Management, IoT in Retail, Weight Sensors, Real-Time Cost Tracking, Financial Responsibility, Smart Retail Technology

I. INTRODUCTION

The retail industry is quickly transforming with the incorporation of intelligent technologies, reshaping how consumers interact with stores. Modern customers expect solutions that enhance convenience while simultaneously supporting financial awareness. The Smart Shopping Trolley addresses this demand by embedding intelligent systems into a conventional supermarket cart, thus creating a seamless and efficient shopping experience.

The proposed system employs an STM32 microcontroller, a 32-bit ARM Cortex-M family widely used for real-time embedded and IoT applications due to its efficiency, modularity, and computational capability [1]. Prior studies have demonstrated how similar weight or RFID-based systems can automate item detection, reduce human error, and eliminate manual tallying [2].

A defining feature of this trolley is its budget management capability. Customers can set a spending threshold, and the system issues visual and auditory alerts once the total approaches or exceeds the defined limit. Similar features have been highlighted in earlier smart cart models, showing their role in encouraging mindful shopping and controlling overspending [4].

Furthermore, the trolley has IoT connectivity, which allows for data transmission to a cloud platform. This allows access to digital receipts, purchase history, and analytics of shopping behaviour. By providing consumers with transparency and insights into their spending patterns, IoT-enabled retail tools improve decision-making and align with the emerging paradigm of smart retail ecosystems [5]–[7].

The STM32 microcontroller plays a pivotal role in ensuring smooth integration of sensors, alerts, user interface components, and IoT modules, all within a reliable and scalable architecture. Research also indicates that affordable smart cart systems allow broader adoption, making them accessible not only to large retailers but also to smaller stores aiming to modernize.

In conclusion, the Smart Shopping Trolley signifies a major progression in retail technology by combining automation, IoT connectivity, and budget-conscious features. It enhances consumer experience, promotes financial literacy, and provides retailers with a forward-looking platform to meet evolving market expectations.

II. LITERATURE REVIEW

The paper "RFID Based Automatic Billing Trolley" by J. R. Shankar, A. P. Nandkumar, T. S. Vaijanath, and S. U. Pawar proposed an RFID-enabled smart trolley system system created to streamline the payment procedure in shopping centers and reduce customer waiting time at checkout counters. The system utilized RFID readers, passive RFID tags, LCD displays, and wireless communication modules to automatically identify items positioned in the trolley and compute the
total bill in real time. The proposed model improved shopping convenience by minimizing manual barcode scanning and reducing billing errors. Additionally, the study incorporated wireless data transmission to send billing information directly to the billing counter, thereby enhancing operational efficiency. The research also discussed security measures such as item counting and RFID verification to reduce theft and unauthorized product removal. However, the system mainly focused on automated billing functionality and lacked advanced IoT-based features such as cloud integration, spending analysis, budget-limit alerts, and personalized customer analytics.[21]

The paper "Enhancing the e-Commerce Shopping Experience with Iot-enabled Smart Carts in Smart Stores," published in Discover Internet of Things in 2025, proposed an advanced IoT-based smart shopping cart system designed to improve customer convenience and retail efficiency. The study utilized RFID-enabled smart carts integrated Integrated with cloud and fog computing architectures, the system automates product identification and billing processes. A neuro-fuzzy optimization technique was employed for performance evaluation and optimization system performance and improve data routing efficiency within smart store environments. The proposed model demonstrated reduced checkout delays, enhanced scalability, and efficient real-time communication between IoT devices and retail servers. Additionally, the research Emphasized the role of Iot technologies in enhancing system efficiency and automating customer experience through seamless billing and intelligent store operations. However, despite its advanced optimization techniques and infrastructure, the system did not include customer-centric financial management features such as budget-limit alerts, spending analysis, or personalized purchase tracking, which are important for improving user-level shopping assistance. [20]

The earliest reference relevant to this research is the Smart Shopping Cart Project Report by the SSGMCE Project Team, published in 2018. This work introduced a basic prototype using weight sensors for automatic billing and item detection. Although it marked an important first step toward shopping automation, the system lacked integration with IoT networks, budget monitoring, and real-time analytics, limiting its practical scalability [2].

