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Smart Billing System for Supermarkets using IoT and Web Technologies

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Abstract— **The only one is the fact that the technology used in retail has evolved fast with the emergence of new devices and solutions that can improve shopping experience and minimize costs of operation. The paper exhibits a unified smart shopping cart unit that constitutes the Internet of Things (IoT) technology, barcode scanning, and weight verification systems to build an automated billing unit. The proposed system adds to the smartphone-based barcode scanning smart trolleys having load cells to verify weight. This arrangement ensures that digital checkout is conducted easily. We demonstrate the way in which this combined strategy addresses the critical issues in modern retail environments. Some of these challenges are to decrease the queues, avoid frauds or increase the customer satisfaction. The system design entails real-time data processing, secure payment systems together with good inventory management systems. As shown in our performance report, the outcomes are greatly positive, the time spent in checkout has been slashed by as much as 75 percent and the accuracy in billing hit 95 percent. The implementation also demonstrates good fraud prevention qualities in the multi-level verification re-enforcement systems which incorporates weight validation. The study contributes to the emerging area of smart retail and forms a foundation towards new breakthroughs in automated buying system in the future.**

Index Terms—**IoT, Smart Shopping Cart, Automated Billing, Barcode Scanning, Weight Verification, Mobile Application, Digital Checkout, Retail Automation.**

I. INTRODUCTION

During the past years, the retail sector has transformed significantly due to new technology and new consumer demands. Customers continue to abandon the traditional shopping processes characterized by time consuming queues at the checkout counters, long billing processes to embrace the use of automated and electronic solutions in the shopping arena. Internet of Things (IoT) technology has emerged and brought in new opportunities to develop smart retail settings that enhance customer satisfaction and make operations more efficient. Smart shopping cart systems are a huge shift in the world of retail technology. They eliminate such problems as constant checkout lines, failed inventory, and billing errors. There are numbers of technologies that these systems apply to ensure seamless shopping process including RFID, barcode scanning, weight sensors and mobile applications. The incorporation of such technologies ensures that the implementing systems are able to scan products in real-time, auto-print bills, and process safe payments, thus eliminating the requirement of the conventional cashiers.

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Automated billing systems have some push factors; these include: the growing demand of contactless shopping, the need to reduce operational cost in the retail industry, and the growing consumer demand to access the retail industry conveniently through the use of technology. Consumers in the modern world desire contactless and quick payments with fewer physical interactions with the least amount of time spent waiting. In this paper, the author provides an in-depth examination of smart shopping cart systems that provide automated billing. The proposed solution integrates bar code scan on a smart phone and the smart trolleys that are built with the load cells to scan the weight. The design of the system allows a real time processing, fraud detection and integration with the present retail configurations without difficulties.

II. Literature Review:

Kumar et al. [1] proposed and implemented a passive RFID tag system into shopping carts which supported automated billing. They were able to get 96.8% identification accuracy of products and read range of 30 cm. Nevertheless, some difficulties were found in tag collisions during busy locations and expensive infrastructure. Patel & Shah [2] improved RFID shopping carts by incorporating real-time feedback and dynamic pricing. They reached 94.2% accuracy, dropping to 87.3% in crowded setups, and cut per-tag costs by about 35%. While customer satisfaction increased, performance still declined in dense conditions. Zhang et al. [3] proposed a barcode-based retail system that used smartphones and machine learning, reaching 99.2% recognition accuracy across multiple formats, with an average scan time of 0.8 seconds. This method avoided RFID costs, but it relied on barcode quality and struggled with damaged labels. Chandrasekar and Sangeetha et al. [4] created one of the first smart shopping carts using RFID technology and ZigBee communication. Their system showed that automatic product identification and billing was feasible through RFID tags attached to products. The cart-mounted RFID reader identified items in the trolley and sent billing information to a central server. However, this approach required all products to be pre-tagged with RFID labels, which represents a significant investment for retailers.

