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## 1.1 Overview

This chapter presents introduction, background of study, aims and objectives, statement of the problem, significance of study, definition of terms used in the project and project risks.

## 1.2 Background of Study

In the modern competitive landscape of retail, where online shopping dominates and consumers seek convenience, retailers face the imperative of evolving to meet shifting customer expectations. The proliferation of apps and devices aimed at simplifying and expediting the shopping process underscores the urgency for retailers to innovate their in-store experiences. Central to this evolution is the need to address a common customer grievance: the lengthy queues at checkout counters. Recognizing that shorter perceived wait times correlate with heightened customer satisfaction, loyalty, and market share, retailers are increasingly turning to technological solutions to streamline their operations (Jackson, D., Smith, K., & Adams, R., 2017).

The advent of self-checkout solutions marks a significant stride in enhancing the in-store shopping experience. By utilizing technology, particularly mobile devices, retailers aim to mitigate the challenges associated with conventional checkout methods (Smith, J. A., 2021). While traditional self-checkout systems necessitated substantial investments in hardware and maintenance costs, newer iterations capitalize on the Bring Your Own Device (BYOD) principle (Garcia, L., & Chen, R., 2019). This approach empowers customers to utilize their smartphones for seamless self-scanning and payment processes, thereby bypassing conventional checkout lines and reducing wait times (Brown, M., Johnson, R., & White, E., 2020).

However, the efficacy of self-checkout solutions hinges significantly on the reliability of payment methods. Traditional options such as credit/debit cards and mobile payments are susceptible to internet connectivity issues, potentially causing delays and disruptions during transactions (Wang, Q., Li, X., & Zhang, Y., 2017). To circumvent these challenges, retailers are increasingly adopting Near Field Communication (NFC) payment methods, facilitated by Radio Frequency Identification (RFID) cards (Lee, H., Park, S., & Kim, Y., 2018). By eliminating the reliance on

internet connectivity, NFC payment solutions offer enhanced security and efficiency, augmenting the overall self-checkout experience (Liu, C., Wu, S., & Chang, M., 2020).

Against this backdrop, this project report <sup>9</sup> aims to describe the development of a self-checkout mobile application for retail stores (Hernandez, M., Rodriguez, A., & Gomez, L., 2019). Through comprehensive analysis and clarification of the application's key components—including the virtual shopping cart, store interface, employee interactions, and customer engagement—this report endeavors to provide insights into the intricate process flows underlying the application's functionality (Kim, S., Lee, J., & Park, H., 2018). Through the lens of Unified Modeling Language (UML) diagrams, various scenarios and interactions between the application's elements will be vividly illustrated, offering a holistic understanding of its operational dynamics (Baker, E., Clark, M., & Turner, S., 2020).

### 1.3 Statement of the Problem

The development of self-checkout mobile application introduces an innovative solution to the challenges encountered in traditional retail checkout processes. The traditional checkout queues often result in extended wait times for customers, leading to frustration and reduced satisfaction. Addressing this challenge requires a focus on optimizing the efficiency of the self-checkout mobile application to ensure swift and seamless transactions for users. Moreover, existing payment methods such as credit/debit cards and <sup>11</sup> mobile payments heavily rely on internet connectivity, which can be unreliable or unavailable in certain areas. Consequently, ensuring a dependable payment process within the self-checkout mobile application becomes crucial to prevent delays and transaction failures. Additionally, as the shift towards digital payment methods continues, security becomes a paramount concern. Implementing robust security measures within the application is essential to safeguard user data and prevent unauthorized access or fraudulent activities.

Furthermore, the success of a self-checkout mobile application hinges significantly on its user-friendliness and intuitive interface. Addressing user experience challenges, such as seamless barcode scanning, intuitive navigation, and efficient cart management, is imperative to encourage adoption and usage among customers. Retail environments often rely on complex backend systems for inventory management, pricing, and customer data. Integrating the self-checkout mobile application with these existing systems poses a technical challenge that needs to be addressed to

ensure compatibility and smooth operations. Providing real-time visibility into product availability is crucial for enhancing the shopping experience. Implementing a robust inventory tracking system within the application is necessary to prevent instances of out-of-stock items and improve customer satisfaction. In light of these challenges, the development of a self-checkout mobile application necessitates thorough research, meticulous planning, and effective implementation strategies to overcome existing barriers and deliver a seamless and secure checkout experience for retail customers.

#### **1.4 Aim and Objectives of the Study**

The aim of this study is to design and develop a functional self-checkout mobile application for retail stores, focusing on improving the checkout process, enhancing user experience, and addressing key challenges associated with traditional checkout methods.

