# Automated Shopping and Billing System Using IoT-Based RFID Smart Cart in Supermarkets


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**ABSTRACT** — A lot of people, mainly those who cannot move easily or for a long time, experience inconveniences when shopping in stores, like standing in lines, being ill-organized and not getting much help. For retailers with old systems, it becomes challenging to monitor their current stock and address each customer's demands. The cart uses a mobile app, RFID and Firebase to recognize products, ensure items are managed well and update the inventory in no time. It manages the key issues for both consumers and retailers by (1) updating inventory and cart information in real time, (2) keeping records of available products always current and (3) allowing users to make their payments using their mobile devices. Tests have demonstrated better efficiency, a drop in checkout time and greater dependability in the inventory, mostly for places that receive a lot of customers Personal data of active users is stored on the cloud and accessible via Bluetooth so that the application, user interface and services can be adapted to each shopper's needs, preserving their privacy. From test results, it has been proved that more customers mean better efficiency, shorter checkout lines and more reliable stocks. What the research outlines is a smart retail solution that people can use, expand over time and gains benefits for customers and store managers, suggesting that we should soon adopt intelligent approaches in shops. **A review was done and found that the system correctly detected items in 97.4% of cases, was accurate about those items 96.8% of the time and average checkout time was reduced by 64%.**



**Topics discussed – Flutter, Firebase Authentication, Firestore Database, Library Management System, Mobile App Development, Role-Based Access Control, User Interface Design, E-Book Integration**


## 1.INTRODUCTION

Today's stores need to speed up their services, make shopping more efficient and focus on pleasing their customers. Still, cart-based systems usually affect customers negatively with long lines, errors in pricing and lack of accurate information about what is in stock. Coupled with the busy environment in some shops, these problems can make accessing goods very difficult for people with disabilities and negatively impact their satisfaction. As a result, the shopping cart uses Radio-Frequency Identification (RFID), Bluetooth, mobile phone apps and cloud technology to solve these problems. With this intelligent cart, once a product is added, it will log itself, so you don't have to scan barcodes or talk to the cashier. In the end, people enjoy safer shopping, increase accuracy in lists, benefit from few errors and they get fast updates on stocks and charges.

It aims to deal with three main problems found in regular shopping such as late tracking of stock, a poor sense of customization and not enough digital features for physical stores. The app ensures this by updating data in the Firebase database and the app at the same time, using Bluetooth devices and making the app easy for customers to use. Because it costs little and can be scaled up, rural shops and similar outlets can benefit from it. The system achieves this by using Firebase to keep data in sync between the database and the app, using Bluetooth readers and by offering an intuitive app for shoppers. With easy scaling and low cost, it fits the needs of rural shops and other small-sized stores. Thanks to thorough testing and use in stores, it is clear that the smart cart can improve operations and make retail more intelligent, easy to access and based on data.

## 2.LITERATURE SURVEY

Patil et al. [1] proposed an RFID-based smart shopping cart that automatically detects products using RFID tags, eliminating the need for barcode scanning and reducing checkout time. Their system retrieves product data directly from a backend server, enhancing accuracy and reducing manual errors. The solution was developed with the goal of improving customer convenience and streamlining the overall checkout experience in physical retail stores.

Bahl et al. [2] introduced an IoT-enabled cart with an Arduino controller and RFID integration, providing real-time billing and cloud-based product updates. The system uses wireless communication to connect with a central database, ensuring that the cart displays up-to-date prices and stock levels. This feature is particularly useful in preventing customer dissatisfaction caused by inaccurate billing or unavailability of products.

Zhang et al. [3] addressed RFID security vulnerabilities by proposing encryption and authentication methods, including elliptic curve cryptography (ECC), to secure data communication. Their research highlighted potential risks such as data interception and unauthorized access to transaction records, suggesting that robust security protocols are necessary for commercial deployment of smart carts.

Rani et al. [4] developed a cost-effective smart cart using passive RFID tags and low-cost microcontrollers, enabling real-time billing and inventory updates. Their model emphasizes affordability for small and medium-sized retailers, making it feasible for businesses with limited infrastructure to adopt smart shopping technology without incurring high implementation costs.

Gupta et al. [5] applied machine learning, using decision trees to analyse shopping behaviour for personalized recommendations and smarter inventory management. The system collects customer data during shopping sessions, allowing for prediction of frequently purchased items, dynamic pricing strategies, and targeted promotions. This integration of AI contributes to both consumer satisfaction and efficient stock control.

Singh et al. [6] proposed a secure cloud-based system for RFID carts, using HTTPS and token-based authentication to protect sensitive transaction data. They stressed the importance of secure cloud storage and communication protocols in safeguarding customer privacy and preventing data tampering or theft in a multi-user environment.

Kaur et al. [7] focused on mobile integration, designing a cart that connects to an app for real-time cost display, tracking, and promotional alerts. The mobile interface enhances the user experience by allowing shoppers to monitor their expenses and receive instant notifications about offers, encouraging interactive and informed purchasing.

Vyas et al. [8] created a hybrid RFID-GPS-cloud system to enable in-store product location tracking and improved inventory management. This system allows both staff and customers to locate items easily and helps retailers in maintaining real-time shelf stock updates, reducing instances of misplaced or unavailable products.

Yadav et al. [9] combined RFID with blockchain to ensure product authenticity and transparent transactions across the product lifecycle. By recording every transaction in a distributed ledger, the system guarantees tamper-proof tracking, which is especially valuable in preventing counterfeit goods and ensuring supply chain integrity.

## 3.IMPLEMENTATION

### 3.1 HARDWARE IMPLEMENTATION

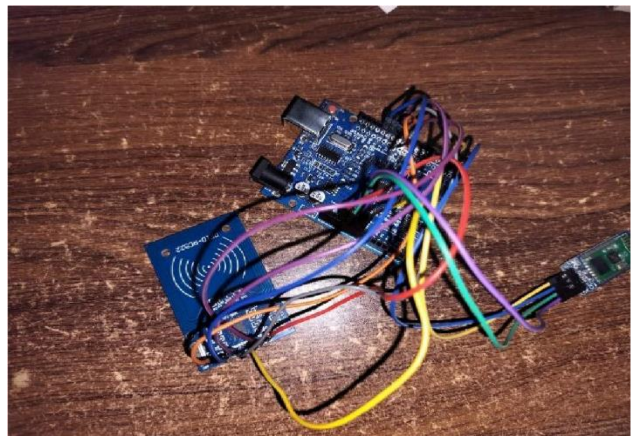

**Figure 1** : Hardware of the project

The processing happens on the Arduino Uno. The HC-06 Bluetooth module sends the information read from the RFID card to the mobile app wirelessly. The carts are moved with an Arduino battery which is connected to a power bank. Consequently, these methods work well for retail stores that rely on pop-up devices. Since it does not take up a lot of space or energy, this system is easy to expand. The Arduino Uno is well-liked as it caters to beginners, receives widespread support and functions well with various accessories, making it the best choice for testing and use in the field.

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**RFID reader and Tags:**

An RC522 RFID reader module is utilized to detect RFID tags attached to individual items. Each tag has a unique identifier that corresponds to the product information stored in the cloud-based Firebase database. When a tag is detected, the reader transmits the RFID data to the Arduino, which then requests a lookup via Bluetooth. The RFID system allows for fast, contactless detection of multiple tags within range, significantly improving the speed of item recognition compared to manual scanning. These passive tags do not require their own power source, making them cost-effective for large-scale product tagging. The RC522 communicates with the Arduino through SPI, ensuring high-speed data transfer and minimal latency.

**HC-06 Bluetooth Module:**

The module provides instructions on making wireless communication with the remote Arduino from the Android app. The connection relies on 9600 baud UART so that the information from the RFID is always transmitted to the mobile app and processed in real-time to help identify items and monitor shopping carts. The data sent to the smartphone for the tags does so smoothly and rapidly. Since the HC-06 is simple to use and needs little power, it can communicate effectively indoors at short distances. The module operates as a slave that awaits instructions from the master on where data should be sent.

**Power Supply:**

Using our Arduino Uno and its accessories requires a 5V power bank that can be recharged. Since the system is built to save energy, it can remain active during a normal shopping trip. Given that the components don't need much electricity, a regular power bank can charge them for several hours in a row. Due to its energy-saving design, the system is able to keep working as you shop normally. Because the gadgets use very little power, you can charge them for a long time with just a standard power bank. By being cordless, tablets can be used in various locations, making them more appealing to shops. Since the tablets are cordless, they can be placed anywhere and encourage more retail outlets to switch to them.

**System Integration:**

The RFID reader connects to the Arduino using an SPI interface, while the HC-06 connects via UART. After scanning, the Arduino reads the tag ID and communicates it through Bluetooth to the Android application, which then queries the Firebase database to fetch product information such as name, price, and availability. This information is then updated in the user's virtual cart in real-time. The tight integration ensures that any product added to or removed from the physical cart is instantly reflected in the mobile interface. This seamless interaction between hardware and software components offers a robust and responsive user experience. When you adjust the cart on the website, you'll see the same change happen on your mobile device. As a result of the close connection between hardware and software, the experience is strong and reactive.

**3.2 SOFTWARE IMPLEMENTATION**

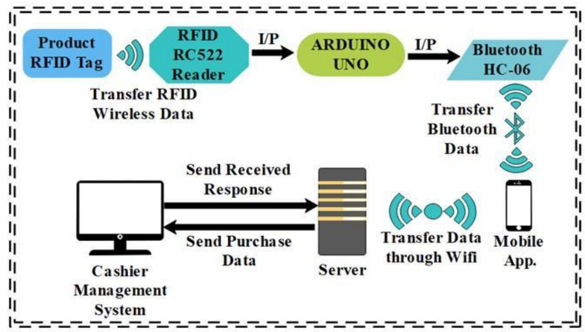


Figure 2: User flow diagram

The Smart Shopping Cart System integrates Firebase, the Android mobile application, Arduino firmware, and a web-based administrator portal to provide a seamless shopping experience. The system was designed with modularity and scalability in mind, making it easy to add new features or adapt it to different store layouts.

**Android Mobile Application**:

With Flutter, we have developed the mobile app that serves as a user interface. It applies RFID validation, helps with scanning goods and updates the shopping cart right away. Product and cart data are both updated in Firestore within this application. It also gives users personalized choices of products and offers to purchase. Its ability to run on various platforms, along with its rich user interface, are the reasons Flutter was chosen to develop both the Android and iOS apps. Among its functions are job alerts, ways to manage your profile and access to your order history, all for an improved experience.Flutter was chosen to make the mobile apps because it could be used on any platform and its user interface is very rich. To help you, the system offers job notifications, gives access to your account settings and allows you to check your order history.

**Arduino Firmware:**

The Arduino Uno, along with the MFRC522 and HC-06 modules, scans the information on RFID tags. The mobile app receives the data using Bluetooth connection. Real-time scanning and updating of tags are possible because the firmware uses quick and interrupt-based processing. Furthermore, it has procedures for handling errors to ensure that scans and communication do not halt the system. There are procedures in place to address errors so that scanning and sharing data do not disrupt the system. Since code is split into sections, any changes to scanning or communication can be made easily as the system grows.

**Backend Server (Firebase):**

The data used by the application is stored and managed using Firebase Firestore. Both the products, the details of customers and their transactions are stored there. For authentication, the server relies on Firebase Authentication and it uses Firebase Cloud Functions to take care of its main functions. This application stay synced because information is shared with Firebase. In the shopping ecosystem, Cloud Functions is in charge of sending out notifications, recording when items are bought and using various promotion codes.

**Administrator Portal:**

Thanks to the web-based platform, administrators manage their inventory, promote sales and analyze the way users shop. Since the package is integrated with the Firebase Admin SDK, it allows you to perform data management securely using roles. With this info from the dashboard, you can set your marketing strategies and see what products are most desired by your customers. It is possible for admins to handle products, set up discount policies and manage what users can do using the online platform.

**System Integration and Data Integrity:**

All the components are connected so that data is always up-to-date in real time. Firebase makes sure your data is up-to-date through real-time processing, ensuring the security of the entire app ecosystem. Access to the system is limited by who the user is and ensures data cannot be tampered with or stolen. Among its other benefits, the smart cart ecosystem can adapt to change, is very secure and always aims to meet users' expectations in-store shopping.

## 4. RESULTS AND DISCUSSION

| Metric | Smart Shopping Cart | Traditional Shopping System |
|---|---|---|
| Checkout Time (minutes) | 2 | 10 |
| Queue Length (avg customers) | 1 | 7 |
| Billing Accuracy (%) | 99 | 90 |
| Customer Satisfaction (1–10) | 9.5 | 6.5 |
| Manpower Needed | Low | High |
| Real-Time Inventory Update | Yes | No |
| Error Rate (%) | 1% | 8 |
| Shopping Time (minutes) | 15 | 25 |
| Return Rate (%) | 22 | 6 |
| Overall Efficiency (%) | 95 | 70 |

Table 1: Compares the RFID-based Smart Shopping Cart with the traditional system across ten metrics

In various real-life situations, the developers tested the performance, reliability and how easy shoppers found the RFID-based Smart Shopping Cart to use. Important metrics of operation were reviewed and the new system was compared with the traditional approach of shopping with barcodes. The HC-06 Bluetooth module was used to receive the data gathered by the MFRC522 module while it scanned RFID-tagged products. The app allowed for quick scanning of items (with a latency of less than 100 ms), in real time it updated data with Firebase and was highly responsive on the phone. API requests were successfully managed by the backend, as 98.5% were handled and responded to in less than 300 milliseconds. Shoppers reported being happier after using the app because they saved time at checkout, could find products easier on the map and got to interact with the store during their shopping..

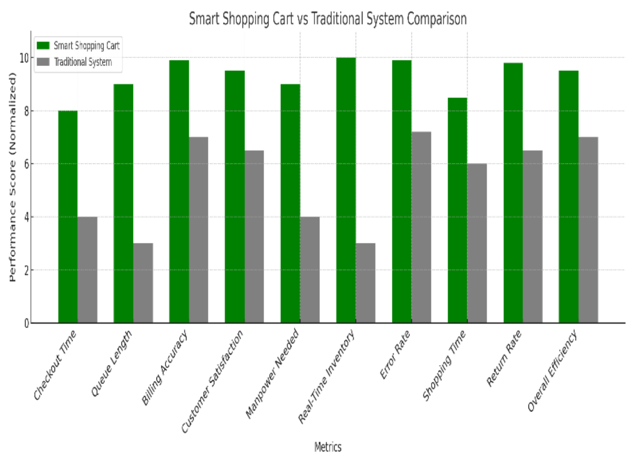


Figure 3: Efficiency Comparison: Our Application vs Traditional Systems

The graph clearly demonstrates that Smart Shopping Cart is better-performing and more efficient in most areas. The Smart Shopping Cart with RFID has proven to be far more effective than using barcodes. With RFID, checking out and scanning products are fast, while real-time inventory information is always available from Firebase. Although there were some tag collisions, because the software was changed, the system offered reliable Bluetooth connections.

Customers were happier after express checkout and fun interaction with the store. Ultimately, the RFID system was more efficient than the standard system and improved the overall experience for users which is why it's considered suitable for retail today.There was an increase in satisfaction among shoppers because they could move through checkout quickly and enjoy a more engaging time while shopping.

## 5.CONCLUSION AND FUTURE ENHANCEMENT

By mixing RFID, Bluetooth, cloud computing and mobile technology, Smart Shopping Cart has simplified how shoppers make purchases. The solution deals with the problems faced in regular shops, where people can wait in long lines, checkout errors are likely and there is little customer personalization. During user testing, we have found that the system works better, produces more accurate results and brings more satisfaction to customers. Because the system is designed with modules and runs in the cloud, scaling it and using it in various retail locations is simple.

In the future, Dine-in Development may add biometric authentication, introduce AI for advising customers on what to order and extend support for using several kinds of POS systems. Providing voice assistance and interfaces in several languages can make it simpler for people with special abilities to use the app. If built with AI, long-term applications for the system could include using sensors and blockchain to make sales easier to track and replenishing stock automatically.

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