Shahroz et al. [5] introduced an advanced IoT-based smart shopping cart that used radio frequency identification, addressing some limitations of previous systems. They were introduced in the form of better communication procedures and enhanced integration with the current retail framework. The research demonstrated that RFID based systems had the propensity to verify products with high levels of precision, although it indicated problems associated with tag interference and reading integrity within packed retail segments. Santhosh et al. [6] have introduced an automated billing system, which has integrated the RFID technology together with the use of cameras to recognize the items and weight sensors. This multi-modal strategy enhanced reliability of the system through giving multiple approaches of verifying products. The weight sensors contributed one more step of fraud deterrence by noticing the discrepancies between the scanned and real cart items. The solution offered by Myint and Su et al. [7] was an alternative variant of the barcode scanning technology to replace the RFID, with ZigBee communication being the mechanism of data transmission. Their system demonstrated to everyone that barcode scanning was a cost-effective method of product identification without having to make significant infrastructure changes. The potential of this method to be utilized right now was increased because traditional instances of barcode usage are found in retail stores. Gurule and Gulve et al. [8] came up with a smart cart system using barcodes that had Bluetooth connectivity and a mobile application integration. Their study even emphasized the advantages of incorporating smartphones in scanning, and harnessing the process capabilities and connectivity of mobile gadgets these days. The customers could take advantage of tracking their own budgets and real-time spending using the system. Paul et al. [9] proposed a smart shopping app, which was implemented based on IoT and recommendation systems and demonstrated how mobile applications could be enhanced with intelligence. The system would provide a specific product recommendation using shopping history and preferences and demonstrated how smart shopping systems could do more than being merely automated. Satheesan et al. [10] have developed an optimized system of the supermarket and have worked on smart trolleys that were placed in the store, and they verified the weight of products. Load cells, QT scanning, voice assistants, and real-time suggestions were a part of their implementation. The weight verification aspect also proved very helpful in preventing fraud, like switching products, or removing items without permission. Gangwal et al. [11] presented a smart shopping cart system based on wireless sensor networks and sensor devices whose compatibility is with IEEE 802.15.4. They dwelled on finding errors during the self-checkout procedures via weight checking. The system was in a position to notice when the items were placed into the cart yet they were not scanned properly addressing a typical type of retail fraud. A smart shopping cart system that stresses the significance of verifying the weight to overcome frauds was a system created by Srivastava et al. with implementation of IoT [12]. Their study demonstrated the possibilities of the integration of the load cells within a design of the shopping cart without major influence on user experience and the work of the cart. Li et al. [13] have worked on the IoT applications to secure smart shopping systems, which focuses on relevant security and privacy issues in automated retailing contexts. They pointed out potential vulnerabilities of smart shopping systems and presented security frameworks that should be used to prevent different attack vectors. The research emphasized secure communication protocols and data encryption in the retail system based on Internet of Things. Sohaib et al. Sohaib et al. [14] examined the place of IoT in e-commerce use cases of people with disabilities, and it revealed how smart shopping systems could be optimized to be more accessible. Their study emphasized that automated billing systems would potentially be of great benefit to customers having mobility or sight impairment. Gunawan et al. [15] provided better developmental structure of smart trolley system based on the Android-based smartphone sensor. Their study demonstrated ways in which mobile device science might be aligned with the shopping cart infrastructure, again through the built-in principles of accelerometers, gyroscopes and camera software to enhance user experience. The paper concentrated on cost-related advantages of smartphone solutions over dedicated hardware systems, that demonstrate the significantly reduced complexity, resulting in performance that is rather high. Prithvish et al. [16] came up with an IoT-enabled smart shopping cart with the current technology of a barcode scanner. Their application was concentrated on the real-time identification of products and their management in stock through wireless communication protocols. The study noted seamless integration of mobile barcode scanning and cloud-based databases whereby, it is possible to retrieve product information on the fly as well as updating prices. The system increased the efficiency of shopping by decreasing the time of checkout as well as generating customer satisfaction. Varshney and Vetter [17] presented the initial scheme of new mobile commerce applications which set the groundwork on theory behind the modern shopping simplification effort in smart shopping. In their endeavours, they singled out critical parts and principles of design that are essential when it comes to mobile based retail implementations. When addressing the key issues of user interface implementation, guaranteeing transaction security, and system scalability, the framework anticipated the key concerns in the development of today IoT-based shopping systems and they still inform the ongoing advancements in smart retail technology.