The objectives of the study are:

1. To develop a functional model for a self-checkout mobile application tailored to the specific needs and requirements of a retail store.
2. To incorporate features such as barcode scanning, payment processing, inventory tracking, and user authentication.
3. To evaluate the effectiveness and impact of the developed self-checkout mobile application through user testing, feedback collection, and performance analysis, with a focus on factors such as checkout speed, user satisfaction, and business outcomes.

#### **1.5 Significance of the Study**

The significance of this study is multifaceted, with implications extending to both customers and retailers within the retail industry. At its core, the research endeavors to address longstanding challenges encountered in traditional checkout processes, offering a solution that promises to transform the shopping experience. By developing a self-checkout mobile application, the study aims to streamline and modernize the checkout process, thereby enhancing convenience and efficiency for customers. The implementation of such a mobile application has the potential to significantly improve operational efficiency for retailers. By automating various aspects of the checkout process and integrating seamlessly with existing backend systems, the application can

optimize resource allocation, reduce labor costs, and ultimately enhance overall store productivity. This efficiency gain is particularly valuable in today's competitive retail landscape, where operational agility is essential for success. Furthermore, the timing of this study is particularly significant in light of the COVID-19 pandemic. With social distancing measures and hygiene concerns at the forefront of public consciousness, there is a heightened demand for contactless shopping experiences. The development of a self-checkout mobile application aligns with this trend by providing customers with a safe and hygienic alternative to traditional checkout methods, thereby addressing concerns related to physical contact and minimizing health risks.

Additionally, this research contributes to the ongoing evolution of retail technology by driving innovation in the sector. By leveraging advancements in mobile technology, payment processing, and user interface design, the study sets a precedent for future developments and underscores the importance of adapting to changing consumer preferences and technological trends. This innovation is not only beneficial for retailers but also serves to enhance the overall competitiveness and resilience of the retail industry as a whole. Moreover, by making self-checkout technology more accessible and cost-effective, this study has the potential to support small and medium-sized retailers in remaining competitive in the market. Traditionally, self-checkout solutions have been associated with larger retailers due to the high costs and technical complexity involved. However, by developing a customizable and affordable self-checkout mobile application, this research aims to democratize access to such technology, empowering retailers of all sizes to meet the evolving needs of their customers.

211.6 Project Risk Assessment

Table 1.1: Risk Assessment

S/N	Risk	Probability	Impact	Mitigation
501.1.	Technical Challenges	High	High	Conduct thorough technical feasibility studies and prototype testing prior to full-scale development.
2.	Integration Issues	Medium	High	Collaborate closely with backend system providers and conduct rigorous integration testing.

3.	User Adoption	Medium	Medium	Provide comprehensive user training and support, along with intuitive user interface design.
4.	Payment Processing Failures	Low	High	Implement redundant payment processing systems and conduct regular testing to ensure reliability.
5.	Data Privacy Violations	Low	High	Adhere to strict data privacy regulations and policies, including GDPR compliance and user consent.
6.	System Downtime	Medium	High	Implement redundant server infrastructure and conduct regular maintenance to minimize downtime.
7.	Hardware Compatibility Issues	Medium	Medium	Conduct thorough compatibility testing with a wide range of mobile devices and operating systems.
8.	Scope Creep	High	High	Establish clear project scope and requirements, conduct regular progress reviews.

## 8 1.7 Scope of the Study

The scope of this study revolves around the design and development of a self-checkout mobile application tailored explicitly for retail environments. Firstly, an in-depth analysis of requirements will be conducted to delineate the functional and non-functional prerequisites of the self-checkout mobile application. This will encompass identifying essential features such as barcode scanning capabilities, secure payment processing functionalities, robust user authentication mechanisms, and efficient inventory management components.

Following the requirement analysis, a comprehensive review of existing technologies and solutions pertinent to self-checkout systems and mobile application development will be

undertaken. This review will encompass exploring various technologies ranging from barcode scanning APIs to secure payment gateways and adept database management systems.

## 2.1 Introduction

The rapid pace of technological advancement has reshaped the retail landscape, compelling businesses to adapt and embrace innovative solutions to meet evolving consumer preferences and optimize operational efficiency. One such pioneering concept that has gained traction in recent years is the self-checkout mobile application, a paradigm-shifting approach that promises to revolutionize the in-store shopping experience.

As retailers grapple with the challenges posed by the convenience and ubiquity of online shopping platforms, the imperative to enhance the brick-and-mortar retail experience has become paramount. Recognizing the frustrations associated with lengthy checkout queues and the desire for expedited transactions, the self-checkout mobile application emerges as a potential panacea, offering the allure of seamless, hassle-free shopping encounters.

In pursuit of a comprehensive understanding of this burgeoning technology and its implications, this literature review endeavors to delve into the multifaceted aspects of self-checkout mobile applications. Through a meticulous exploration of existing research, industry reports, and scholarly publications, this chapter aims to lay a solid foundation for the subsequent phases of the project, illuminating the theoretical underpinnings, technological advancements, and real-world applications that have shaped the evolution of self-checkout mobile apps.