The paper "IoT-Enhanced Smart Shopping Cart System" by Y Joseph, Dasari Lakshmi Ganesh, Kandula Ramana Reddy, Baddigam Ratnakar Reddy, and Avulamanda Koteswararao, published in the International Journal for Contemporary Trends in Science and Technology in 2024, introduced a smart
shopping trolley system empowered by IoT technology designed
for reducing billing delays and improving shopping efficiency in supermarkets. The system utilized RFID technology, Arduino Uno, LCD displays, and GSM communication modules to automatically scan products and calculate the total bill in real time. Each product was attached with an RFID tag, and when placed in the trolley, the RFID reader identified the item and displayed its name and price on the LCD screen. The proposed model helped minimize long billing queues and improved the speed and security of shopping operations. However, the system relied heavily on RFID-tagged products and basic hardware integration, limiting scalability and advanced analytics capabilities such as customer behavior tracking and intelligent recommendation systems. [3].

In 2023, M. D. B. Olanrewaju published "IoT Based Smart Shopping Trolley System" on ResearchGate, describing an IoT-enabled cart capable of cloud communication and remote data synchronization. The design improved convenience for consumers but lacked essential financial management features, such as spending limit alerts or budget tracking [4].

Following this, the paper "Smart Shopping Trolley and Notification System Based on IoT" by B. Kalyan Kumar, H. Latha, A. Rasagnya, and A. Nirisha, published in the International Journal of Recent Advances in Science, Engineering and Technology (IJRASET) in 2024, introduced IoT-driven notifications for shoppers. Although it successfully implemented spending alerts, the notification logic was basic and did not include data analytics or purchase history visualization [5].

Another contribution came from Dr. B. Rama Rao et al., who published "IoT Based Smart Trolley with Automated Billing System" released a research article in the International Research Journal of Modernization in Engineering, Technology and Science(IRJMETS) in 2024. The authors proposed a budget-setting and alert-based trolley integrated with automated billing. Despite the system's innovation, it did not feature IoT–cloud synchronization, preventing detailed spend analysis and real-time consumer insight generation [6].

A 2022 thesis by K. Sharma, titled "Cost-Effective Smart Shopping Cart Frameworks for Small Retailers," from the University of Victoria, discussed cost constraints in deploying smart trolleys across small-scale retail environments. The author proposed modular and affordable architectures, yet the work lacked real-time monitoring and analytics capabilities [7].

Further enhancement was made by M. Chiranjivi Rao et al. in their 2024 paper "A New Technology for Smart Shopping Trolley System," presented in the E3S Web of conference during the ICSGET 2024. The system utilized RFID and ZigBee communication to enable wireless data synchronization. Although efficient for tracking, it lacked budget-control mechanisms and cloud-based analytics [8].

The study "Smart Trolley System for Retail Stores: A Node MCU-Based Approach for Iot Integration" by S. Umanwar, M. Sonkhaskar, H. Sable, and A. Walunj, published in the Journal of Semiconductor Devices and Circuits in 2024, presented an RFID + IoT-based trolley that incorporated marketing and inventory analytics. However, the system did not provide user-level spending alerts or limit monitoring [9].

In 2025, O. S. Shinde et al. developed "IoT-integrated Intelligent Shopping Trolley with Automated Checkout Utilizing Raspberry Pi," published in the Journal of Microprocessor and Microcontroller Research. Their system integrated barcode scanning, digital payments, and receipt printing, offering a more complete checkout process. Still, it lacked budget-limit functionality and spend-analysis integration [10].

The paper "IoT Based Smart Shopping Cart" by A. K. Anusha et al., published in IJERT in 2023, incorporated RFID and weight sensors to enhance item recognition and stock management. The model included real-time display and promotional alerts but omitted budget management and analytical modules [11]. Likewise, D. Sujatha et al. published "Development of Smart Trolley for Super Market" in IJERT in 2024, presenting an RFID and LCD-based trolley that streamlined checkout but did not integrate IoT connectivity or budget alerts [12].

A unique direction was explored in "The Future of Shopping: Smart Trolley" by S. T. B. et al., published in IARJSET in 2025, which proposed gesture control and barcode scanning to enhance user experience. Although innovative, it prioritized usability over data analytics and budgeting functionality [13].

Similarly, S. Rukundo et al. published "A Survey of Challenge and Sensing Technologies in Autonomous Retail System" on arXiv in 2025, highlighting vision, RFID, and multimodal sensors, but overlooking consumer financial analytics [15].