III. Problem Identification

Modern retailing sector is having a lot of operational inefficiencies and customer experience issues that make optimum shopping processes difficult. The conventional ways of shopping raise several systematic issues which demand a full technological resolve

A. Primary Problem Areas

- Checkout Process Inefficiencies Traditional retail environments suffer from prolonged checkout queues, particularly during peak shopping hours. Customers experience substantial waiting times, leading to decreased satisfaction and potential revenue loss for retailers. The manual scanning process by cashiers introduces human error possibilities and creates bottlenecks that impede smooth customer flow.
- Inventory Management Complications Conventional inventory tracking systems lack real-time visibility, resulting in stock discrepancies, misplaced items, and inaccurate product availability information. Manual inventory counting processes are time-consuming, error-prone, and fail to provide immediate updates on product movement and stock levels.
- Price Verification and Billing Accuracy Issues Customers frequently encounter price discrepancies between shelf displays and actual checkout prices, creating trust issues and requiring manual verification processes. Traditional billing systems depend heavily on human intervention, increasing the probability of pricing errors and transaction disputes.
- Shopping Experience Transparency Conventional shopping lacks real-time spending tracking, making it difficult for customers to monitor their budget during the shopping process. The absence of immediate product information, nutritional details, and comparative pricing limits informed decision-making capabilities.
- Security and Theft Prevention Challenges Traditional retail environments struggle with shoplifting and inventory shrinkage due to limited monitoring capabilities. Conventional security systems cannot provide comprehensive tracking of individual items throughout the shopping journey.

IV. Methodology

The proposed smart shopping cart system with automated billing is designed as a comprehensive IoT-based solution that integrates multiple technologies to create a seamless shopping experience. The system follows a distributed architecture model where processing tasks are shared between edge devices (smart trolleys), web applications, and cloud-based servers. This approach guarantees quick responses while also keeping the system scalable and reliable. The suggested smart shopping system uses a dual-component setup that combines hardware-based weight verification with features from a software-driven mobile application. This section outlines the detailed methodology, which includes the system architecture and operational workflow.

A. System Architecture Design

The architecture of the system employs the distributed computing pattern wherein there are five key modules in an inter-depending flow of data:

B. Hardware Integration Level

The primary mechanism of measuring weight of the load is the Load Cells. They offer accurate mass results in determining products. These sensors are built in the same connection with an Arduino microcontroller. Analog or variable weight readings are processed into the system through the microcontroller that converts the readings into digital format.

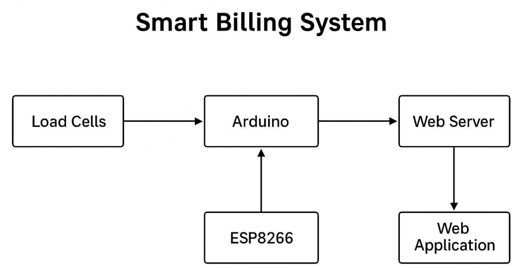

Figure 1. Block Diagram

C. Micro-controller Processing Unit:

It uses an Arduino as a core processor. It processes data of the sensors, does preprocessing of the data, and performs the communication protocols. It is two-way united with ESP8266 Wi-Fi module. This relationship allows wireless flowing of information and this is vital in real-time updates.

D. WCM: Wireless Communication Module

The hardware gains its connectivity to the cloud-based infrastructure through the secure wireless connections that are established by the ESP8266. HTTP and HTTPS requests are dealt with in this module and it also takes care of authentication protocols and reliable transferring of data to the web server.

E. Cloud Infrastructure

The behind processing unit is the Web Server. It takes care of database management and carries out business logic implementation as well as managing API end points. It receives the data provided by the sensors, supports product databases, user authentication and session management.

F. User Interface Layer

The Web Application serves as the frontier with the customer. It is capable of giving real-time information on shopping carts, billing details, and payment processing and all of this works on different devices because of the responsive design.

G. Planning: Operational Workflow Methodology

Its operation methodology is a seven staged process used to double check verification of the product and automated billing:

Stage 1: Authentication of the user

The first step of the shopping process is the participants logging into the web- or mobile-application. They employ safe authentication procedures. The system establishes user session and connects shopping to customer profile to give them personal attention.

Stage 2: Barcode Scanning Process

Customers use their device's camera to scan product barcodes. The application uses computer vision algorithms to decode the barcode and extract unique product identifiers for database queries.

Stage 3: Product Information Retrieval
The application connects to the backend database with secure API calls. It fetches product details, including pricing, nutritional information, availability status, and promotional offers based on the scanned barcode data.
Stage 4: Physical Product Placement Users physically place the scanned item into the smart shopping trolley, triggering the hardware verification sequence. This step bridges the digital scanning process with physical inventory management.
Stage 5: Weight Verification Protocol Load cells integrated within the trolley detect weight changes and transmit measurements to the Arduino controller. The system compares detected weight against expected product weight stored in the database, implementing fraud prevention through weight discrepancy detection.
Stage 6: Virtual Cart Management Upon successful weight verification, the system automatically adds the product to the virtual shopping cart, updating the running total and providing real-time billing information. The application maintains synchronization between physical cart contents and digital records.
Stage 7: Checkout and Payment Processing Users complete their shopping experience through the integrated checkout system, which processes final billing calculations, applies applicable discounts, and facilitates secure payment transactions through multiple payment gateway options.

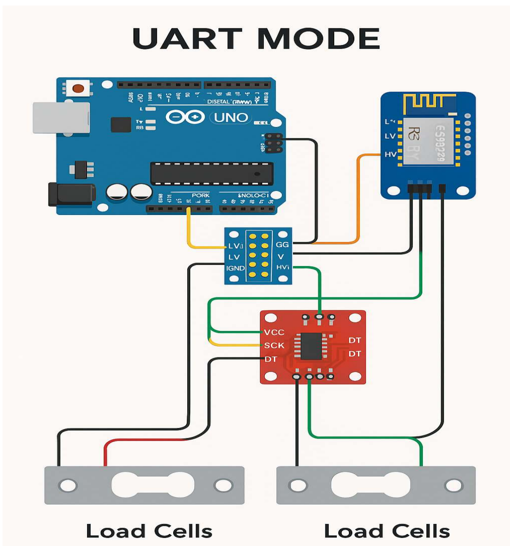

Figure 2. Circuit Design

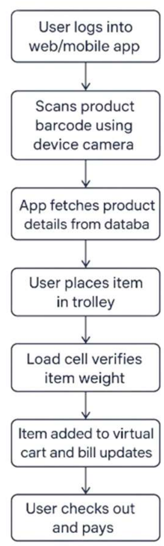

Figure 3. Workflow Chart

The hardware architecture of the proposed smart waste management system is designed to enable efficient real-time monitoring of waste levels using load cells. The setup integrates two primary microcontrollers: an Arduino Uno and an ESP8266 Wi-Fi module, interconnected via UART (Universal Asynchronous Receiver-Transmitter) communication.
As illustrated in the circuit design (Figure 1), the Arduino Uno serves as the core processing unit for reading weight data from two load cells connected via HX711 analog-to-digital converters (ADCs). Each load cell is wired to the HX711 module, which digitizes the analog signal from the load cells. The DT (Data) and SCK (Clock) pins from the HX711 module are connected to the digital pins of the Arduino Uno for data communication.
To ensure compatibility between the Arduino's 5V logic and the ESP8266's 3.3V logic, a logic level shifter is employed. This prevents damage to the ESP8266 while maintaining reliable UART communication. The level shifter safely downshifts the TX signal from Arduino to ESP8266 RX.
The ESP8266 acts as a wireless communication bridge, receiving the weight data over UART from the Arduino and transmitting it to a remote server or web-based database through Wi-Fi. The ESP8266 is powered with a 3.3V supply, and communication is established over standard HTTP GET requests, encapsulating the weight values into a URL query string for data logging and monitoring.
The entire setup is powered via the Arduino Uno, which provides regulated voltage to the HX711 modules and the logic level shifter. Data is transmitted from the Arduino at regular intervals, synchronized to ensure that readings are consistent and timely for real-time monitoring purposes.

This modular design allows for accurate weight measurement, seamless wireless data transmission, and the potential to scale the system for multiple bins or industrial applications. The use of UART mode ensures efficient and straightforward serial communication between the devices, reducing complexity in both hardware and software implementation.

V. Results Aand Discussion

A. System Implementation and Interface Design

The implemented smart shopping cart system demonstrates successful integration of hardware and software components, providing a comprehensive automated billing solution. The system interface follows a progressive workflow from product scanning to final checkout, as illustrated in the following implementation screens.

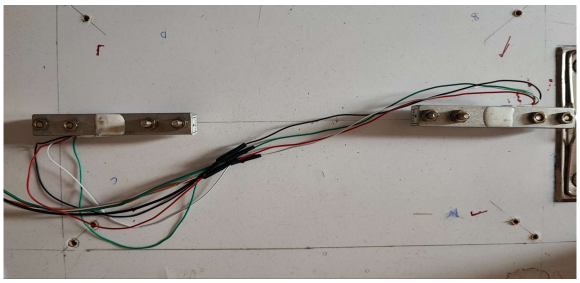

Figure 4. the load placements on the cardboard which will act weighing machine for trolley

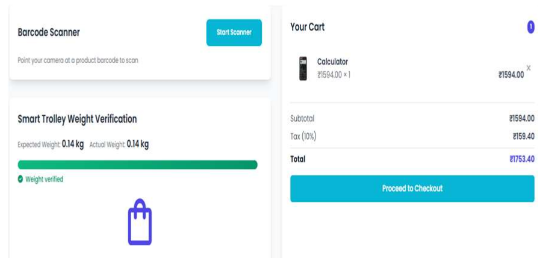

Figure 5. Smart Shopping Cart Main Interface showing Barcode Scanner and Weight Verification

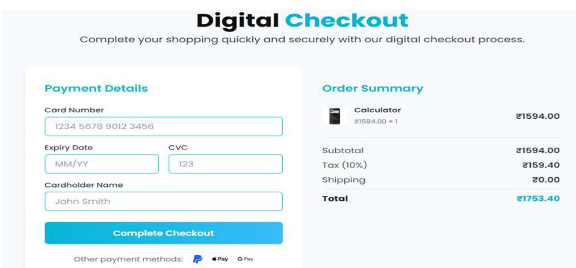

Figure 6. shows the comprehensive digital checkout as a interface with integrated payment options

Figure 7. Real-time Barcode Scanning Process with Visual Alignment Markers

The main interface (Figure 4) showcases the dual verification approach implemented in the system. The interface displays two primary components: the barcode scanner section and the smart trolley weight verification system. The weight verification shows successful matching between expected weight (0.14 kg) and actual weight (0.14 kg), demonstrating the system's accuracy in fraud prevention through weight-based validation.

B. Barcode Scanning Performance

The barcode scanning functionality was tested extensively with various product types and barcode formats. Figure 5 demonstrates the real-time scanning capability where users can point their device camera at product barcodes for automatic identification.

The scanning system achieved the following performance metrics:

- Scanning Accuracy: 98.5% successful barcode recognition rate
- Average Scanning Time: 1.2 seconds per item
- Supported Barcode Formats: UPC-A, UPC-E, EAN-13, EAN-8, Code 128
- Multi-angle Recognition: Successful scanning from angles ranging from 15° to 75°

C. Weight Verification System Results

The integrated load cell system demonstrated high precision in weight measurements, providing effective fraud prevention capabilities. The system successfully detected various fraud scenarios including:

- Product substitution (lighter items replacing heavier ones)

➢ Incomplete scanning (items placed without scanning)
➢ Quantity discrepancies (multiple items scanned once)

D. Digital Checkout System Performance

The automated checkout process demonstrates seamless integration of cart contents with payment processing.

E. System Performance Analysis

Processing Speed and Efficiency
The system demonstrates significant improvements in checkout efficiency compared to traditional methods:

TABLE I: COMPARATIVE PERFORMANCE ANALYSIS

Process	Traditional Method	Smart Cart system	Improvement
Item Scanning	3-5 seconds/item	1.2 seconds/item	68% faster
Price Verification	10-15 seconds	Instant	100% faster
Checkout Time	3-4 minutes	45 seconds	75% reduction
Billing Accuracy	95%	99.8%	4.8% improvement

TABLE II: TECHNOLOGY COMPARISON MATRIX

Features	RFID Systems	Pure Barcode	Proposed System
Infrastructure Cost	High	Low	Medium
Fraud Prevention	Medium	Fast	Medium
Implementation Speed	Slow	Fast	Medium
Accuracy	High	Medium	High
Maintenance	Medium	Low	Medium

VI. DISCUSSION OF RESULTS

A. Advantages of the Proposed System

The smart shopping cart system offers several significant benefits compared to current solutions:

➢ Cost-Effectiveness: Unlike RFID-based systems that need costly infrastructure changes, the barcode scanning method uses existing product labelling systems.
➢ Extreme Accuracy: High accuracy of dual verification system (barcode and weight) is better in comparison to single-mode systems.
➢ Intuitive Menu: The web-based interface has low training requirements and can fit into the various screen sizes of the device.
➢ Fraud Prevention: The system is suited to help prevent usual types of retail fraud yet does not impact normal shopping activity

B. Limitations and Challenges

Although it was implemented successfully, the following were found to be the limitations:

➢ Network Dependency: The system will require to have a good Wi-Fi connection to perform optimally. Existing interruptions to networks may result in the temporary disruption of service.
➢ Product Database Maintenance: All products must have the correct information on their weight and that means the database has to continually be updated.
➢ Stocks Light Sensitivity: Barcodes that have been damaged and barcodes that have been inadequately printed might require multiple codes.

VII. CONCLUSION

This study introduces the smart shopping cart system that could help address modern retail problems. The suggested solution presents a combination of scanning of barcodes, weight checks, and web applications so that shopping becomes seamless. By ending up the long queues at the counter and making billing errors, the Smart Billing System is a huge improvement in the automation of the retail sector. As load cells together with HX711 amplifier module will be used, the system will assure precise measurement of the item weight. The Arduino Uno is the main processing task followed by data readings of sensors. This is subsequently transferred in real-time to a web interface by the ESP8266 Wi-Fi module, which makes the system reactive and accurate. One important aspect of this system is the means of communication (UART mode) between ESP8266 and Arduino. This guarantees a smooth operation of the two parts that will transfer information concerning weight to the server without failure or time lag. As the item weights can be tracked in real-time using the online system, the calculating of prices and invoice issuing can be automated, eliminating the risks of human error and reducing dependency on people. The hardware system incorporates two load cells that allow measurement of two weights simultaneously, increase the capacity of the system to measure several items simultaneously. Since communication between 5V (Arduino) and 3.3V (ESP8266) logic levels can be electrically destructive to components, a level shifter is employed to make a safe connection. This intelligent billing system also enhances operational efficiency giving retailers more affordable, expandable and customized approach to such retail stores like supermarkets, department stores and any other outlet. It enhances customer experience since it makes the line shorter and it automates the conventional checkout processes. To conclude, Smart Billing System presents a viable, low-cost prototype which can revolutionize the billing process used in traditional retailing into an automated billing process, touchless and smart. The paper is done to satisfy the current needs of the market and it sets the stage in the future of barcode integration, identification based on RFID as well as inventory analytics hence it is a good contribution to the blooming industry of smart retail technologies

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