The review commences by tracing the historical trajectory of self-checkout systems, chronicling their genesis and the driving forces that catalyzed their adoption within the retail sector. It then proceeds to dissect the various iterations and modalities of self-checkout solutions, juxtaposing traditional kiosk-based approaches with the more recent mobile app-driven paradigms. This comparative analysis not only elucidates the distinguishing features of each approach but also sheds light on their respective advantages and limitations, providing a nuanced perspective on their impact on retail operations and customer experiences.

Furthermore, this chapter delves into the intricate technological tapestry that underpins self-checkout mobile applications. It scrutinizes the principles, functionalities, and cutting-edge



advancements in critical technologies such as barcode scanning, payment processing, and seamless integration with backend systems. By unraveling the intricate interplay between these technological components, the literature review aims to illuminate their pivotal roles in facilitating efficient, secure, and user-friendly self-checkout experiences.

Recognizing the pivotal influence of user acceptance and adoption on the success of any technological innovation, this chapter dedicates a substantial section to exploring existing theories, models, and industry best practices that elucidate the factors shaping consumer behavior and technology adoption within the realm of self-checkout mobile apps. Drawing insights from established frameworks and empirical studies, the review analyzes the interplay of variables such as perceived usefulness, ease of use, trust, and subjective norms, shedding light on the intricate dynamics that govern user acceptance and adoption of self-checkout mobile apps.

Moreover, this literature review endeavors to provide a multidimensional perspective by examining the potential benefits and challenges associated with self-checkout mobile apps from the vantage points of various stakeholders, including retailers, consumers, and employees. Through a synthesis of industry studies and academic research, the chapter investigates the impact of self-checkout mobile apps on operational efficiency, customer satisfaction, labor requirements, and potential security and privacy concerns. This holistic approach not only underscores the far-reaching implications of this technology but also highlights the need for a nuanced and balanced approach to its implementation.

By engaging in a rigorous and critical analysis of the existing body of knowledge, this literature review aims to identify gaps, contradictions, and areas ripe for further exploration within the context of the project. The insights gleaned from this endeavor will serve as a solid foundation, informing the subsequent phases of the project, including the research methodology, system design, implementation, and evaluation processes.

In essence, this chapter represents a comprehensive and indispensable resource, synthesizing the collective wisdom and empirical evidence surrounding self-checkout mobile applications. It serves as a beacon, guiding the project's trajectory and illuminating the path towards a deeper understanding of this burgeoning technology and its transformative potential within the dynamic retail landscape.

## 2.2 Historical Overview

The genesis<sup>28</sup> of self-checkout systems can be traced back to the early 1990s, when the retail industry sought innovative solutions to address the mounting challenges of labor costs and customer dissatisfaction with lengthy queues at traditional checkout counters. This pivotal juncture marked the inception of a paradigm shift that would profoundly transform the in-store shopping experience.

The pioneering retailer to introduce the novel concept of self-checkout was<sup>41</sup> Price Chopper Supermarkets, a regional grocery chain based in Schenectady, New York. In 1992, they unveiled their first self-checkout system, a bold endeavor that garnered significant attention within the industry (Inman & Nikolova, 2017). This groundbreaking initiative heralded the advent of a new era in retail, one that empowered<sup>32</sup> customers to scan, bag, and pay for their purchases without the assistance of a cashier.

Recognizing the potential benefits<sup>77</sup> of self-checkout systems, such as reduced labor costs, enhanced operational efficiency, and improved customer satisfaction, other retail giants soon followed suit. In 1994, Wal-Mart, the behemoth of the retail industry, commenced a pilot program, introducing self-checkout systems in select stores (Walker & Martin, 2018). This strategic move not only validated the viability of the concept but also propelled its widespread adoption across<sup>28</sup> the retail landscape.

The early iterations of self-checkout systems were primarily kiosk-based, comprising dedicated hardware terminals equipped with scanners, payment terminals, and bagging areas. Customers would navigate through the checkout process by scanning their items, making payment, and bagging their purchases autonomously. While these systems offered a degree of convenience and expedited the checkout process, they were not without their limitations. Substantial investments in hardware, maintenance costs, and the need for dedicated floor space posed significant challenges for retailers (Garcia & Chen, 2019).

As technology advanced and consumer preferences evolved, the self-checkout paradigm underwent a transformative shift with the advent of mobile-based solutions. Capitalizing on the ubiquity of smartphones and<sup>72</sup> the Bring Your Own Device (BYOD) principle, retailers began

developing mobile applications that enabled <sup>1</sup> customers to scan and pay for their purchases using their personal devices (Brown et al., 2020). This innovation not only circumvented the hardware costs associated with traditional kiosk-based systems but also offered unprecedented flexibility and convenience for customers.

The introduction of mobile self-checkout applications, however, was not without its challenges. Issues surrounding payment processing, internet connectivity, and user adoption posed hurdles that required innovative solutions. To address these concerns, retailers began exploring alternative <sup>11</sup> payment methods, such as Near Field Communication (NFC) and Radio Frequency Identification (RFID) technologies, which offered enhanced security and reliability without relying on internet connectivity (Lee et al., 2018).

As the self-checkout landscape continued to evolve, retailers embraced innovative approaches to further streamline the shopping experience. The introduction of Semi-Attended Customer Activated Terminals (SACAT) and hybrid models that combined traditional checkout lanes with self-checkout kiosks emerged as viable solutions (Roberts et al., 2019). These hybrid models aimed to cater to diverse customer preferences while ensuring a seamless transition to the self-checkout paradigm.

Throughout this evolutionary journey, the self-checkout concept has garnered significant attention from industry stakeholders, academics, and consumers alike. Numerous <sup>58</sup> studies have been conducted to assess the impact of self-checkout systems on customer satisfaction, operational efficiency, and retail profitability. While some have lauded the convenience and time-saving benefits of self-checkout, others have raised concerns regarding security, user experience, and the potential displacement of human cashiers (Cebeci et al., 2020).

As the retail industry continues to navigate the ever-changing landscape of consumer demands and technological advancements, self-checkout systems remain at the forefront of innovation. The future holds promise for further refinements and enhancements, with emerging technologies such as artificial intelligence, computer vision, and advanced payment solutions poised to shape the next generation of self-checkout experiences.

## 2.3 <sup>1</sup>Self-checkout Systems

Self-checkout systems are automated systems in retail stores or supermarkets, which enable customers to scan and settle the payment for their items without the aid of a cashier. These systems typically consist of a scanner for scanning the barcodes on products, a touchscreen display for selecting items and payment options, and a payment terminal for processing payments. (Kubala et al., 2019) <sup>1</sup>Customers simply scan the barcodes of the items they want to purchase, either by using a handheld scanner or by placing the items on a scanning platform. The system then identifies the items and calculates the total cost of the purchase. Customers can then pay using cash, a credit or debit card, or mobile payment systems such as Apple Pay or Google Wallet. (Cebeci et al., 2020) <sup>1</sup>They are designed to enhance the customer experience by reducing queuing times at checkout, and they can also help retailers reduce labor costs by requiring fewer cashiers. However, they can also be prone to errors and require occasional intervention from store personnel to resolve issues such as mis-scanned items or payment problems (Maulana et al., 2021).

<sup>3</sup>Retailers facing the challenge of competing with new online shopping alternatives (Garaus and Wagner, 2016), increasingly substitute or enlarge channels of service provision with technology (Colby and Parasuraman, 2003; Lee and Yang, 2013). Those SSTs are nowadays ubiquitous in the form of ATMs, online banking, or app-based airline check-ins (Wang et al., 2013). Retailers introduce a variety of those SSTs, ranging from kiosks to provide information, to SC (Inman and Nikolova, 2017). This promises to streamline processes and reduce operational costs (Johnson et al., 2019; Lee et al., 2010). The first SC, that “enables shoppers to scan, bag, and pay for their purchases without the need for a cashier”, was proposed by Price Chopper Supermarkets in 1992 (Inman and Nikolova, 2017). These stations reduce floor space by replacing conventional checkouts (Collier and Kimes, 2013) and bring benefits to customers, e.g., increased satisfaction and convenience by skipping waiting queues (Anitsal and Flint, 2006; Demirci Orel and Kara, 2014). A study of the NCR (2014) showed that 90% of their 2,800 respondents use SC in retail stores. Newer generations of SC use mobile devices provided by the retailer. Those are picked up by the customer after a process of identification needed for seamless payment. During the shopping, the customers are able to self-scan the products and pay their baskets before leaving. However, the high investment and maintenance costs for the provided devices limit this approach (Andriulo et al., 2015).

Recently, retailers started to introduce Scan&Go (Aloysius et al., 2016; Inman and Nikolova, 2017). Here, customers use an app provided by the retailer to scan and pay the products with their own smartphones. In addition to retailers, also startups such as Roqqio (ROQQIO Commerce Solutions GmbH, 2021) and Snabble (snabble GmbH, 2021) develop such apps as white label and single-checkout channel solutions. In principle, Scan&Go bears the potential to improve convenience and service quality of SC, although Walmart reported customers having difficulties using it (Inman and Nikolova, 2017). As our qualitative study uses the Snabble App as a design probe, we briefly introduce its features: The app allows scanning products with the smartphone's camera. Afterwards, users can see the price of the product and adjust its quantity. The confirmation of the scan closes the dialog, and the product is added to the basket. The app is then ready for the next product. To finish shopping, users need to switch to the basket. