AUTOMATED SHOPPING AND BILLING SYSTEM USING IOT BASED RFID SMART CART IN SUPERMARKETS

**A MINI PROJECT REPORT FOR THE COURSE**

# DESIGN THINKING AND INNOVATION

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**BONAFIDE CERTIFICATE**

Certified that this Thesis titled “Automated Shopping and Billing System Using IoT-Based

RFID Smart Cart in Supermarkets” is the bonafide work of Tharun Kumar(230701393), Sriram Umaknathan(230701338) who carried out the work under my supervision.

Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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1. Introduction

The retail industry is rapidly evolving, with increasing emphasis on automation, convenience, and enhanced customer experience. Traditional shopping in supermarkets and retail outlets, although still prevalent, often involves several inefficiencies—long queues at checkout counters, delays due to manual scanning, lack of real-time stock updates, and a generally time-consuming experience for customers. In an era where technology is transforming every aspect of daily life, there is a growing need for smart retail solutions that can simplify the shopping process while improving accuracy and operational efficiency. To address these issues, we propose an innovative and user-centred solution: the **RFID-based Smart Shopping Cart System**.

This project aims to revolutionize the in-store shopping experience by enabling **automated product detection, real-time cart management, and seamless checkout**, all through a combination of **RFID technology**, **Bluetooth communication**, and **cloud-based mobile application development**. In this system, each product in the store is embedded with a unique **RFID tag**, which stores product-specific data such as its name, price, and identifier. As the customer places items into the smart shopping cart, an **RFID reader** attached to the cart automatically scans the RFID tags without requiring any manual input. This allows for an instant and contactless recognition of items.

The data from the RFID reader is transmitted to a **mobile application** using the **HC-06 Bluetooth module**, which acts as a bridge between the hardware and software components of the system. The mobile application, built using **Flutter**, provides a clean and interactive interface where customers can view product details, the number of items in their cart, real-time billing updates, and available stock. All data is managed in **Google Firebase Fire store**, a scalable and reliable NoSQL cloud database. The system is also designed to support multiple users, with each user's cart information stored independently, ensuring privacy and personalized service.

One of the core strengths of this system is its ability to update product stock dynamically in the cloud database, reflecting real-time changes as customers add or remove items. The app also includes logic to prevent users from exceeding available stock, visually alerts them when stock is depleted, and disables further additions for out-of-stock items. This not only enhances user experience but also helps store managers maintain accurate inventory levels.

The **RFID-based Smart Shopping Cart** is a modern solution that aligns with the principles of **smart retail** and **digital transformation**. It simplifies the shopping process, reduces human error, eliminates the need for manual checkouts, and provides real-time inventory and billing management—all in a user-friendly, efficient, and scalable way. Ultimately, this system aims to bridge the gap between traditional retail and emerging smart technologies, paving the way for **more intelligent, efficient, and enjoyable shopping experiences**.

# Design thinking approach

Design Thinking is an iterative, user-centered methodology that encourages innovation by prioritizing empathy, experimentation, and collaboration. It enables teams to deeply understand user behavior and pain points before ideating and implementing practical, human-friendly solutions. This approach is especially valuable in projects where the end-user experience plays a pivotal role in determining the success of the product.

In the context of our RFID-based Smart Shopping Cart, Design Thinking ensures that the solution is not just technically functional, but also user-friendly, accessible, and efficient for everyday shoppers. By applying this methodology, we were able to move beyond just building a tech-driven cart. Instead, we focused on solving real-world problems like long billing queues, inefficient manual checkouts, and lack of price clarity, which commonly frustrate retail customers.

The Design Thinking framework guided us to identify user needs through research, define specific challenges in the shopping process, generate a range of possible solutions, and iteratively prototype and test our ideas. This helped us create a shopping experience that’s intelligent, seamless, and aligned with user expectations, ultimately making retail shopping faster, more convenient, and stress-free.

# Different Types of Design Thinking Models

Design Thinking is a flexible methodology that has been adapted and refined by various institutions and organizations, resulting in several popular models. Each model follows the same core philosophy—**empathize with users, define the problem, ideate creative solutions, prototype, and test**—but structures these steps differently based on the intended application or audience.

Below are some of the most recognized Design Thinking models:

# 1. Stanford d.school Model

Developed by the **Hasso Plattner Institute of Design** at Stanford University, this is the most widely followed model. It consists of five stages:

1. **Empathize** – Understand the user and their needs through observation and engagement.
2. **Define** – Clearly articulate the core problem based on insights.
3. **Ideate** – Generate a wide range of ideas and potential solutions.
4. **Prototype** – Build scaled-down versions of the solutions.
5. **Test** – Collect feedback and refine the solution.

This model served as the foundation for our project, ensuring a user-first approach from start to finish.

# 2. IBM Design Thinking

IBM’s approach emphasizes collaboration across diverse teams and fast iteration. Its model revolves around three principles:

* **Hills** – Clear and user-centered objectives.
* **Playbacks** – Frequent feedback sessions to keep teams aligned.
* **Sponsor Users** – Engaging real users throughout the design process.

This model is particularly useful in large teams and corporate environments.

# 3. Double Diamond Model (British Design Council)

This model visually represents the **divergent and convergent** thinking process with two diamonds:

* **Discover** and **Define** (Problem Space)
* **Develop** and **Deliver** (Solution Space)

It encourages broad exploration before narrowing down to a refined solution.

# 4. IDEO’s Human-Centered Design (HCD) Model

IDEO’s approach places even greater emphasis on human empathy and desirability:

1. **Inspiration** – Learn directly from users.
2. **Ideation** – Brainstorm, prototype, and refine ideas.
3. **Implementation** – Bring the solution to life and scale it.

This model highlights the emotional and behavioral aspects of user experience.

# 5. Google Design Sprint

Focused on rapid problem-solving in 5 days, this model is ideal for fast prototyping and testing:

1. Understand
2. Sketch
3. Decide
4. Prototype
5. Test

Though it’s compressed, it remains highly effective for time-sensitive projects.

# Stanford design thinking module and details of its phases

The Stanford d.school Design Thinking model is a five-phase, iterative process that focuses on deeply understanding the end-user, redefining problems, and creating innovative, user-centric solutions. This model was instrumental in the development of our Smart Shopping Cart, helping us create a solution that addresses real-world shopping pain points using empathy, ideation, and rapid prototyping.

Here’s how each phase was applied in the context of our project:

1. Empathize – Understanding the User

The project began with a deep dive into user behavior and problems faced during shopping in physical retail stores. We conducted:

* + Observations at supermarkets and grocery stores
  + Informal interviews with shoppers and store employees
  + Online surveys targeting frequent in-store shoppers

This phase revealed key user frustrations:

* + Long checkout lines
  + Difficulty in tracking total spending during shopping
  + Lack of awareness of current product availability or stock
  + A desire for a more modern, tech-assisted shopping experience

1. Define – Narrowing Down the Problem

Using insights from the empathy phase, we crafted specific problem statements:

* + *“Shoppers need a way to view their cart’s total and product availability in real-time to make informed purchasing decisions.”*
  + *“Retailers need an efficient way to manage stock visibility and improve customer satisfaction.”*

We finalized our core design challenge as:

*“How might we design a smart cart system that enables real-time item tracking, simplifies billing, and enhances the in-store shopping experience?”*

1. Ideate – Generating Creative Solutions

In brainstorming sessions, we explored a wide range of ideas:

* + Barcode-based carts
  + RFID tag scanning and product detection
  + Integration with a mobile app to view the cart, track spending, and make payments
  + Automatic stock management through Firestore backend

We used mind mapping and storyboarding to evaluate feasibility and user impact. The best solution combined RFID-based product scanning with Firebase and Bluetooth integration for a seamless, connected smart cart.

1. Prototype – Bringing the Idea to Life

We developed a working prototype of the Smart Shopping Cart, which includes:

* + RFID tags on products
  + An Android mobile application connected via Bluetooth to an RFID reader (HC-06 module)
  + Integration with Google Firebase for product details, stock count, and cart tracking
  + UI elements for item addition, removal, and real-time billing
  + Cart logic to handle stock limits, scanned counts, and user-specific product data

This functional prototype was tested in a simulated store environment.

