Supervised by:

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Automated Checkout System Using RFID

ShopNgo

Your journey to smart shopping starts here!

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1. **Abstract**

The increasing demand for efficiency and convenience in supermarkets has highlighted the need for automation and reduced reliance on human resources. Traditional shopping methods often lead to inefficiencies, such as long checkout queues, difficulty in inventory management, and suboptimal customer experiences. Our project aims to address these challenges by automating the shopping process using RFID technology.

We propose an innovative solution where RFID chips are embedded in products, and RFID readers are integrated into shopping carts. As customers add items to their carts, the RFID readers automatically scan the chips, updating the database in real time. A mobile application accompanies this system, enabling customers to track their selected products, view their total bill, and complete payments using their cards. The system also includes an inventory management feature for supermarket administrators to monitor stock levels and optimize operations.

Additionally, artificial intelligence will be utilized to analyze data from RFID scans, providing insights into shopping patterns, peak hours, and product popularity. These insights can help supermarkets enhance customer satisfaction and improve operational efficiency. The project combines RFID technology, mobile application development, and AI-driven analytics to create a seamless, automated shopping experience.

2. **Background**

Supermarkets face numerous challenges in delivering a smooth shopping experience, managing inventory effectively, and optimizing operational costs. Traditional systems often rely heavily on human resources, leading to inefficiencies such as long checkout lines, human errors, and outdated inventory management methods. These inefficiencies can affect customer satisfaction and increase operational expenses, making it essential to explore innovative solutions.

2.1. Motivation

The primary motivation for this project is to revolutionize the shopping experience by automating critical supermarket operations. By leveraging RFID technology and artificial intelligence, we aim to create a seamless process that benefits both customers and supermarket administrators. Automating the shopping and inventory processes not only enhances efficiency but also provides a modern, tech-enabled shopping environment that aligns with customer expectations in today's digital age.

2.2. Beneficiaries

- **Customers:** Will benefit from reduced checkout times, improved convenience, and a better shopping experience.
- **Supermarket Administrators:** Will gain real-time visibility into inventory, reduced labor costs, and valuable insights into consumer behavior.

2.3. Main Techniques

- **RFID Technology:**
  - RFID chips embedded in products for automatic identification and tracking.
  - RFID readers integrated into shopping carts to detect and record items.
- **Mobile Application Development:**
  - Customer-facing app for tracking scanned items, viewing totals, and completing payments.
  - Admin-facing app for inventory management and data analysis
- **Artificial Intelligence:**
  - AI algorithms to analyze shopping patterns, peak times, and product demand.
- **Database Management:**
  - Real-time database updates for seamless synchronization of inventory and sales data.

2.4. Main Application

This system will be primarily applied in supermarkets, where automation can address common pain points like long checkout queues, inventory inaccuracies and reliance on human resources. It also holds potential for adaptation in other retail environments, such as department stores and wholesale outlets, where RFID-based automation can improve efficiency and customer satisfaction.

3. **Related Work**

- **Amazon Go**
  - Uses a combination of cameras, weight sensors, and computer vision to enable a cashier-less shopping experience. Customers scan their app upon entry, pick up items, and leave without a traditional checkout process. Payments are automatically deducted from their accounts.
  - **Limitations:** High implementation costs due to advanced infrastructure like cameras and sensors; privacy concerns due to the use of surveillance technology.
- **Tesco's RFID Deployment**
  - Tesco, a major UK retailer, uses RFID for tracking inventory in their supply chain rather than in stores. Products like clothing are tagged with RFID to improve stock accuracy and reduce out-of-stock incidents.
  - **Successes:** Enhanced supply chain visibility, reduced inventory errors, and streamlined restocking.
  - **Limitations**: Limited to backend operations and does not directly improve the customer experience or checkout process.
- **Walmart's Smart Inventory System**
  - Walmart uses RFID to manage inventory at the store level. Products are tagged with RFID, and handheld or fixed readers monitor stock levels in real time.
  - **Successes**: Improved inventory management and faster restocking.
  - **Limitations**: Does not extend to customer-facing processes like automated checkout.
- **Sephora's RFID-Based Customer Experience**
  - Sephora, a global cosmetics retailer, incorporates RFID technology in their stores to allow customers to scan product tags using kiosks or apps for additional product details and recommendations.
  - **Successes**: Enhances customer interaction and improves product discovery.
  - **Limitations**: Limited scalability to larger supermarkets and does not address checkout automation.

3.1. Insights from Examples

From these examples, it is clear that while RFID technology has been used in various aspects of retail, gaps such as high costs, scalability issues, and integration with customer-facing processes remain common challenges. Our project seeks to address these issues by:

- Combining **affordable RFID technology** with mobile applications.
- Providing **real-time updates** to customers and administrators.
- Integrating **AI for analytics**, enhancing inventory management, and providing business intelligence.

3.2. Gaps in Current Solutions

- **Limited Customer-Facing Integration**
  - Solutions like **Tesco's RFID Deployment** and **Walmart's Smart Inventory System** focus primarily on backend operations such as inventory tracking and restocking. They do not extend RFID's capabilities to customer-facing processes like automated checkout or real-time price tracking.
  - **Our Project's Approach**: By integrating RFID readers directly into shopping carts and connecting them to a mobile application, customers can track scanned items, view real-time totals, and streamline the checkout process without requiring cashier intervention.
- **Cost and Scalability**
  - High implementation costs for solutions like **Amazon Go**, which use cameras, sensors, and advanced AI, make them inaccessible to mid-sized supermarkets or businesses with limited budgets.
  - **Our Project's Approach**: By using affordable RFID technology, our project reduces costs while maintaining the benefits of automation. The cart-based RFID system is easily scalable for supermarkets of various sizes.

- **Checkout Automation**
  - Solutions like **Walmart's Smart Inventory System** and **Sephora's RFID-Based Experience** do not fully automate the checkout process. Customers still rely on traditional or self-checkout systems, requiring manual intervention.
  - **Our Project's Approach**: Automating the checkout process completely eliminates the need for manual scanning at self-checkout counters, saving time and reducing queues.
- **Unified System for Customers and Administrators**
  - Most solutions, such as **Tesco's RFID Deployment** and **Walmart's Inventory System**, focus on either customer experience or backend operations but not both.
  - **Our Project's Approach**: The system integrates customer-facing features (real-time product tracking, payment) with administrative tools (inventory management, restocking alerts) in a single mobile application, providing value to both parties.
- **Data Analytics and Insights**
  - Solutions like **Sephora's RFID-Based Customer Experience** enhance interaction but do not leverage collected data for analytics or business intelligence.
  - **Our Project's Approach**: By incorporating AI-driven analytics, our project utilizes RFID data to generate insights into shopping patterns, peak hours, and popular products, enabling supermarkets to optimize stock and marketing strategies.
- **Scalability to Small or Diverse Retail Formats**
  - Solutions like **Amazon Go** are designed for highly controlled environments with limited product types and store formats, making them less suitable for large, diverse supermarkets.
  - **Our Project's Approach**: The cart-based RFID system is adaptable to stores of various layouts and product ranges, from small grocery stores to large supermarkets, making it a versatile and scalable solution.
- **Customer Privacy Concerns**
  - Solutions such as **Amazon Go**, which rely on surveillance technologies like cameras, raise significant privacy concerns.