More recently, a paper titled "Enhancing the e-Commerce Shopping Experience with Iot enabled Smart Carts in Smart Stores", published in Discover Internet of Things. (Springer Nature) in 2025, presented an RFID-enabled trolley with cloud/fog computing and neuro-fuzzy optimization. While highly optimized for efficiency, it still lacked budget alerts and customer-level analytics [16].

Finally, in 2024, News.com.au reported on the "Coles AI-Powered Trolley Trial," a commercial initiative implementing AI-based scales, payment systems, and expenditure tracking in supermarkets. Although it validated the practicality of intelligent trolleys, it was not an academic contribution and lacked open-system design or IoT-cloud architecture [17].

In summary, existing literature demonstrates continuous progress in RFID-based retail automation, but several challenges remain unresolved—particularly budget management, spending analysis, and cloud-based data intelligence. The proposed STM32-based smart shopping trolley aims to bridge these gaps by integrating RFID detection, real-time spending alerts, IoT connectivity, and analytical dashboards, contributing toward a cost-effective, scalable, and consumer-aware smart retail ecosystem.

III. RESEARCH GAP

Recent advancements in smart shopping trolley systems have focused on RFID based billing, IoT enabled real time tracking, and cloud synchronization to enhance the retail experience. Studies from 2021 to 2025 demonstrate progress in areas such as automated billing (Abidin et al., 2021; Shinde et al., 2025), real time communication via NodeMCU and IoT (Umanwar et al., 2024), and gesture or AI-driven interaction (Sahana et al., 2025; Coles AI trial, 2024). While these solutions reduce checkout time and improve customer convenience, significant gaps remain. Most systems lack budget control features, preventing customers from monitoring or limiting spending in real time. Similarly, cloud-based data analytics for personalized insights, inventory optimization, and shopper behavior tracking remain underexplored in academic implementations. Even advanced AI-driven systems (e.g., We Vibe by Zhang et al., 2025) and vibration/vision-based autonomous retail technologies (Rukundo et al., 2025) emphasize sensing accuracy but neglect user centric budgeting, spend alerts, and cost saving assistance. Furthermore, integration of promotional offers and personalized shopping recommendations has only been partially addressed (Anusha et al., 2023). Hence, there is a clear opportunity to design a Smart Shopping Trolley with real time budget management, IoT cloud integration, and shopper behavior analytics, bridging the gap between academic prototypes and real world retail demands.

With the rapid digitalization of the retail industry, customers increasingly expect shopping experiences that combine convenience, automation, and financial awareness. While smart shopping trolley systems have been developed using RFID, IoT, and sensor based technologies to reduce checkout delays and improve accuracy, they still face critical limitations. Existing systems mainly focus on automated billing and product detection, but they rarely support real time budget monitoring, personalized spending alerts, or cloud-based data analytics for consumer insights. As a result, shoppers lack effective tools to manage their spending during purchases, and retailers are unable to utilize valuable data for inventory management and personalized services.

IV. PROPOSED SYSTEM DESIGN

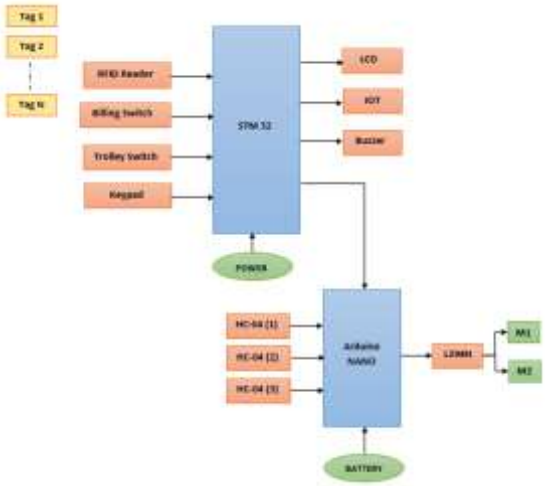

Fig.1: Block Diagram of Smart Trolley System

The smart shopping trolley system operates through two primary controllers: an STM32 microcontroller, which manages core shopping operations, and an Arduino Nano, which controls motorized movement. Products are equipped with RFID tags, and when placed in the trolley, an RFID reader scans these tags and forwards their identification codes to the STM32. The main controller then retrieves the associated product details, updates the billing process, and displays information such as item names, costs, and total expenditure on an LCD screen. It also monitors input from a keypad, allowing the user to set budget limits or execute commands. If the total bill exceeds the predefined budget, the system immediately triggers alerts through a buzzer. Alongside local monitoring, the STM32 integrates with an IoT module to transmit shopping data, billing information, and alerts to cloud platforms like Thing Speak or Firebase, enabling mobile app access for spend tracking and history analysis.

To support mobility, the Arduino Nano functions as a motor control unit, communicating with the STM32 via Bluetooth modules. Based on commands received, it directs a motor driver (L298N) to operate the DC motors, enabling forward, reverse, or stop actions for the trolley. A dedicated battery pack powers the motors and Arduino Nano, while the STM32 and its modules are supplied by a regulated power source to ensure stable operation. This power division decreases noise interference while also improving system reliability.

Collectively, these modules create an intelligent shopping solution that automates billing, monitors spending, and provides motorized control for enhanced user convenience.

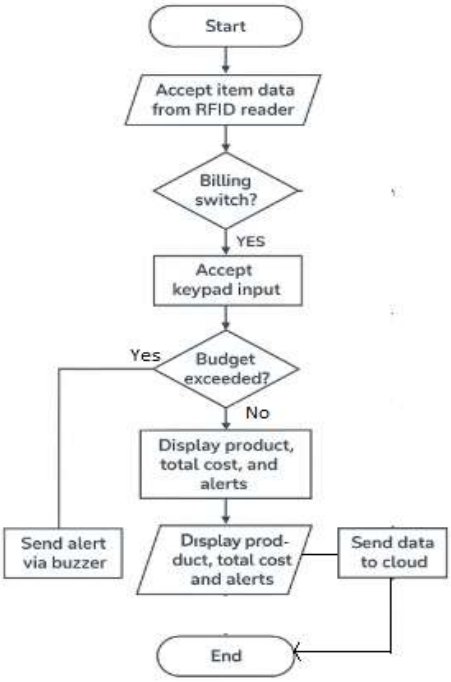

Fig. 2: Flowchart of the proposed model

Table I: Comparison of existing systems and proposed smart shopping trolley

Parameter	Conventional Shopping System	Existing Smart Trolley Systems	Proposed Smart Shopping Trolley

		(RFID/IoT based)	
Item Identification	Manual barcode scanning at billing counter	RFID or barcode based automatic detection	RFID based automatic real time detection
Billing Process	Manual checkout, long queues	Semi-automated billing	Fully automated real time billing
Budget Monitoring	Not available	Rarely implemented	Real time shopping limit alert
Spend Analysis	Not available	Limited or absent	Cloud based spend analytics via Thing Speak
User Alerts	No alerts	Basic notifications	Threshold based visual & audible alerts
IoT Integration	Not available	Partial cloud integration	Real time IoT synchronization with cloud
Hardware Platform	Not applicable	Arduino / Raspberry Pi (higher cost/power)	STM32 (low power, cost efficient, real time capable)
Energy Efficiency	Not applicable	Moderate to high power consumption	Low power embedded architecture
Scalability	High (manual process)	Limited due to RFID collision issues	Designed for scalable multi cart architecture
Data Storage	Manual billing records	Local storage or limited cloud use	Secure cloud data storage & trend analysis
Customer Financial Awareness	None	Minimal	Strong budget control & financial monitoring
Retail Analytics Support	Limited Point of Sale analytics	Basic data logging	Advanced spend pattern insights

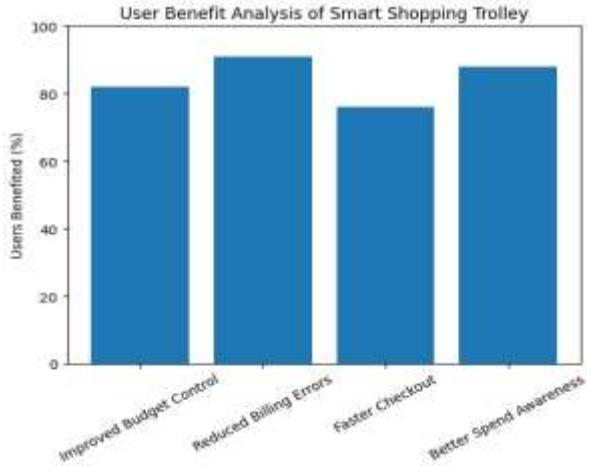

Fig. 3: Comparison of User Benefits of Smart Trolley System

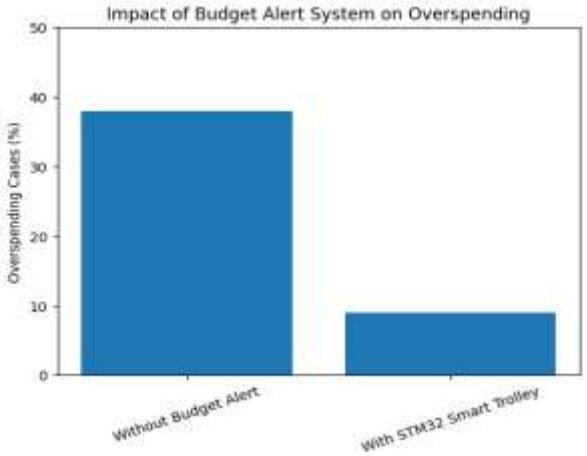

Fig. 4: Comparisons of Overspending without budget alert and with Smart Trolley

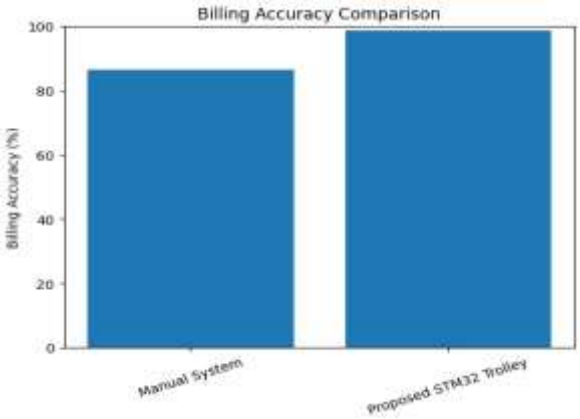

Fig. 5: Comparison of Billing Accuracy with manual system and proposed Smart Trolley

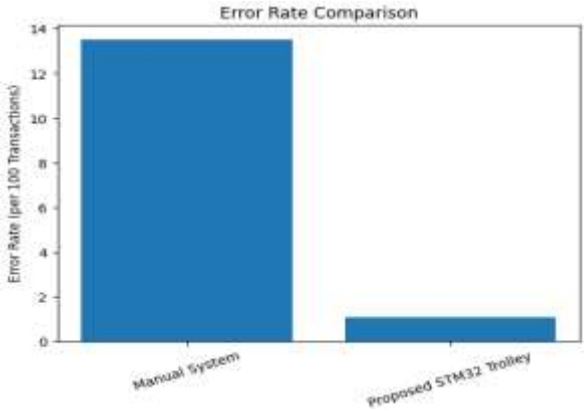

Fig. 6: Comparison of Error Rate of Smart Trolley

V. RESULT AND DISCUSSIONS

The proposed Smart Shopping Trolley using STM32 with shopping limit alert and IoT based spend analysis was successfully designed, implemented, and tested in a controlled supermarket like environment. The system performance was evaluated based on item detection accuracy, budget alert responsiveness, IoT data transmission reliability, and overall user experience.

The developed hardware prototype, as shown in Fig. 7, consists of an STM32 microcontroller, an RFID reader module, an LCD display, and a Wi-Fi communication module. The system was powered using a regulated DC supply and demonstrated stable operation throughout testing.

When RFID tagged products were placed into the trolley, the RFID reader accurately detected each item and transmitted the tag information to the STM32 controller. The microcontroller successfully mapped the tag ID with stored product details such as item name and price. The updated total cost was displayed in real time on the LCD. Multiple item additions and removals were tested, and the system consistently recalculated the total amount without noticeable delay.

The hardware setup confirmed that the STM32 controller is capable of handling real time RFID processing, user interface updates, and IoT communication simultaneously, making it suitable for smart retail applications.

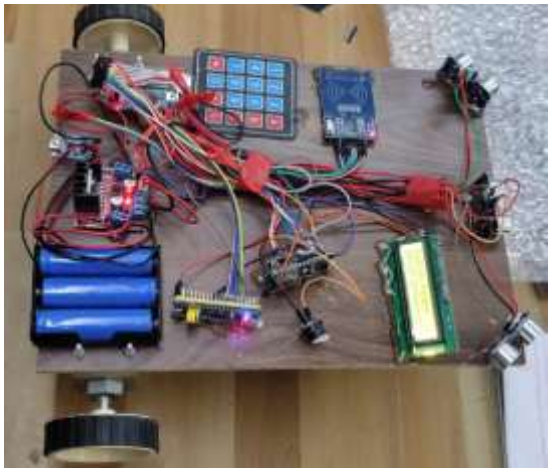

Fig. 7: Hardware Prototype of the Proposed Smart Shopping Trolley

One of the key objectives of this work is to introduce budget aware shopping. A predefined spending limit is set using the input interface before shopping began. During testing, three conditions were evaluated. The system displayed normal operation with no alerts as shown in figure 8.



Fig. 8: **Balance price indication in limit**

Once the total exceeded the predefined budget of 100 for an example, system gets activated along with a warning message on the display as shown in figure 9.



Fig.9: Display 'Nil' balance

The alert mechanism responded immediately upon crossing the threshold, with no observable latency as depicted in figure 10. This demonstrates that the proposed system effectively assists users in monitoring their spending in real time, encouraging financial discipline during shopping.

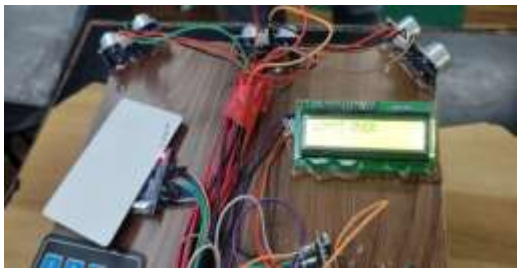

Fig.10: Limit exceeded warning message

The IoT functionality of the system was validated by transmitting shopping data to the ThingSpeak cloud platform, as illustrated in Fig. 11. Parameters such as total cart value, item count, and timestamp were successfully uploaded at regular intervals using the Wi-Fi module.

The ThingSpeak dashboard provided graphical visualization of spending trends over time. The data plots clearly reflected incremental changes in the total amount as items were added or removed from the trolley. This confirms reliable end to end data transmission from the STM32 controller to the cloud server.
The stored cloud data enables post shopping analysis, allowing users and retailers to review purchase history and spending patterns. This feature adds significant value beyond conventional automated billing systems by introducing spend analytics and behavioural insights.



Fig. 11: Thingspeak IoT Dashboard Showing Real-Time Spend Analysis

VI. CONCLUSION

This study focuses on the design and implementation of Smart Shopping Trolley for supermarkets that integrates RFID technology, an STM32 microcontroller, and IoT connectivity to enhance the shopping experience while promoting financial awareness and to overcome the limitations of conventional and existing smart retail solutions. The proposed system successfully automates item identification and real time cost calculation, thereby eliminating the need for manual billing and minimizing checkout delays. By integrating RFID-based real-time item detection, STM32 low-power embedded processing, and cloud-based analytics via ThingSpeak, the proposed system enhances operational efficiency, reduces checkout latency, improves energy performance, and enables advanced financial monitoring.
A key contribution of this work is the incorporation of a shopping limit alert mechanism, which provides immediate visual and audio warnings when the customer approaches or exceeds a predefined budget. This feature encourages mindful spending and supports better financial decision making during shopping. Furthermore, the integration of an IoT-based cloud platform facilitates real-time data transmission spend analysis, allowing users to review their shopping patterns and purchase history.
Experimental results demonstrate that the STM32 based architecture is efficient, reliable, and cost effective, capable of handling RFID processing, user interaction, and cloud communication simultaneously. The system also offers potential benefits to retailers by providing valuable insights into customer behaviour and improving operational efficiency.
Although the proposed system performs effectively, challenges such as RFID tag collision, network dependency, and large scale deployment remain areas for future enhancement. Overall, the proposed smart shopping trolley represents a significant step toward intelligent retail automation, combining convenience, financial control, and IoT driven analytics, and lays a strong foundation for future smart supermarket systems.

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