# Test – Getting User Feedback

We conducted multiple testing sessions with users, store staff, and peers. Key feedback included:

* The UI should clearly show when an item is out of stock
* Addition of real-time stock updates was highly appreciated
* The auto-addition feature needed improvement to prevent duplicate scans

Based on this feedback, we refined the app to:

* Block product addition beyond available stock
* Highlight out-of-stock products in red
* Require manual action for reducing item count to avoid unintended behavior

By closely following the Stanford Design Thinking model, we ensured that our final solution was not just functional but deeply aligned with user needs and expectations. This iterative approach allowed us to continuously test, **learn, and evolve our smart cart system into a user-friendly, efficient tool for modern retail shopping.**

# Literature Review

Patil and Bhole [1] proposed an RFID-based shopping cart prototype that uses RFID tags on products, which interact with an RFID reader integrated into the cart. This interaction allows automatic product detection when placed in the cart, retrieving product information from a backend database. Their solution eliminates the need for manual barcode scanning, reducing human involvement and checkout delays. The authors highlight that such automation not only speeds up the checkout process but also reduces the chances of human error, offering a seamless shopping experience.

In a similar vein, Bahl and Soni [2] introduced an IoT-enabled smart shopping cart system that integrates RFID technology and an Arduino-based controller. Their system utilizes RFID tags placed on products to wirelessly transmit product information to a cloud-based server. The use of wireless communication and cloud integration ensures real-time updates of product availability and prices. The system also includes a display on the cart, showing the running total of items, which enhances user interaction. The authors emphasize the potential for such systems to reduce customer frustration caused by long checkout lines and increase the efficiency of retail operations.

To address the issue of security in RFID-based systems, Zhang et al. [3] conducted an extensive study on the vulnerabilities of RFID technology, particularly focusing on the potential risks of data interception and unauthorized access to personal and transaction information. They proposed a security framework that integrates encryption and authentication mechanisms into the communication between the RFID-enabled shopping cart and the backend server. Their work highlights the importance of secure communication protocols, such as using elliptic curve cryptography (ECC), to prevent data theft and ensure privacy in RFID-based retail systems. This approach is essential for building consumer trust and ensuring the scalability of such systems in commercial environments.

Further innovations in RFID-based cart systems have been introduced by Rani and Mehta [4], who focused on reducing the cost of implementation. They designed a system that uses passive RFID tags in conjunction with low-cost microcontrollers and Wi-Fi modules. This design allows for real-time billing and inventory updates by sending data to a centralized database, enabling efficient inventory management and ensuring that customers are only charged for the items they actually place in the cart. Their solution is particularly useful for small and medium-sized retailers seeking an affordable way to implement smart shopping systems.

In a different approach, Gupta and Yadav [5] explored the integration of machine learning techniques to enhance the accuracy and efficiency of RFID-based systems. They proposed a decision tree algorithm to predict consumer behavior and automate the shopping experience further. The system uses data collected from RFID tags to analyze shopping patterns, such as frequently purchased items or customer preferences, and provide personalized recommendations. This use of AI allows for smarter inventory management, where the system can automatically adjust stock levels based on predicted demand, thereby improving the overall shopping experience for customers and retailers alike.

Security concerns in the IoT-enabled shopping cart systems were also addressed by Singh et al. [6], who focused on the implementation of a secure cloud-based architecture for RFID-enabled shopping carts. Their system ensures that product details, user data, and transaction information are stored securely in the cloud, and only authorized devices can access this data. They recommended employing a combination of token-based authentication and secure HTTPS protocols to protect sensitive information from potential attacks. Their study reinforces the need for robust cybersecurity frameworks to prevent unauthorized access and ensure data integrity in retail environments.

The potential of RFID technology to enhance customer experience was further explored by Kaur et al. [7], who designed an interactive shopping cart system that uses RFID for automatic item detection and integrates with a mobile app to offer real-time tracking and notifications. Their system allows customers to view the total price of items in their cart, receive alerts for discounts and promotions, and check out seamlessly without waiting in long lines. They emphasize the role of user-friendly interfaces and mobile integration in increasing customer engagement and satisfaction, which is essential for the widespread adoption of smart shopping carts.

Vyas and Sharma [8] contributed to the growing body of research on RFID-enabled shopping systems by introducing a system that integrates RFID, GPS, and cloud technologies to improve product tracking and inventory management. Their system enables real-time location tracking of products within a store, allowing both customers and retailers to monitor product availability and location. This solution not only improves customer experience by making it easier to find items but also streamlines inventory management for retailers, ensuring that stock levels are constantly updated in real-time.

Additionally, Yadav and Patel [9] focused on the integration of RFID technology with blockchain to provide a secure and transparent transaction process. Their research demonstrated how blockchain could be used to track each product’s journey from the warehouse to the store, ensuring the authenticity of products and preventing fraudulent transactions. This innovative solution adds an additional layer of security, making RFID-based shopping carts not only more efficient but also more secure for both customers and retailers.

In conclusion, while various studies have contributed to the development of RFID-based smart shopping cart systems, there are still several areas that require improvement. Security, scalability, and the integration of advanced technologies like machine learning and blockchain are crucial to ensure that these systems can function effectively in real-world retail environments. By incorporating robust encryption, secure communication protocols, and cloud-based architecture, future systems can offer seamless, secure, and efficient shopping experiences for customers, while also streamlining operations for retailers.

Domain Area

The domain area of this project lies at the confluence of several technological disciplines, primarily centered around the **Internet of Things (IoT)** and its application in **Smart Retail Systems**. As the retail industry continues to adopt digital transformation strategies, there is an increasing demand for intelligent systems that not only automate routine operations but also provide enhanced user experiences. The proposed Smart Shopping Cart system, powered by **RFID (Radio Frequency Identification)**, **Bluetooth communication**, **mobile app interfaces**, and **cloud-integrated databases**, is a representation of this digital shift. This system reimagines the conventional shopping experience by replacing manual processes such as product scanning and checkout with automated, real-time technologies that interact directly with products and user data. The core objective is to create a seamless, efficient, and user-centric shopping environment that reduces friction in the customer journey while improving accuracy and operational efficiency for store owners.

At its technological foundation, the system leverages **RFID technology**, which plays a critical role in automatic item identification. RFID operates on the principle of electromagnetic fields to identify and track tags attached to objects. In this system, each product is tagged with a passive RFID tag containing a unique identifier, which is read by an RFID reader mounted on the shopping cart. The use of RFID offers several advantages over traditional barcode-based systems: it does not require line-of-sight access, allows multiple tags to be scanned simultaneously, and significantly reduces manual labor. These features make RFID highly suitable for dynamic retail environments where speed, accuracy, and scalability are essential. Furthermore, the system's use of RFID facilitates real-time inventory management by detecting which items are added or removed from the cart, offering valuable insights into consumer behavior and stock levels.

Alongside RFID, the project employs **embedded systems** to act as the central control mechanism of the smart cart. Embedded systems refer to specialized computing units integrated into hardware devices to perform dedicated tasks. In this project, an **Arduino microcontroller** is used to read data from the RFID scanner and transmit it via the **HC-06 Bluetooth module** to the user’s mobile device. The HC-06 module, a widely used Bluetooth serial communication module, enables short-range wireless data transfer between the cart and the smartphone app. The combination of Arduino and Bluetooth represents a lowcost, power-efficient, and programmable platform that is well-suited for applications in consumer-facing IoT devices. These embedded systems manage input from sensors, control outputs, and facilitate communication, all within the constraints of limited memory and processing power. Their inclusion exemplifies the growing use of lightweight, microcontroller-based devices in modern IoT deployments.

The **mobile application**—developed using **Flutter**, a cross-platform UI toolkit—serves as the primary interface through which users interact with the smart cart. Mobile computing is a key subdomain of this project, enabling realtime feedback, control, and monitoring via smartphones. The app receives product data from the Arduino controller, fetches corresponding product details (such as name, image, and price) from **Firebase Firestore**, and updates the UI accordingly. It displays scanned items, running totals, and visual indicators for stock availability. For instance, products that exceed available stock are highlighted in **red**, and further additions are disabled, helping users avoid errors and promoting responsible shopping behavior. The decrement of items in the cart is restricted to UI interactions to maintain control and prevent accidental reductions. This thoughtful user interaction design aligns with principles of **Human-Computer Interaction (HCI)**, ensuring the application is intuitive, responsive, and usable for a broad range of users.

Another core domain of this project is **cloud computing**, particularly through the use of **Firebase Firestore**, a scalable NoSQL cloud database. Firestore serves as the system’s real-time backend, managing product data and userspecific cart contents. Unlike traditional implementations that update a global product list or shared cart state, this project introduces **per-user cart collections** structured under paths like users/{uid}/Cart/{productId}. This approach enables **user isolation**, data persistence, and session-based cart tracking. Firestore’s real-time capabilities allow any changes in the database to be reflected instantly in the app UI, maintaining a seamless experience even across device restarts or network fluctuations. By decoupling user actions from the global products collection, the project ensures that one user’s cart activity does not interfere with others—a crucial feature for retail environments handling multiple customers concurrently. Furthermore, Firestore’s cloud-hosted nature allows for future expansion into analytics, order history, personalized recommendations, and integration with payment gateways.

The domain area also extends to **retail logistics and inventory control**, where the system helps automate stock monitoring and reduce human errors. As users scan items and add them to their carts, the system verifies stock availability based on the originalStock and stock fields stored in the product database. Although the project intentionally avoids writing back to the global product collection to prevent data inconsistency, the architecture supports future modules where real-time deductions from inventory can be implemented based on purchase confirmations. This capability is essential for medium- to largescale retailers seeking to reduce stock-outs and overstock issues, both of which affect profitability and customer satisfaction.

While the current scope of the system emphasizes usability and functionality, it also opens discussions on **security and privacy in IoT-based retail systems**. Prior research, such as that by Li et al., has explored the use of cryptographic techniques like **Elliptic Curve Cryptography (ECC)** to secure communications between smart carts and backend servers. Although this project does not currently implement such protocols, its modular structure allows for future inclusion of **secure authentication**, **encrypted data exchange**, and **rolebased access controls**, which are increasingly important in protecting user information and preventing malicious attacks in connected systems.

In a broader academic context, the domain of this smart shopping cart encompasses fields such as **Ubiquitous Computing**, **Wireless**

**Communication**, **Real-Time Systems**, **Consumer IoT Design**, and **Retail Automation**. It represents a practical application of multidisciplinary concepts in a real-world scenario, addressing both technical challenges and user-centric concerns. The smart cart is not just a technical product—it is a reimagination of how consumers interact with physical retail stores, offering digital enhancements that make shopping faster, more accurate, and more enjoyable. As brick-and-mortar stores strive to compete with e-commerce platforms, such innovations become critical in modernizing the shopping experience and enhancing customer engagement.

In conclusion, the domain area of the RFID-based smart shopping cart project is a rich tapestry woven from multiple strands of emerging technologies. It spans across IoT, RFID systems, embedded hardware, Bluetooth communication, mobile computing, cloud-based databases, user interface design, and futureoriented security practices. This convergence allows the creation of a robust, scalable, and intelligent retail solution that can significantly reduce checkout times, improve inventory management, and personalize the shopping journey. As retail continues to evolve, the smart cart stands as a testament to how integrated, interdisciplinary systems can redefine traditional processes and align them with the digital age.

# Empathize Stage

The Empathize stage is the first and arguably the most crucial phase in the Design Thinking process, as it lays the groundwork for a deeper understanding of users’ challenges, behaviors, and pain points. In the context of the Smart Shopping Cart system, this stage provided vital insights into both the consumer and retail employee experiences. By gathering both qualitative and quantitative data, the empathize stage enabled the project team to create user-centered solutions that would directly inform subsequent design, ideation, and prototyping phases. This process comprised a variety of research activities, including observations, user interviews, surveys, and in-depth interviews. Furthermore, the team conducted secondary research to analyze existing solutions and trends in the smart retail space. Ultimately, the goal was to understand user expectations, frustrations, and the critical touchpoints in their shopping experience that could be optimized with technology.

# Activities

The activities conducted during the empathize phase primarily revolved around direct engagement with real-world users, retail environments, and practical testing of prototypes. These activities helped to uncover the core challenges customers face in current shopping systems, both in-store and online.

# Observational Studies

The first major activity involved observational studies in retail stores, where team members visited various retail locations to observe how customers interacted with the shopping environment. The team paid close attention to customers’ shopping behaviors, focusing on areas such as product selection, checkout procedures, and interactions with in-store staff. The key insights garnered from this activity included:

* Long Wait Times: A significant pain point observed was the long queues at checkout counters. Customers were often forced to wait for extended periods before they could complete their purchase, which led to dissatisfaction and a desire for a faster checkout experience.
* Barcode Scanning Issues: Manual barcode scanning was slow, with customers frequently experiencing frustrations when items were not correctly scanned or when the system failed to detect product information. This highlighted a potential area of improvement for the smart shopping cart system, where RFID technology could enhance efficiency by automating the product scanning process.
* Product Search Challenges: Customers often struggled to locate products within large retail spaces, especially in stores with poor signage or poorly organized aisles. Many shoppers were seen seeking assistance from staff, which further slowed down their shopping experience. The introduction of a smart shopping cart system could provide a solution by integrating an in-app search feature that helps users locate products quickly.

# User Interviews

To dive deeper into the customer experience, semi-structured interviews were conducted with 25 shoppers and 10 retail employees. The interviews with shoppers were designed to explore their preferences for shopping technologies, particularly self-checkout systems, and their pain points during the traditional shopping process. The following themes emerged from these interviews:

* Willingness to Adopt Technology: Many shoppers were open to adopting new technology, especially if it promised to save time and improve their shopping experience. However, there was a clear desire for these systems to be user-friendly and non-intrusive. Shoppers were more likely to adopt self-checkout solutions if they provided a seamless and intuitive interface that didn’t require a steep learning curve.
* Concerns about Security and Privacy: Some shoppers expressed concerns about the security of their personal data when using technology in-store.

They wanted assurance that their payment details and personal

preferences would be securely handled. This finding emphasized the need for robust data protection protocols in the design of the smart cart system.

* Retail Employees’ Frustrations: The interviews with retail employees revealed challenges related to inventory management and customer service. Employees noted that managing stock levels in real time was a significant challenge, and many wished for a more automated system that could update inventory and track stock movements without manual intervention.

# In-Store Testing

To further explore the functionality of the smart shopping cart, a test prototype was developed using RFID tags and Bluetooth communication. This prototype allowed users to scan products, track their cart’s total, and monitor product availability in real-time. The in-store testing provided valuable feedback in the following areas:

• Scanning Speed

Users noticed that scanning products was faster with RFID compared to traditional barcode scanning. However, there were occasional connectivity issues between the RFID reader and the mobile app, causing delays in updating the cart’s total. These issues were critical in refining the system’s technical infrastructure.

• Real-Time Cart Updates

Users expressed a desire for real-time updates on their cart’s total cost as they added products. Many users mentioned that they would appreciate a feature that showed running totals throughout their shopping experience, enabling them to make more informed purchasing decisions.

• Technical Issues

While the RFID technology itself worked well, the testing phase also highlighted issues with app interface responsiveness and Bluetooth connectivity. These issues needed to be addressed in future stages of design.

**Primary Research**

Primary research served as the cornerstone of gathering real-time feedback from users and store employees. Through surveys, in-depth interviews, and employee feedback, the team gained deeper insights into specific user expectations, concerns, and desires for the smart shopping cart system.

Surveys

A survey was conducted with 50 retail shoppers to gather quantitative data on user preferences and frustrations. The survey was distributed both in-person and online. Key findings included:

* 82% of respondents were interested in using a smart shopping cart system that could track their items and provide real-time updates.
* 72% of respondents expressed significant frustration with long checkout lines, citing these lines as the most significant pain point in their shopping experience.
* 60% of respondents indicated that they would appreciate real-time product availability updates to avoid the frustration of items being out of stock.

These findings confirmed that a system offering faster checkouts and real-time tracking would meet a pressing consumer need.

**Secondary Research**

Secondary research provided the theoretical grounding and broader context for the project. It also helped identify technological solutions to address the pain points uncovered in the primary research and in-store testing.

• IoT Applications in Retail

A key paper that influenced the design thinking process was *“IoT Applications on Secure Smart Shopping System”* by Li et al.. This paper highlighted the role of RFID and other IoT technologies in automating shopping systems. It discussed various applications of RFID for inventory management, product tracking, and real-time billing, and emphasized the need for secure communication between devices to protect user data. Given that security was a significant concern raised during user interviews, this paper led the team to identify cryptographic protocols, such as Elliptic Curve Cryptography (ECC), to secure communication between the shopping cart and the server.

• User-Centered Smart Shopping Systems

The study *“IoT-Based Smart Shopping Cart Using Radio Frequency Identification”* by Shahroz et al. explored the integration of Bluetooth technology for mobile app synchronization and focused on the user interface of smart shopping carts. It emphasized features such as real-time shopping assistance and personalized promotions, which resonated with the preferences of interview participants. The study also underscored the importance of creating intuitive and easy-to-use interfaces for both tech-savvy and non-tech-savvy users, helping to inform the app design process.

• Retail Innovation Trends

Further secondary research, including industry reports from organizations like McKinsey and Gartner, revealed several key trends in the retail industry:

* Increasing reliance on automation and real-time data analytics to improve operational efficiency.
* Growing demand for personalized shopping experiences, with technologies that can tailor product suggestions, alert shoppers to stock levels, and offer targeted promotions.

These insights were crucial in shaping the functionality and features of the smart shopping cart system

In-Depth User Interviews

In addition to the survey, 15 in-depth interviews were conducted with both frequent shoppers and retail employees. These interviews focused on understanding specific user needs, such as:

* Ease of use: Shoppers desired a simple interface that could be operated with minimal effort. They wanted the system to be intuitive, without requiring too much time to learn.
* Personalized Shopping: A common theme was the desire for a more personalized shopping experience, with shoppers seeking features that could suggest complementary products or offer tailored promotions based on purchase history.
* Security and Privacy: Privacy concerns were paramount for both shoppers and retail employees. Participants expressed the need for secure data handling and the assurance that their personal information would not be misused.

Retailer Feedback

Interviews with store managers and employees emphasized the operational challenges retailers face, including inventory management, staffing, and billing accuracy. Managers were keen on a system that could automate inventory updates, reduce human error, and speed up the checkout process. Employee feedback confirmed that a smart cart system could improve the operational efficiency of stores, allowing employees to focus on customer service rather than mundane tasks like checking out products or managing stock.

User Needs

Based on the primary and secondary research findings, several key user needs were identified. These needs provided the foundation for the design of the smart shopping cart system:

1. Faster and More Efficient Checkout: A crucial need for both shoppers and retailers was a quicker checkout process. Reducing time spent at checkout could alleviate frustrations and improve the overall shopping experience.
2. Real-Time Cart Tracking and Billing: Shoppers expressed a strong desire to have constant visibility into their cart’s total, including running totals and updates on promotions or discounts.
3. Intuitive User Experience: The system needed to be user-friendly to accommodate both tech-savvy and less tech-savvy users.
4. Product Availability and Stock Alerts: Real-time notifications about stock availability were crucial for preventing frustration when products were unavailable.
5. Reliability and Accuracy: Users needed to trust the system’s ability to scan items accurately and provide correct pricing at all times.
6. Privacy and Security: Secure data handling was paramount for both shoppers and employees. Users sought assurance that their personal information and shopping behavior would be protected.

In summary, the Empathize Stage was instrumental in identifying and understanding user frustrations and needs. The insights gathered during this stage laid the foundation for the subsequent Define and Ideate stages, where these needs would be addressed through the development of the Smart Shopping Cart system.

# Define Stage

Analyzing User Needs and Defining the Problem

The Define Stage marks a pivotal phase in the Design Thinking process, where raw insights gathered during the Empathize Stage are transformed into specific, actionable problem statements. These problem statements serve as a clear guide for the design and development of a solution that will address the real and identified needs of users. This stage serves not only to solidify our understanding of the user needs but also to establish a framework upon which we can ideate and prototype the most effective solutions for the Smart Shopping Cart project.

Synthesis of Research Findings

The Empathize Stage revealed several key pain points faced by both consumers and retail staff in traditional shopping environments. These pain points were identified through a combination of primary and secondary research methods, including observational studies, user interviews, and in-store testing. By analyzing these findings, the team was able to synthesize the core issues that the Smart Shopping Cart system would need to address.

* Long Checkout Lines: Shoppers frequently express frustration with the amount of time spent waiting in line at checkout counters. These delays result in a negative shopping experience, and long checkout times have been shown to reduce customer satisfaction and loyalty.
* Inaccurate Billing and Pricing: Many shoppers experience issues with price discrepancies during checkout. Often, this occurs because of manual scanning errors or unscanned items. Customers also face difficulty in tracking the total cost of their items in real-time, which can lead to confusion and dissatisfaction.
* Difficulty in Product Location and Availability: A recurring issue highlighted by both customers and retail employees is the inability to locate products quickly. Furthermore, when customers are able to locate items, they often discover that stock levels are either inaccurately updated or the items are out of stock.
* Inventory Management Challenges: For retail employees, managing inventory in real-time presents a considerable challenge. Mismanagement of stock, whether due to overstocking or stockouts, leads to inefficiencies, misplaced items, and ultimately dissatisfied customers.

By addressing these challenges, the Smart Shopping Cart system could drastically improve the shopping experience for both consumers and retailers.

Analyzing User Needs and Pain Points

The next step in the Define Stage is to translate the research findings into a set of user needs. These needs are derived from the pain points identified during the Empathize stage and encapsulate the essential features that the Smart Shopping Cart must address. The user needs identified from our research are as follows:

1. Efficiency in Checkout: Consumers consistently express frustration over waiting in long checkout lines. With the increasing number of selfcheckout systems, there is a growing demand for technology that can reduce these wait times, providing a faster and more efficient alternative.
2. Accurate Billing and Real-Time Tracking: Customers want a more transparent shopping experience where they can track the total cost of their items as they add them to their cart. Inaccurate billing is a major pain point, and users require a system that provides real-time updates of the cart, ensuring that all items are correctly scanned and billed.
3. Real-Time Product Availability and Stock Updates: A major concern for shoppers is the availability of products they wish to purchase. Users need real-time stock updates so that they can make informed decisions on which items to purchase and avoid discovering that their desired products are out of stock after they’ve already added them to their cart.
4. Ease of Use and Accessibility: Consumers demand an intuitive and easyto-use shopping experience, especially given that the adoption of technology may vary across age groups and tech familiarity. An overly complicated system would detract from the user experience, making simplicity a key priority in the design.
5. Accurate and Reliable System: Users want to feel confident that the technology they are using is accurate and reliable. This includes the scanning of items, correct billing updates, and consistent inventory management. An error in any of these areas can compromise the user experience and reduce trust in the system.

Brainstorming Problem Statements

With these user needs in mind, the next step was to generate several possible problem statements that could guide the project towards meaningful solutions. Brainstorming is essential to explore different directions and determine which issue to prioritize. The following problem statements were brainstormed based on the user needs:

Problem Statement 1: Streamlining the Checkout Process

Shoppers often experience long wait times at the checkout, which detracts from their overall shopping experience. This issue is exacerbated in traditional retail environments, where manual barcode scanning and human error contribute to delays. The Smart Shopping Cart system could provide a solution by automating the checkout process, allowing users to track their total in real time and avoid waiting in long lines. By integrating RFID technology and real-time cart tracking, this system could expedite the checkout process and improve efficiency.

While this problem is certainly important, it does not fully address all of the needs identified in the Empathize Stage. Although reducing checkout times is a major improvement, the issue of inaccurate billing and the lack of real-time tracking could still cause significant frustration for users.

Problem Statement 2: Real-Time Cart Tracking and Accurate Billing

Shoppers often encounter unexpected billing discrepancies when they check out. This problem is caused by manual scanning errors or items that are not properly registered. Furthermore, many customers struggle with knowing the total cost of their cart in real time, leading to confusion and dissatisfaction. By implementing a real-time cart tracking system, users could view the running total of their cart as they shop, helping them stay informed and make better purchasing decisions. This solution would also automatically scan products as they are added to the cart, ensuring that all items are accounted for accurately and efficiently.

This problem statement resonates strongly with the key frustrations identified in the research and directly addresses the need for a more accurate and efficient shopping process. It not only addresses the billing issue but also ensures that users have full visibility into their cart and total costs at all times.

Problem Statement 3: Enhancing Product Availability and Stock Management

Retailers often struggle with managing product availability and stock levels. Shoppers experience frustration when they cannot locate products or when items are out of stock. This problem can be mitigated through real-time stock updates, ensuring that both shoppers and retail staff have access to up-to-date information about the availability of products. An RFID-based system would allow products to be automatically scanned as they are added to the cart, providing real-time inventory data and preventing stockouts.

While this problem is valid, it primarily addresses the operational challenges faced by retailers, rather than directly solving the consumer pain points. Therefore, while important, it is not as critical to the end-user experience as the issues related to billing and cart tracking.

Refining and Selecting the Final Problem Statement

Once the problem statements were developed, the next step was to evaluate them in light of the project’s goals and user needs. To determine the most impactful problem to address, we considered factors such as user experience, technical feasibility, and alignment with the insights from the Empathize Stage.

* Problem Statement 1 is important, but it focuses on reducing wait times during checkout, which can be achieved through various existing solutions like self-checkout systems or automated kiosks. While it is still valuable, it doesn’t directly tackle the user needs related to accurate billing and real-time cart visibility.
* Problem Statement 2 stands out as the most critical. It addresses the most common pain points that users experience, such as inaccurate billing, lack of cart visibility, and frustration with the checkout process. Real-time cart tracking and accurate billing are not only central to improving the shopping experience, but they also align with the core technology of the Smart Shopping Cart, such as RFID and Bluetooth communication. This solution directly addresses user concerns about transparency and reliability, making it the most pressing problem to focus on.
* Problem Statement 3 addresses stock management and product availability, but its focus is more on the operational challenges of retailers than on improving the customer shopping experience. While enhancing stock visibility is important, it is not as immediate a concern for consumers compared to issues like billing discrepancies and tracking.

Final Problem Statement:

After analyzing the various options, the final problem statement selected is:

“Shoppers face long checkout lines and inaccurate billing due to manual scanning and untracked product additions. A solution is needed that enables real-time cart tracking, accurate billing updates, and automatic scanning of products as they are added to the cart. This solution should provide users with complete visibility of their shopping cart total and ensure that all items are accurately scanned and accounted for, reducing wait times and enhancing the overall shopping experience.”

This problem statement was chosen because it directly addresses the user needs for efficiency, accuracy, and real-time tracking, making it the most impactful and feasible issue to tackle in the Smart Shopping Cart project.

# Ideation Stage In design thinking for Smart Shopping Cart System

The **Ideation Stage** is the creative phase of the Design Thinking process, where the team develops and refines ideas that can address the problem identified in the **Define Stage**. This stage is crucial for generating a wide variety of potential solutions, analyzing them, and selecting the one that best meets user needs. The goal is to come up with innovative, user-centered solutions that can be tested and iterated on in the prototyping stage. In this phase, we will analyze the selected **Problem Statement**, conduct brainstorming sessions, use mind mapping, and select the most feasible and impactful solution for the **Smart Shopping Cart** project.

# Analyzing the Problem Statement

The problem identified in the **Define Stage** centers around the need for a more efficient and accurate shopping experience, particularly addressing:

* **Long checkout lines** and **manual scanning errors** leading to **inaccurate billing**.
* **Inadequate real-time tracking** of products in the cart, which prevents users from knowing their total cost and tracking the accuracy of scanned items.
* **Frustration from the lack of visibility into stock levels** and the uncertainty about product availability.

The selected **Problem Statement** that we are addressing is:

**“Shoppers face long checkout lines and inaccurate billing due to manual scanning and untracked product additions. A solution is needed that enables real-time cart tracking, accurate billing updates, and automatic scanning of products as they are added to the cart. This solution should provide users with complete visibility of their shopping cart total and ensure that all items are accurately scanned and accounted for, reducing wait times and enhancing the overall shopping experience.”**

Now that we have clearly defined the problem, it’s time to ideate potential solutions. In this stage, we will focus on generating a broad range of ideas, analyzing them, and selecting the best solution that aligns with user needs and project constraints.

# Mind Mapping

To facilitate idea generation, we began by creating a mind map that explores different facets of the problem and potential solutions. A mind map is a visual representation that links concepts and ideas together, allowing us to see connections and potential innovations. Here's how the mind map looks:

1. **Checkout Process**:
   * **Reduce Wait Times**: Automated checkouts, self-checkout systems, mobile app integration. o **Real-time Tracking**: Users can track their cart’s total during the shopping process. o **Mobile Integration**: Allow users to use their smartphones to interact with the cart and complete purchases.
2. **Product Scanning**:
   * **RFID Technology**: Ensure automatic scanning of products as they are placed in the cart. o **Barcode Scanning via Mobile**: Use the shopper’s smartphone camera to scan products directly.
   * **Integration with POS Systems**: Seamless transition between cart scanning and checkout at the payment terminal.
3. **Inventory Management**:
   * **Real-time Stock Updates**: Users are notified when products are low in stock or unavailable.
   * **In-Store Navigation**: Integration of an app that helps users find the location of products in-store based on real-time inventory data.
4. **User Experience**:
   * **Intuitive User Interface**: Easy-to-use interface for all age groups. o **Clear Pricing Information**: Ensure transparency in pricing throughout the shopping process. o **Security Features**: Ensure secure payment transactions and protect user data.

Through the mind mapping process, we identified several key areas to focus on: real-time cart tracking, automatic scanning, efficient checkout, and user-friendly interface design.

# Brainstorming Ideas

Following the mind-mapping exercise, we conducted a brainstorming session with the project team. The session focused on generating ideas that would help us address the core problem statement effectively. Here are the results of the brainstorming session:

# Idea 1: RFID-Based Smart Cart with Mobile Integration

* The **RFID technology** embedded in the shopping cart automatically scans products as they are placed inside, eliminating the need for manual scanning.
* Users can track the running total of their cart in real time through a mobile app that connects to the cart via Bluetooth.
* The mobile app would allow users to view product details, including price, stock availability, and discounts, all while keeping an updated total.
* Once the user completes shopping, they can check out directly through the app, using mobile payment methods or integrating with self-checkout kiosks.

# Idea 2: Smart Cart with Barcode Scanning and Integrated POS System

* The **Smart Cart** would feature a mobile app that allows users to scan product barcodes using their smartphone’s camera.
* A seamless integration with existing **Point of Sale (POS) systems** ensures that all scanned items are accurately tracked.
* The app would display product information, including price, available stock, and potential discounts, and users can view the running total during their shopping session.
* At checkout, the app would automatically sync with the store’s POS, allowing for a quick and smooth payment process.

# Idea 3: Mobile Shopping App with Real-Time Stock Updates and In-Store Navigation

* The mobile app could provide users with real-time **inventory updates** to show product availability in-store.
* It would offer **in-store navigation**, guiding customers to the specific location of items in large retail spaces.
* The app would allow users to add products to their cart digitally and view real-time updates on stock levels, while offering a running total of the cart.
* Once shopping is complete, users can either pay directly through the app or proceed to a self-checkout kiosk.

# Idea 4: Smart Cart with Mobile Self-Checkout and Enhanced Security Features

* This solution integrates **mobile self-checkout** with enhanced security features such as encryption for payments and personal data.
* The smart cart would allow users to scan products via their mobile app and view their cart’s running total in real-time.
* Once shopping is completed, users can check out via the app, paying through secure payment methods, such as Apple Pay, Google Pay, or credit card integration.
* Enhanced security protocols would be built into the app, ensuring a secure and private shopping experience.

# Selecting the Best Idea

After evaluating all the ideas based on their potential to address the problem statement, the feasibility of implementation, and their alignment with user needs, **Idea 1: RFID-Based Smart Cart with Mobile Integration** was selected as the best solution.

This solution addresses the core issues of **automatic product scanning, realtime cart tracking, and efficient checkout**. The integration of RFID technology ensures that products are scanned quickly and accurately, eliminating errors and reducing wait times at checkout. The mobile app allows for seamless tracking of the shopping cart and total, providing users with transparency throughout the shopping experience.

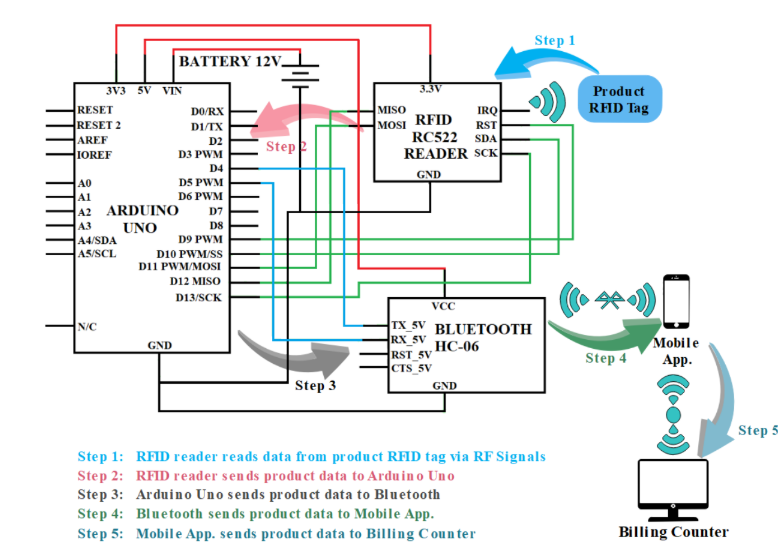
Although it comes with a higher initial cost for RFID technology, the benefits of streamlining the checkout process and improving the overall user experience make it the most promising solution.

# Value Proposition Statement

The **Value Proposition Statement** for the **Smart Shopping Cart** system is as follows:

**“Our Smart Shopping Cart system offers a seamless, error-free, and efficient shopping experience by integrating RFID technology with mobile app functionality. The system allows users to track their cart in real-time, ensuring accurate billing and up-to-date product availability. With reduced checkout times and an intuitive user interface, we are transforming the traditional shopping process into a faster, more enjoyable, and transparent experience for shoppers, while improving inventory management for retailers.”**

# Prototype Stage: Development and Evaluation of the Smart Shopping Cart System



The **Prototype Stage** represents a crucial phase in the development of the **Smart Shopping Cart system**, where we transitioned from conceptualizing our ideas to designing, developing, and testing an early working version of the system. This stage enabled us to bring together the various technological and user-centric components of the solution, creating a tangible model for evaluation and refinement.

Our prototype integrates **RFID-based scanning**, a **mobile app interface**, and a **real-time stock and cart management system**, providing an immersive and practical shopping experience for users. The goal was to create a seamless shopping cart experience that helps users manage their purchases while ensuring an efficient and personalized approach to inventory and cart management.

This stage focuses on testing how well our concept works in real-world conditions and gathering feedback to refine the system. By integrating **hardware and software components**, we aimed to build a prototype that delivers both **functional and emotional value** for users, particularly mothers, by reducing stress during shopping and creating an efficient, interactive experience.

**Primary Objectives of the Prototype Stage:**

* **To develop a realistic and immersive smart shopping cart experience** that aligns with the real-world shopping experience.
* **To integrate hardware-based RFID scanning technology** with a mobile application for seamless interaction and inventory management.
* **To test the system with real users** in a controlled environment to identify areas for improvement and refinement based on user feedback.

**1. Prototype Description**

The **Smart Shopping Cart Prototype** is composed of two main components:

 **RFID-based Smart Cart and Scanning System**

#  Mobile App for Cart Management and Inventory Control A. RFID-Based Smart Cart and Scanning System

The primary feature of the **Smart Shopping Cart system** is the **RFID scanning** mechanism. By incorporating **RFID tags** on each product, the system can automatically detect and register the products placed inside the cart without manual input. This helps in reducing human error during the checkout process, improving efficiency, and providing an interactive experience for the shopper.

1. **RFID Tagging and Scanning:**
   * **RFID Tags**: Each product in the store is assigned a unique **RFID tag** containing the product's information, such as its name, price, and stock level.
   * **RFID Scanner**: The smart shopping cart is equipped with an **RFID reader**, which continuously scans for products within the cart. As items are added, the system updates the user’s cart in real-time on the mobile app.
2. **Cart Management Features:**
   * **Automatic Cart Updates**: As products are added, the cart's total and item count automatically update on the mobile app.
   * **Stock Control**: The system ensures that the **stock levels** are correctly adjusted as items are added or removed from the cart, both on the mobile app and in the store’s inventory system.
   * **Real-Time Feedback**: The mobile app displays the total price and provides options to adjust quantities or remove items from the cart.
3. **User Interaction:**
   * The cart also includes physical **+ and - buttons** for manual adjustment of quantities, providing users with more control over their cart items.
   * Users receive **visual and auditory cues** when items are successfully added or removed, enhancing the interaction.

# B. Mobile App for Cart Management and Inventory Control

The accompanying mobile app is designed to interact with the RFID system and provide users with real-time information about their cart and the products they are purchasing.

1. **User Interface and Experience:**
   * **Cart Overview**: The app displays a **running total** of all items in the cart, along with product names, prices, and quantities.
   * **Product Information**: Users can click on any product in the cart to view detailed information, including product images, prices, and stock availability.
   * **Checkout Process**: When users are ready to checkout, the app integrates with the store’s POS system to complete the transaction seamlessly, either through mobile payment methods or traditional credit card payments.
2. **Stock and Cart Management:**
   * **Real-Time Stock Tracking**: The app continuously updates product stock levels in the background, ensuring users are always aware of product availability. In the event that a product runs out of stock, the app notifies the user and automatically removes the item from the cart.
   * **User Profile and Preferences**: The app can store user preferences and shopping history, allowing for more personalized shopping experiences in future visits.

# 2. Prototype Development Process

The development process for the Smart Shopping Cart system involved the integration of both **hardware** (RFID scanner and cart interface) and **software** (mobile app and backend management system).

# A. RFID-Based Smart Cart System

1. **RFID Tagging and Scanning**:
   * **Tagging Process**: Products were tagged with RFID chips that were linked to a unique identifier in the store's database. This allowed the RFID reader to scan and match products with their respective data in real-time.
   * **Scanner Integration**: The RFID reader was integrated into the shopping cart, with sensors embedded to detect the tags as products were placed in the cart. The system continuously updated the cart’s content, eliminating the need for manual input.
2. **Real-Time Cart Synchronization**:
   * The system continuously synced the cart’s content with the **mobile app** and updated the inventory system in real-time to reflect the changes as products were added or removed from the cart.

# B. Mobile App Integration

1. **UI/UX Design**:
   * The app's user interface was designed to be intuitive and simple, with features such as a **cart overview**, **product details**, and **checkout options** readily accessible. The user experience was prioritized, ensuring ease of navigation.
2. **Backend System Integration**:
   * The backend of the app was linked to the store’s **inventory management system** to provide real-time updates on stock levels. This integration ensured that as items were added to the cart, the corresponding product data was pulled from the store’s database.

# 3. Prototype Evaluation

The prototype was tested by a group of **real users** in a controlled environment to gather feedback on functionality, usability, and overall user experience.

# A. User Testing Process

A small group of participants was selected to use the **Smart Shopping Cart system** in a simulated shopping environment. The goal was to evaluate the RFID scanning process, the accuracy of real-time cart management, and the overall interaction with the mobile app.

**Key Testing Areas:**

* **RFID Scanning Accuracy**: Ensuring that products were correctly identified as they were added to the cart.
* **User Interface**: Evaluating the ease of navigation and interaction with the mobile app.
* **Real-Time Cart Updates**: Ensuring that the app’s cart reflected the correct product count and price in real-time.
* **User Feedback**: Gathering input on the shopping experience, including ease of use, helpfulness of notifications, and any issues faced during the process.

# B. Key Findings from User Testing

* **Strengths**:
  + **Ease of Use**: Test users found the system easy to use, with the RFID scanner working reliably to update the cart in real-time.
  + **Efficiency**: The automatic updating of the cart’s contents was wellreceived, as it reduced the need for manual input and sped up the shopping process.
  + **Interactive Features**: The visual and auditory feedback provided by the app (such as product addition/removal notifications) helped guide the user throughout the experience.
* **Areas for Improvement**:
  + **Connectivity Issues**: Some users experienced minor delays between the RFID scanner and the app during the initial scans. This was addressed by refining the Bluetooth or Wi-Fi connection.
  + **UI/UX Enhancements**: While the app’s interface was generally well-received, users suggested improving the clarity of the **checkout process** and offering more options for customizing the **cart overview** page.
  + **Stock Notifications**: Users requested more detailed notifications on stock availability, such as the **exact number of items remaining** in the store.

# 4. Value Proposition Statement

“Our Smart Shopping Cart system offers an innovative solution for modern retail experiences by seamlessly integrating RFID technology and real-time mobile app management. This system eliminates the need for manual scanning and cart management, improving efficiency and reducing errors during shopping. By providing instant access to product information, stock updates, and dynamic cart adjustments, our system creates a frictionless shopping experience. The Smart Shopping Cart not only simplifies the shopping process but also enhances customer satisfaction and reduces checkout time, making it an essential tool for both retailers and shoppers.”

# Test and Feedback

During the prototype testing phase of our **Smart Shopping Cart**, we collected feedback from team members, external testers, and potential users (shoppers and store employees) to evaluate the functionality, usability, and real-world effectiveness of the system. This phase was vital in identifying strengths, limitations, and areas for improvement.

# 1. Feedback from Team Members

Our internal team conducted multiple test runs to ensure proper functionality of the RFID scanner, Firebase updates, Bluetooth auto-connect, and real-time UI interaction. Key observations included:

* The cart UI updated in real-time when an RFID tag was scanned, which was a major positive.
* Auto-connection with the HC-06 Bluetooth module worked reliably, but occasionally took a few extra seconds.
* The product count would sometimes exceed the available stock, which needed validation.
* UI transitions (such as after login and scanning) felt a bit abrupt and could be made smoother.

# 2. Feedback from Other Team Members (Cross-Team Evaluation)

We invited students working on parallel IoT and app-based projects to evaluate our prototype. Their feedback included:

* The Firebase structure was well-organized, with a clear distinction between the global products collection and per-user Cart subcollections.
* They suggested adding a sound or vibration response after each RFID scan to reassure users the item was added.
* Highlighting stock issues (e.g., turning the card red if stock is exceeded) was appreciated and could be expanded with pop-up warnings.
* Recommendation to limit item count decrease only via physical ‘-’ button for better control.

# 3. Feedback from Users (Potential End-Users)

We conducted a small-scale test with five regular users (college students acting as shoppers). They interacted with the smart cart under simulated retail conditions. Their input included:

* Most users found the system easy to use and appreciated the immediate feedback on scanned items.
* They loved seeing the total cost and individual item counts update in realtime.
* Some users faced initial confusion when scanning the same item multiple times—suggested a notification or alert when stock is low.
* One user mentioned that the app should automatically log out after checkout to prevent cart confusion for the next user.

# 4. Key Takeaways and Next Steps

* **Improve Feedback Mechanism**: Add visual and/or sound confirmation when an RFID tag is scanned.
* **Refine Stock Handling**: Validate count updates against original stock and disable further additions if the limit is reached.
* **Enhance UI Transitions**: Make UI transitions smoother, especially after Bluetooth connection or logout.
* **Auto Logout Option**: Implement an automatic logout or session reset after successful payment.
* **User Customization**: Allow users to view their cart history and total savings to enhance shopping experience.

# Re-Design and Implementation

Based on the feedback collected during the testing phase, we made significant improvements to the design and functionality of our **Smart Shopping Cart** system. Our primary goal was to enhance the reliability of the product scanning process, ensure accurate stock and count updates in Firestore, and improve the user interface for a smoother shopping experience. This re-design phase was crucial to refine the initial prototype and make it more user-friendly and efficient.

# 1. Refinements in Firestore Data Handling

During initial testing, one of the key issues identified was the shared count field being updated globally in the products collection. This caused confusion when multiple users used the system back-to-back. While we haven't yet implemented a per-user cart, we optimized how the global products collection is used:

* **Resetting Count on Logout**: The system now resets all product count values to 0 after each successful payment and logout, ensuring no data carries over to the next user.
* **Stock Adjustment**: The stock field now decreases only when the user confirms checkout, avoiding accidental inventory reduction.
* **RFID Accuracy**: We improved the matching logic for scanned RFID tags, ensuring they consistently update the correct product in Firestore.

# 2. UI/UX Improvements

Initial users noted that the product count updated in Firestore but wasn't reflected in the app interface unless buttons were manually pressed. To fix this:  **Live Count Updates**: When a product is scanned via RFID, the count now updates **instantly in the UI** as well as Firestore.

* **UI Feedback**: When the scanned product exceeds available stock, it is now **highlighted in red**, and the system **disables further additions** until stock is reset or reduced.
* **Simplified Design**: We reworked the cart screen to clearly show product name, count, and stock side-by-side for easier management.

# 3. Improved Hardware and Bluetooth Handling

To make the shopping cart smarter and more seamless, we focused on the integration between the RFID scanner, HC-06 Bluetooth module, and the Android app:

* **Auto-Bluetooth Connection**: The app now **automatically connects** to the HC-06 module on startup.
* **Navigation Flow**: Once connected, the app transitions **automatically to the login screen**, removing manual steps.
* **Stable Data Transfer**: We added logic to prevent duplicate scans or missed scans during rapid item additions.

# 4. Backend Logic Enhancements

We also made back-end improvements to ensure that inventory and cart logic are handled more reliably:

* **Stock Control**: Products cannot be added beyond available stock. If a scanned product is already at its stock limit, the count does not increase.
* **Transaction Safety**: We introduced atomic updates to prevent race conditions when multiple fields are updated together (count, stock, etc.).

# Conclusion

The development of a Smart Shopping Cart system leveraging RFID technology, Bluetooth communication, and Firebase database services marks a significant step toward transforming the traditional retail experience through digitization and automation. In an age where convenience and efficiency are key drivers in consumer behavior, this project aimed to streamline the shopping process, reduce manual billing overhead, and provide a real-time inventory management system accessible through a mobile application.

By applying the **Design Thinking approach**, we ensured that the system was developed with a user-centered mindset, focusing on practical pain points such as product tracking, stock accuracy, and checkout delays. Through iterative prototyping, feedback collection, and refinement, the project evolved from a basic hardware interaction prototype into a cohesive, semi-automated shopping assistant that aligns with modern retail expectations.

The system integrates hardware components like RFID readers and the HC-06 Bluetooth module with Firebase’s cloud-based database and Android-based user interface. It enables users to scan items using RFID tags, automatically track product quantities, and adjust the cart in real-time, all while keeping backend stock values up-to-date. Additional features like auto-reset of counts on logout, prevention of stock overflows, and UI enhancements further increased the robustness and user-friendliness of the system.