- **Our Project's Approach**: By focusing solely on RFID and mobile app integration, our system ensures customer privacy by avoiding invasive tracking technologies.

- **Interactive Customer Engagement**

- Current solutions like **Tesco's RFID Deployment** or **Walmart's System** do not provide interactive features for customers during shopping, such as product recommendations or nutritional information.

- **Our Project's Approach**: The mobile app provides an interactive shopping experience, offering details about scanned products, discounts, and personalized recommendations, enhancing customer engagement.

4. **Integration of RFID Chips in the System**

- **Tagging Products**

- Each product in the supermarket will be tagged with a unique RFID chip.

- These tags will store essential information such as:

- Product ID (a unique identifier).

- Product name.

- Price.

- Category (e.g., perishable, household, electronics).

Process

- Tags can be embedded in packaging, labels, or directly attached to the product.

- For small products, **miniature RFID tags** will be used to ensure they do not interfere with the product's usability.

- **RFID Readers in Shopping Carts or Kiosks**

- Shopping carts will be equipped with fixed RFID readers.

- The reader scans RFID tags automatically when products are placed in or removed from the cart.

Process

- When a product with an RFID tag enters the cart's range, the reader detects it and retrieves the tag's data.
- The data is sent to the cart's onboard system and synchronized with the central database.

Features

- Real-time updates: The product is added to the customer's virtual cart, and the total price is updated in the accompanying mobile app.
- Automatic removal: If a product is taken out of the cart, the system removes it from the virtual cart.

- **Automating Checkout**

- The RFID-enabled cart eliminates the need for manual scanning.
- Once shopping is complete, customers can proceed to payment via a mobile application linked to their cart.

Process

- At checkout, the mobile app displays the total bill, reflecting all scanned items.
- Customers confirm their purchase and pay using saved payment methods (e.g., credit/debit cards or digital wallets).
- After payment, the system marks the RFID tags as "purchased" in the database.

Advantages

- No queues: Customers bypass traditional checkout lines.
- Speed: Multiple items can be scanned simultaneously by the RFID reader, reducing time compared to barcode scanning.

- **Inventory Tracking and Restocking**

- RFID tags allow real-time inventory updates:

- When an item is scanned into a cart, the system reduces the stock count in the database.
- Alerts are generated for low-stock or out-of-stock items.

Process

- RFID scanners integrated into store shelves monitor stock levels.
- When stock falls below a predefined threshold, the system notifies staff or automatically places a restocking order.

- **AI Integration for Analytics**
- The RFID system generates a vast amount of data from item tracking.
- AI algorithms analyze this data to provide insights such as:
  - Popular products and peak shopping times.
  - Customer preferences and behavior.
  - Optimized product placement in the store.

4.1. RFID vs. Barcodes & QR Codes: Why RFID?

Feature	RFID	Barcodes	QR Codes
Scanning Speed	Reads multiple items at once instantly.	Scans one item at a time.	Scans one code at a time.
Line of Sight	Not required (reads through packaging).	Required (must be visible).	Required (must be visible and scanned).
Durability	More durable (resistant to dirt/damage).	Can get damaged, affecting readability.	Printed on paper, prone to wear and tear.
Range	Up to several meters.	A few centimeters.	A few centimeters.
Automation	Fully automated checkout & tracking.	Manual scanning needed.	Manual scanning needed.
Security	Encrypted data, harder to counterfeit.	Easily copied and forged.	Can be duplicated or tampered with.

Integrating RFID chips into the system revolutionizes the shopping experience by automating tedious processes, reducing human error, and providing a seamless checkout system. The combination of RFID technology, mobile app synchronization, and AI analytics ensures efficiency and customer satisfaction.

5. **Overview of AI Usage**

- Our system utilizes **AI-driven data analysis** to process RFID scan data and extract insights about shopping behavior.
- The AI model analyzes **customer shopping patterns, peak times, and popular products** based on real-time and historical RFID scan data.

5.1. Machine Learning Architecture

- **Data Collection**
  - RFID readers scan product tags at different locations (entry, checkout, aisles).
  - The data is stored in a database.
- **Data Preprocessing**
  - Remove duplicate entries, clean missing values, and structure timestamps.
  - Aggregate customer shopping sessions and transaction histories.
- **Feature Engineering**
  - Extract useful features (e.g., time spent in store, most frequently purchased items, etc.).
  - Convert categorical data (products, customer types) into numerical representations.
- **AI Model Processing**
  - Use clustering algorithms (e.g., K-Means) to group customers by shopping behavior.
  - Apply time-series forecasting (e.g., ARIMA, LSTM) to predict peak shopping times.
  - Use association rule mining (e.g., Apriori, FP-Growth) to identify frequently bought products together.
- **Output and Insights**
  - Generate reports on shopping trends and product demand.
  - Provide recommendations for inventory management and dynamic pricing.

5.2. Data Used

The system collects and analyzes the following data:

Data Type	Description
Timestamp	When the RFID scan occurred
Product ID	Unique identifier for each scanned item
Customer ID	Anonymous ID for tracking shopping behavior
Purchase History	Past purchases linked to customer ID

5.3. Data Preparation

Before training the AI models, data is processed through the following steps:

- **Data Cleaning:** Remove duplicates, incorrect timestamps, and missing values.
- **Normalization:** Convert timestamps into hourly/daily trends.
- **Feature Selection:** Choose key attributes like shopping frequency, product category, and peak times.
- **Encoding:** Convert categorical values into numerical representations (e.g., one-hot encoding for product categories).

5.4. Machine Learning Techniques

AI Technique	Purpose
K-Means Clustering	Group customers based on shopping behavior
Apriori / FP-Growth	Identify product bundles and frequently purchased items
Time-Series Forecasting (ARIMA, LSTM)	Predict peak shopping hours and demand fluctuations
Anomaly Detection (Isolation Forest)	Detect unusual purchase behaviors (e.g., fraud detection)

6. **Project Specification**

6.1. Functional Requirements

1. **Item Tracking**

- RFID readers in shopping carts must detect and record products automatically when they are added or removed.
- The mobile application should display a real-time list of scanned items and their prices.

2. **Checkout Automation**

- Customers should be able to view their total bill and make payments directly through the mobile app.
- Once payment is completed, the system should mark items as purchased in the database.

3. **Inventory Management**

- The system should update inventory levels in real time as items are scanned for purchase.
- Alerts should be generated when stock levels drop below a predefined threshold.

4. **Product Information Retrieval**

- The mobile app must provide details about scanned items, such as nutritional facts, expiration dates, and discounts.

5. **Admin Interface for Inventory Control**

- Admins should be able to:

1. Add, update, or remove products in the database.
2. View sales analytics and reports.
3. Monitor inventory levels and restock products.

6. **AI Integration for Analytics**

- The system should analyze shopping data to identify trends, peak shopping times, and popular products.

7. **Support for Multiple Carts**

- The system should handle multiple shopping carts simultaneously without interference.

8. **System Notifications**

- Notify customers of special offers or discounts for items they scan.
- Send alerts for unscanned items in the cart before checkout.

6.2. Non-Functional Requirements

1. **Speed**

- RFID readers must scan tags within **1 second** of item placement or removal from the cart.
- The database should update inventory and the mobile app in real time without noticeable lag.

2. **Scalability**

- The system should support expansion to accommodate larger stores or multiple branches.
- The database should handle simultaneous requests from hundreds of carts and mobile apps.

3. **Reliability**

- The system should operate with a **99.9% uptime** to ensure uninterrupted shopping experiences.
- RFID readers must have a **high detection accuracy rate** to prevent errors in scanning.

4. **Security**

- Payment processing must comply with **PCI DSS standards** to protect customer financial data.
- RFID data and customer information must be encrypted during transmission and storage.
- The mobile app and admin interface must require secure login credentials.

5. **Usability**

- The mobile app interface should be user-friendly, with clear navigation and intuitive design.
- Admin tools should provide straightforward access to inventory and sales data.

6. **Compatibility**

- The system should be compatible with commonly used RFID standards and mobile operating systems (iOS, Android).

7. **Maintainability**

- The system must be modular to allow easy updates or replacements of components (e.g., RFID readers, mobile app features).

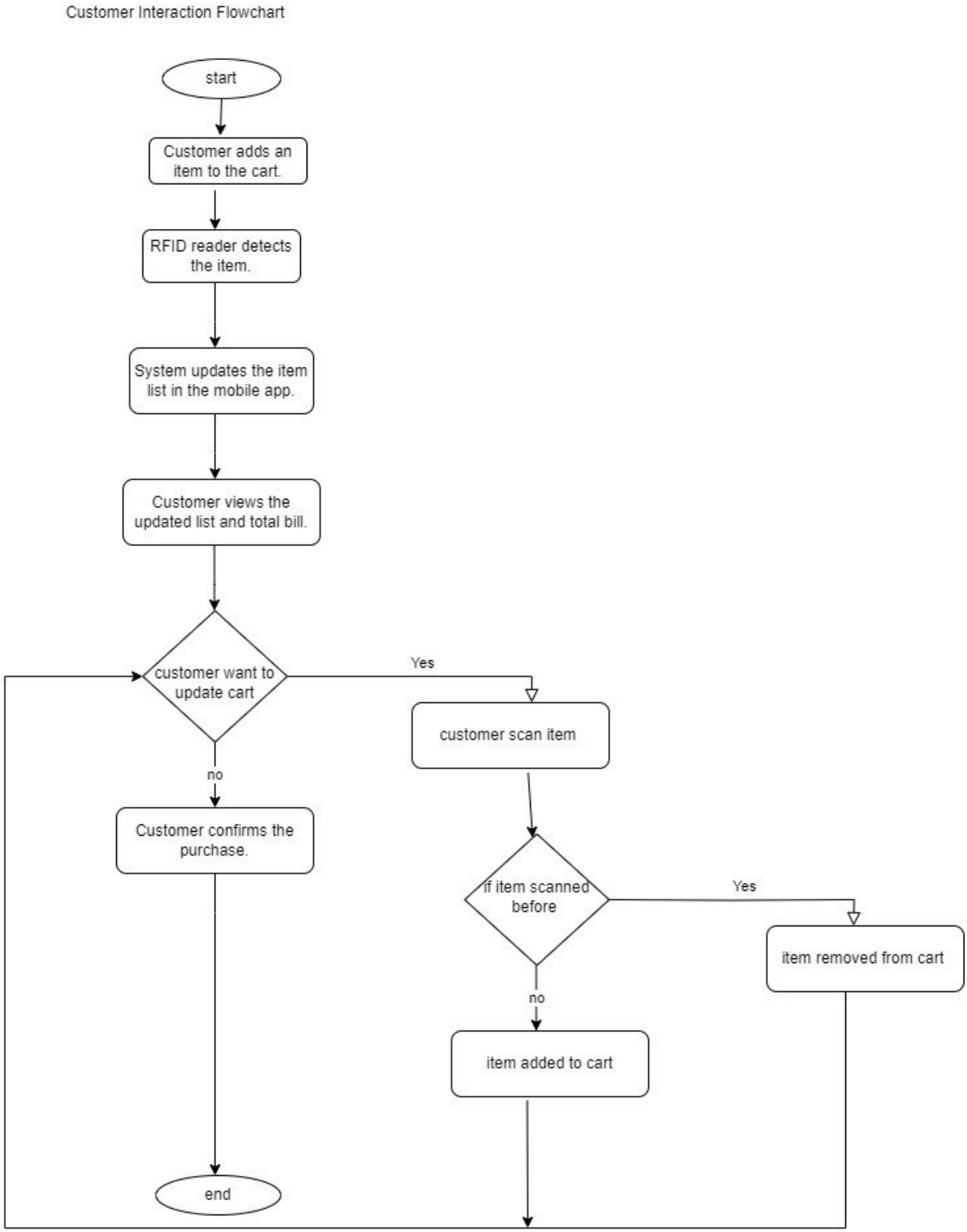
8. **Cost-Efficiency**

- The overall system implementation and operational costs should remain within a reasonable budget for supermarkets of different sizes.

6.3. Use Case Diagram

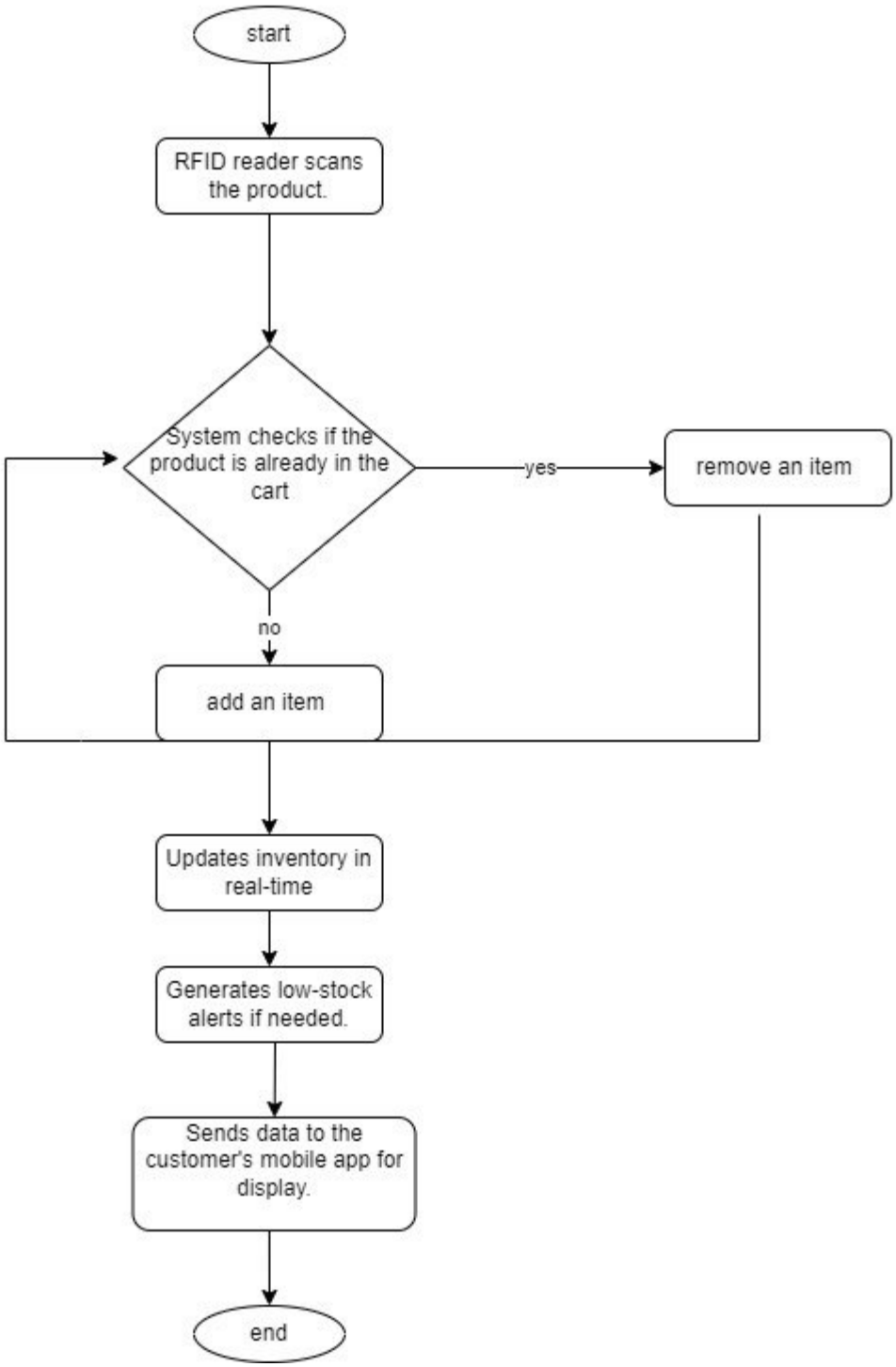
6.4. Flowcharts

6.4.1. Customer Interaction



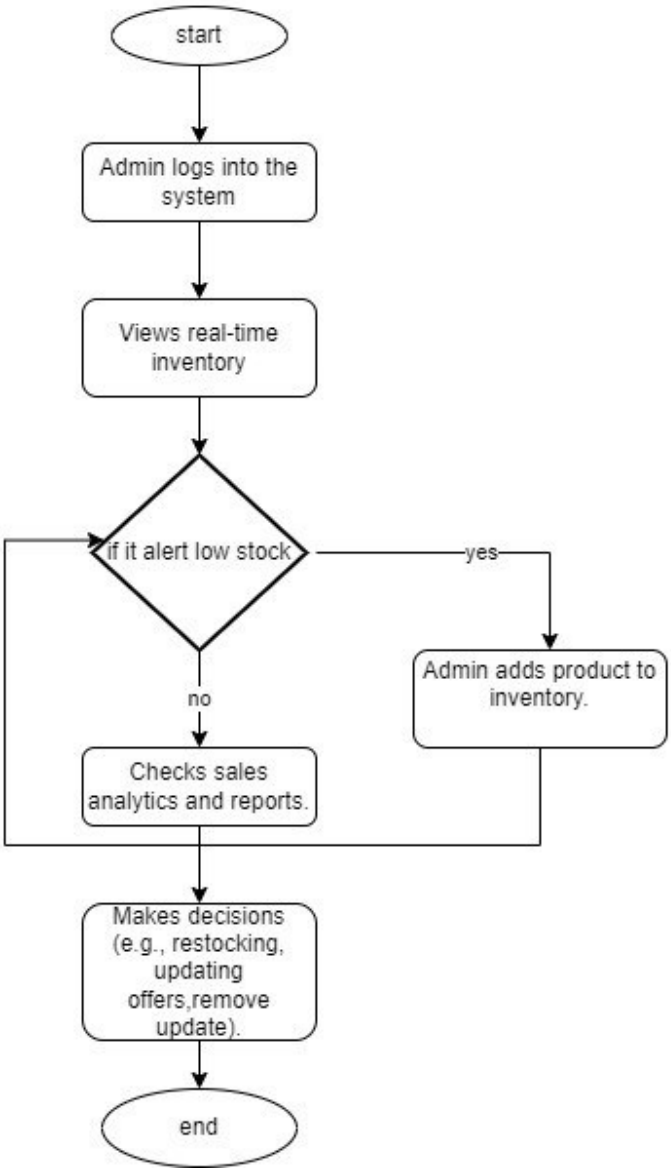
6.4.2. System Backend

System Backend Flowchart: Shows how the system handles RFID detection, updates inventory, and synchronizes with the app.



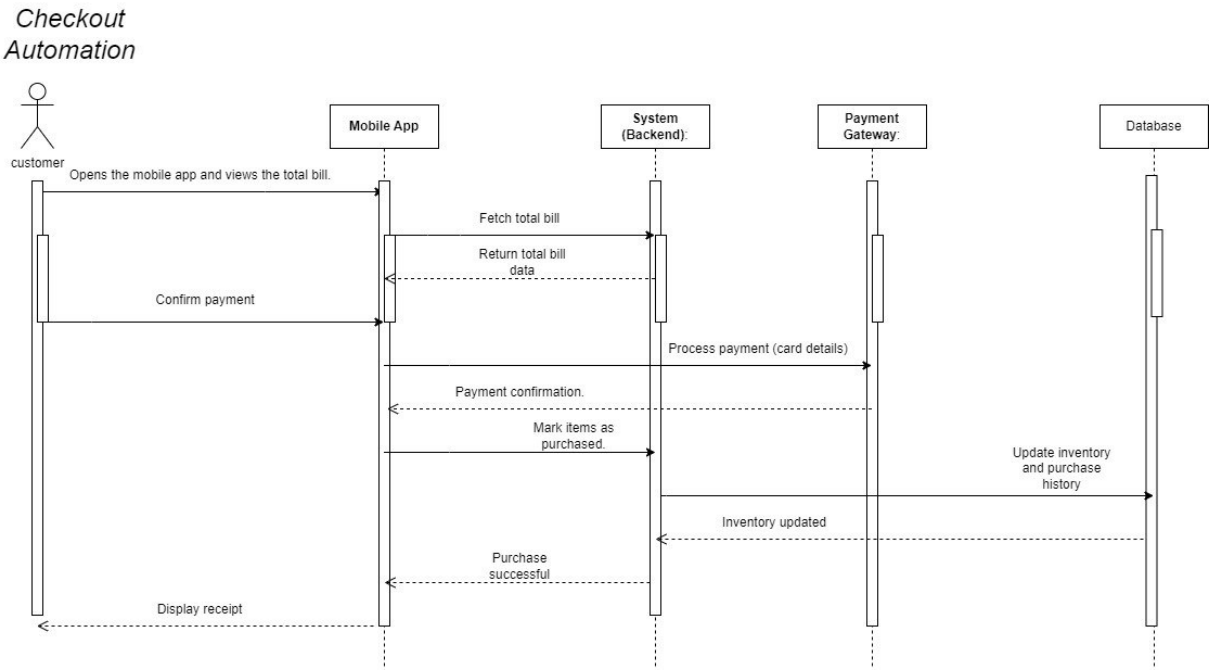
6.4.3. Admin Interaction

Admin Interaction Flowchart: Focuses on how admins manage inventory, receive alerts, and view analytics.

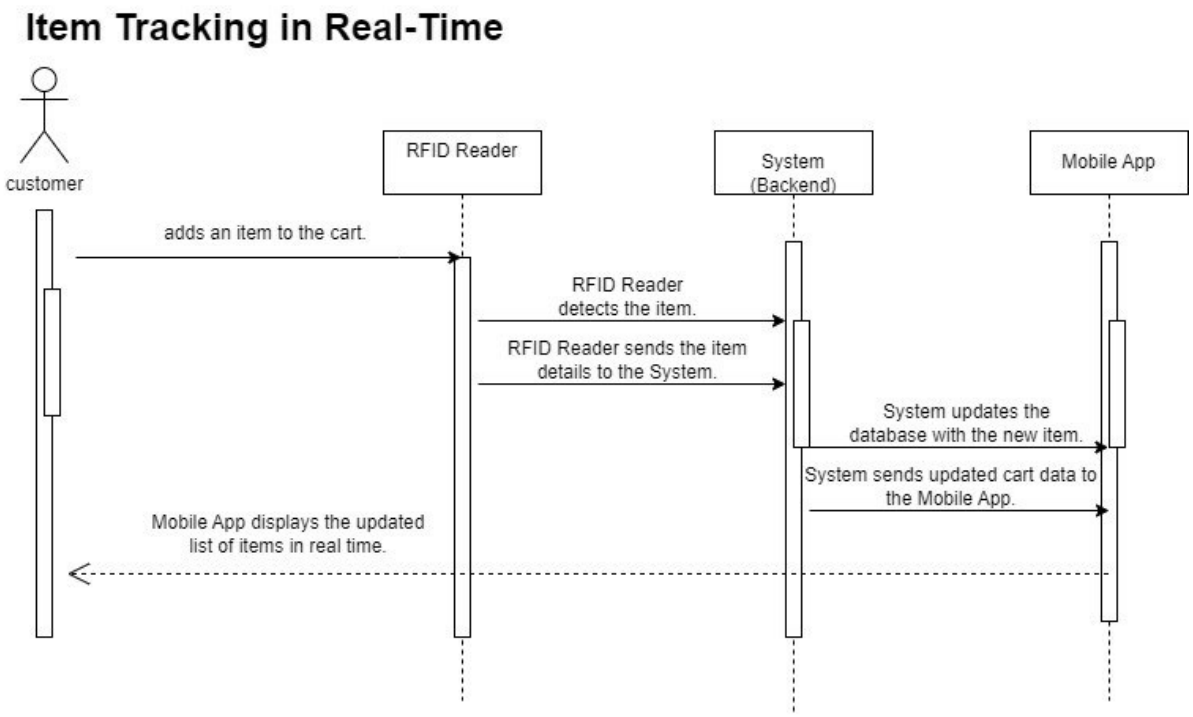


6.5. Sequence Diagrams

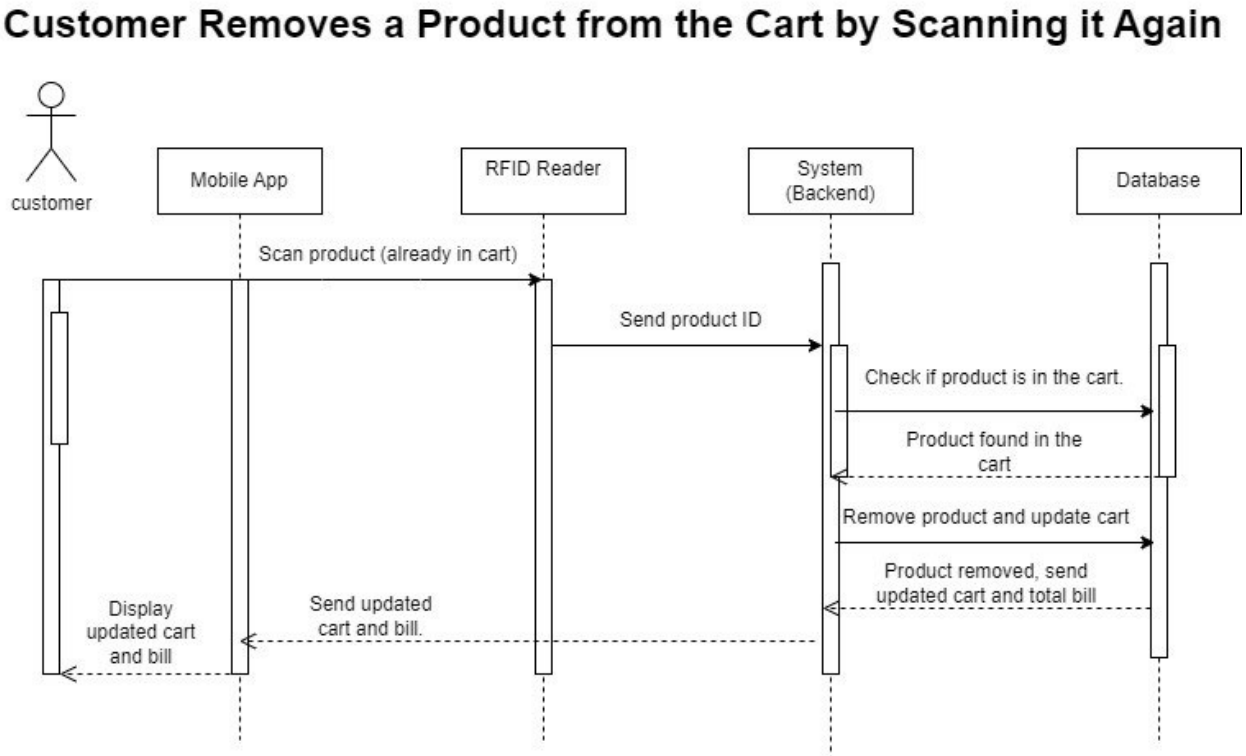
6.5.1. Checkout Automation



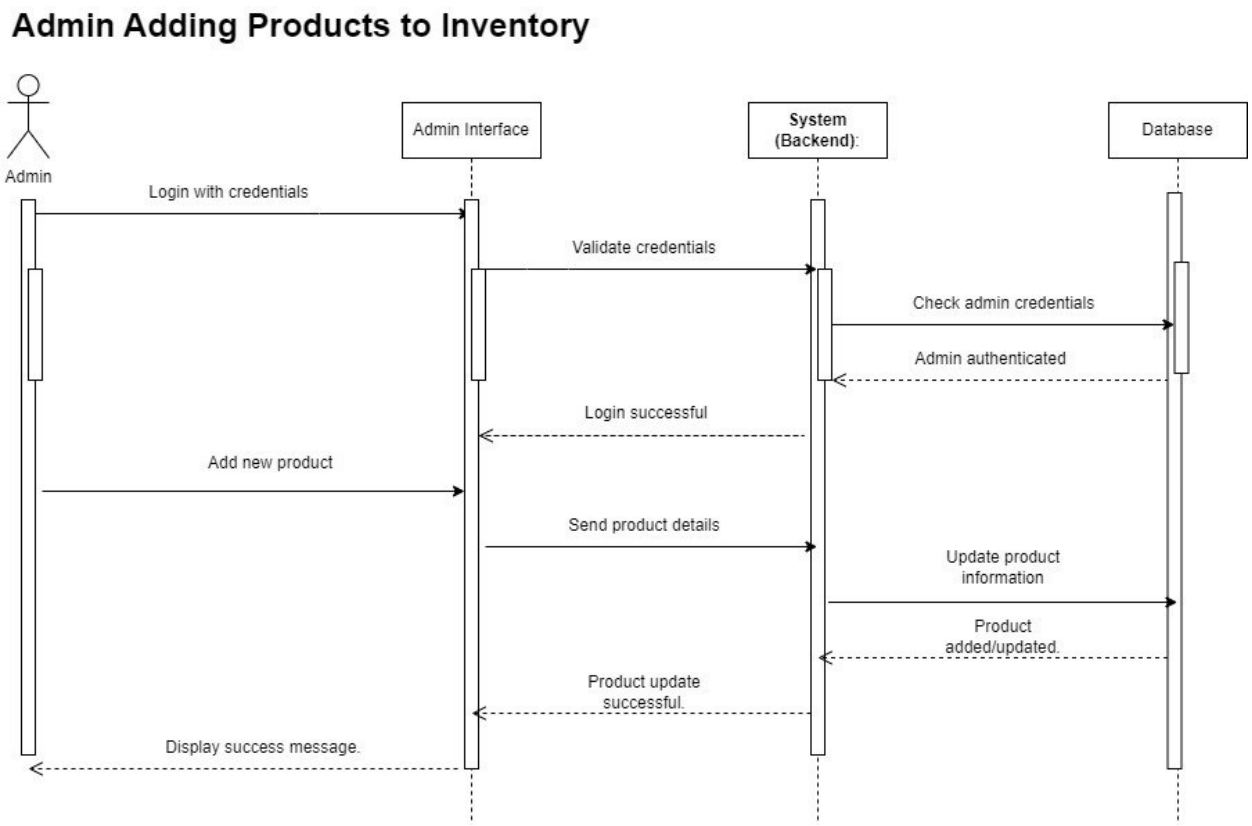
6.5.2. Item Tracking in Real Time



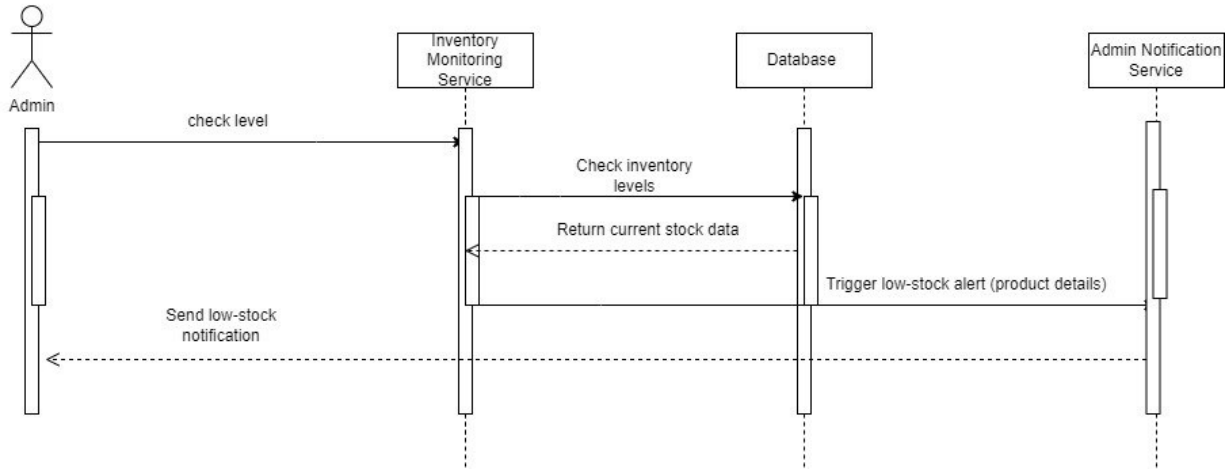
6.5.3. Customer Removing a Product from the Cart



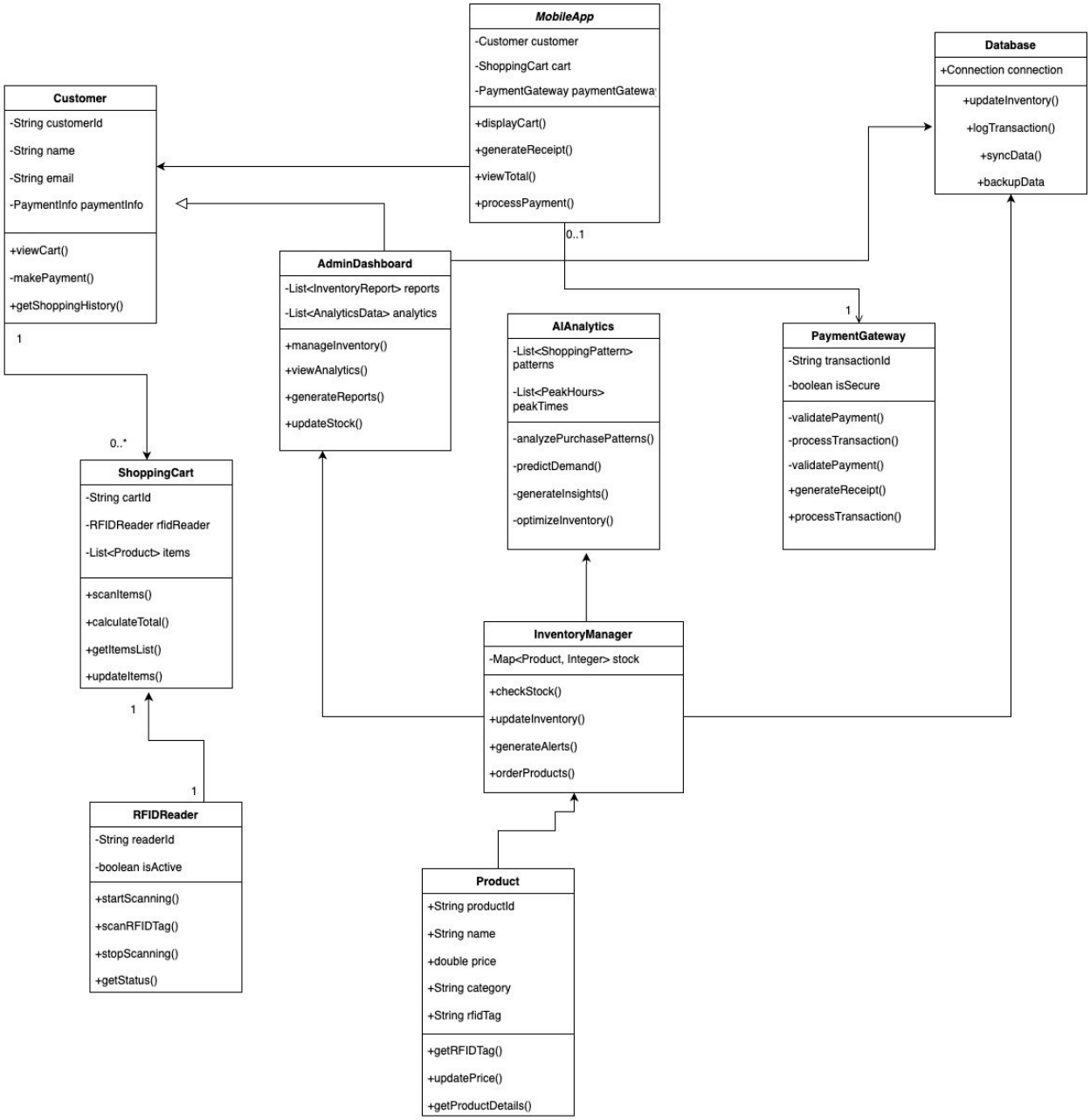
6.5.4. Admin Adding Products to Inventory



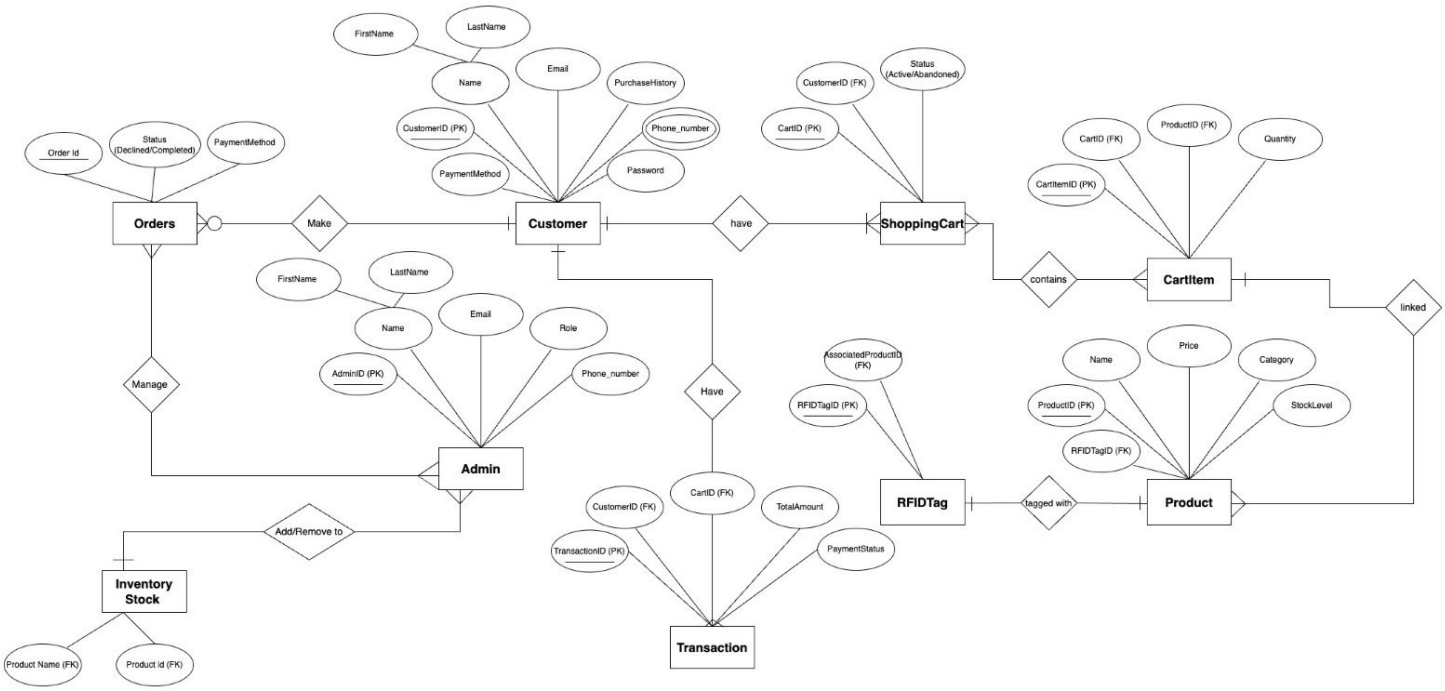
6.5.5 System Generating Alerts for Low Inventory Levels



6.6. Class Diagram

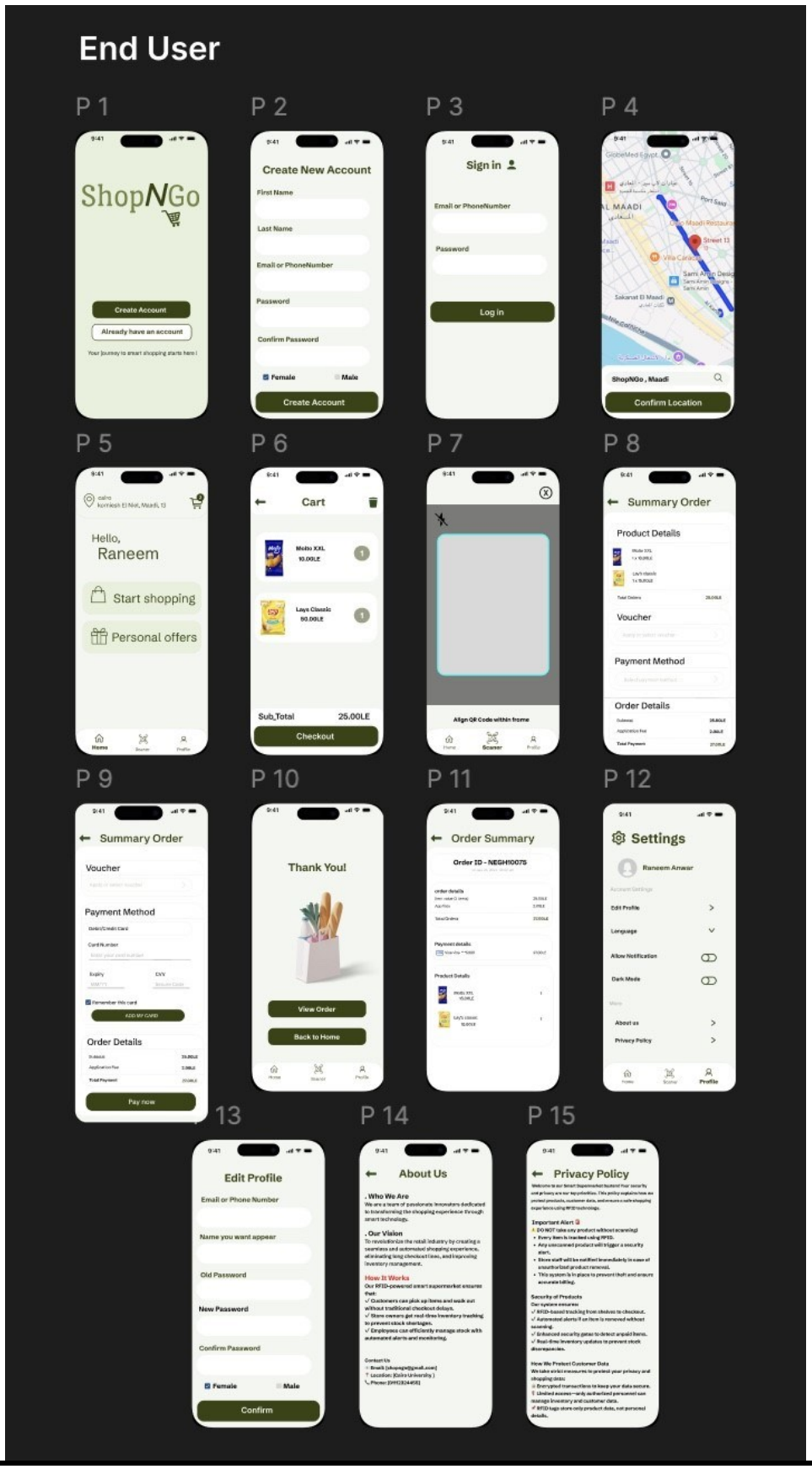


6.7. ERD


FirstName
LastName
Name
Email
PurchaseHistory
CustomerID (PK)
Phone_number
PaymentMethod
Password
Order id
Status (Declined/Completed)
PaymentMethod
Orders
Make
Customer
have
ShoppingCart
CustomerID (FK)
Status (Active/Abandoned)
CartID (PK)
CartID (FK)
ProductID (FK)
Quantity
CartItemID (PK)
contains
CartItem
linked
FirstName
LastName
Name
Email
Role
AdminID (PK)
Phone_number
Manage
Admin
Have
AssociatedProductID (FK)
RFIDTagID (PK)
Name
Price
Category
ProductID (PK)
StockLevel
RFIDTagID (FK)
RFIDTag
tagged with
Product
Add/Remove to
CustomerID (FK)
CartID (FK)
TotalAmount
TransactionID (PK)
PaymentStatus
Inventory Stock
Product Name (FK)
Product id (FK)
Transaction

6.8. GUI

6.8.1 End User



6.8.2 Admin UI


Admin's App
p 18
ShopNGo
Admins
p 19
Sign in
Email or PhoneNumber
Password
Log in
p 22
Inventory Stock
Molto XXL
10.00LE
Lay's classic
50.00LE
Juhayna zabado
25.00LE
Add New Item
p 23
Completed Purchases & Customer Bills
Purchase History
Live Carts
Refunds & Adjustments
Sales & Analytics
Purchase History
Trending Products & Peak Shopping Times
p 26
Purchase History
Order ID : #INV-20260234
Customer : Ahmed Ali
Total Amount : 75.50LE
Payment Method : Credit Card (Visa)
Status: Completed
More Details :
p 27
Live Carts
Customer: Ahmed Ali
Customer: Nada Khaled
p 28
Refunds & Adjustments
Order ID: #INV-20260345
Order ID: #INV-20260240
p 29
Purchase History
Sales Report
Total Revenue: $25,000
Total Orders: 1,500
Unique Customers: 1,200
Average Order Value: $16.67
p 30
Trending Products & Peak Shopping Times
Top-Selling Products
Peak Shopping Time Heatmap
Most Active Shopping Hours: 8 PM - 8 PM
Busiest Shopping Days: Saturday & Sunday
p 24
Create & Send New Notification
Send Notification
p 25
Store Details
Promotions & Discounts Section
Save changes