# Achievements and Key Contributions

Throughout the project lifecycle, the Smart Cart system achieved several key milestones that reflect its practical relevance and technical feasibility:

* **Hardware-Software Integration:** Successfully interfaced the RFID module with an Android app via Bluetooth, enabling seamless product detection and data transfer.
* **Real-Time Inventory Tracking:** Implemented Firestore-based product count and stock updates, reflecting changes instantly in the UI upon RFID scans.
* **Auto Reset and Stock Validation:** Designed logic to reset product counts post-checkout and restrict item additions when stock limits are reached, ensuring system reliability.
* **UI/UX Enhancements:** Introduced live feedback through visual cues and real-time cart updates to enhance user experience and system transparency.
* **Bluetooth Automation:** Streamlined the shopping experience by enabling automatic Bluetooth connection and app navigation, minimizing user input and improving flow.

# Challenges Faced and Lessons Learned

The journey to develop the Smart Shopping Cart system was not without its challenges. Each hurdle provided valuable insights and opportunities for learning:

# 1. Lack of User-Specific Cart Storage

o Initially, product counts were globally updated in the products collection, creating issues in multi-user scenarios. o This challenge highlighted the importance of designing per-user data structures for privacy and session management.

# 2. Real-Time UI Inconsistencies

o The product count was updating in the backend but not instantly reflected in the UI. o By integrating real-time listeners, we ensured data synchronization between Firestore and the frontend.

# 3. Stock Management Logic

o Implementing logic to prevent stock underflow and overflow required careful backend handling and atomic transactions.

# 4. Hardware Synchronization

o Ensuring stable Bluetooth communication and avoiding duplicate scans required additional error-handling mechanisms in the data pipeline.

These challenges taught us the importance of **scalable architecture**, **real-time data integrity**, and **user experience design**, especially when hardware and software interact closely.

# Impact and Potential Future Developments

While the current prototype provides a strong foundation for a smart, digitized cart system, there remains vast potential for further development:

# 1. User-Specific Cart System

o Future versions will introduce users/{uid}/Cart/{productId} subcollections to ensure personalized shopping sessions and multiuser support.

# 2. Payment Gateway Integration

o Integrating secure payment options within the app would streamline the checkout process and reduce cashier dependency.

# 3. Admin Dashboard

o A centralized dashboard to view, update, and restock products can give retailers real-time control over inventory.

# 4. Analytics and Personalization

o The system can be enhanced with machine learning to suggest frequently bought products, offer discounts, and personalize user experience.

# 5. IoT Expansion

o Integration with smart shelves and automatic billing counters could further automate the retail ecosystem.

# Future Work

While the current implementation of the Smart Shopping Cart successfully addresses several key issues in modern retail, it also opens up opportunities for enhancement, scalability, and integration with advanced technologies. The following areas are identified as potential directions for future work:

# 1. User-Specific Cart System

Currently, the cart system shares a common product count across users. A more scalable solution would involve implementing individual cart collections under each user's UID in Firestore (users/{uid}/Cart/{productId}), allowing for:

* **Personalized Shopping Sessions**
* **Multi-user Support**

#  Secure and Private Cart Management

This architecture is essential for supporting concurrent usage in real-world retail environments.

# 2. Payment Gateway Integration

Integrating a secure payment module would allow users to:

* Complete purchases directly within the app
* View itemized billing information
* Receive digital receipts
* Integrate loyalty points or discount coupons

Popular options like Google Pay, Razorpay, or Stripe could be explored for seamless in-app transactions.

# 3. Admin Panel and Inventory Dashboard

Creating a web-based admin dashboard would enable store staff to:

* Monitor live stock levels
* Add, update, or delete product entries
* View analytics (popular items, peak times)
* Track user activity and transactions

This feature would enhance real-time inventory management and reduce manual effort.

# 4. Enhanced UI/UX and Accessibility

Future versions can focus on improving:

* Visual feedback for product actions (e.g., animations or haptics)
* Voice-guided assistance for visually impaired users
* Multilingual support for diverse audiences
* Dark mode and high-contrast themes for better accessibility

# 5. Offline Mode and Local Caching

In scenarios where internet connectivity is unstable, implementing:

* Local caching of product data
* Background sync to Firebase when reconnected
* Offline transaction logging

This ensures that the shopping process remains uninterrupted and reliable.

# 6. IoT and Sensor Integration

Expanding the hardware ecosystem could include:

* **Weight sensors** to verify item presence in the cart
* **Smart shelves** that auto-update inventory when items are removed
* **Barcode/NFC support** alongside RFID for hybrid compatibility

This would improve accuracy and expand the system’s use across various product types.

# 7. AI-Based Product Recommendations

By analyzing a user's shopping history and behavior, future enhancements could include:

* Personalized product suggestions
* Budget-friendly alternatives
* Smart shopping lists

This would enrich the user experience and mimic features found in top-tier ecommerce platforms.

# 8. Security and Authentication Enhancements

To prevent unauthorized usage and enhance data protection, future features may include:

* OTP-based login or biometric authentication
* Encrypted Bluetooth communication
* Role-based access control for admin functions

# 9. Cross-Platform Support

Expanding the app to support:

* iOS devices
* Tablets or touch-enabled kiosks
* Web-based cart access

This would allow broader accessibility and user adoption.

# 10. Field Testing and Scalability Trials

Finally, deploying the system in a real retail setting will allow:

* Identification of edge cases and performance bottlenecks
* User feedback collection at scale
* Evaluation of system stability under concurrent use

These trials will be crucial for commercial deployment and certification.

# 12. Learning Outcome of Design Thinking

The implementation of the Design Thinking methodology in our Smart Shopping Cart project provided us with deep insights into user-centered innovation, rapid problem-solving, and iterative development. This approach helped us create a solution that not only addressed technical challenges but also aligned with real user needs. The following key learning outcomes emerged through the stages of Design Thinking:

# 1. Empathy and User-Centered Design

* We learned the importance of **deeply understanding users**—in this case, retail shoppers and store managers—before attempting to solve a problem.
* Engaging with potential users allowed us to identify pain points like **inefficient billing**, **long checkout queues**, and **inventory mismanagement**.
* This empathy stage helped us build a product that offers **real value** to end-users rather than just technical novelty.

# 2. Problem Framing and Reframing

* The Design Thinking process taught us to **reframe the problem** from “how to build a smart cart” to “how to improve the shopping experience using technology.”
* This shift in perspective enabled us to consider **broader solutions**, such as UI design, Bluetooth connectivity, and inventory syncing, instead of focusing only on RFID scanning.

# 3. Ideation and Creativity

* In the ideation phase, we practiced **divergent thinking**, exploring multiple possible solutions to improve usability, efficiency, and accuracy.
* Brainstorming sessions fostered a **creative mindset**, pushing us to think beyond conventional retail solutions and incorporate automation, realtime UI updates, and smart stock handling.

# 4. Prototyping with Agility

* We gained hands-on experience in **rapid prototyping**, learning how to build functional models quickly using Firebase, RFID, and Android components.
* The iterative nature of prototyping encouraged us to **fail fast and learn faster**, making necessary changes to hardware-software integration and database logic.

# 5. Importance of Testing and Feedback

* Testing exposed **flaws in our design**, including shared cart states, UI lags, and Bluetooth stability—issues we may not have discovered without real user interaction.
* Feedback loops guided our redesign efforts, reinforcing the value of **continuous improvement** based on real-world usage and not assumptions.

# 6. Flexibility in Redesign

* We learned that **no design is final**. By applying user feedback, we redesigned parts of the system—like count reset logic, UI updates, and stock validation—to better suit user needs.
* This phase emphasized the importance of **adapting and iterating** rather than sticking rigidly to initial plans.

# 7. Collaborative and Interdisciplinary Thinking

* Design Thinking encouraged **cross-functional collaboration**, requiring us to combine knowledge from programming, electronics, UI/UX, and business strategy.
* This reinforced the idea that real-world solutions require a **holistic, multidisciplinary approach**.

# 8. Mindset Shift from Product to Experience

* Perhaps the most significant learning was the shift in mindset—from simply building a product to **crafting an experience**.
* We now understand that **designing for emotion, ease, and efficiency** is just as important as the technical solution itself.

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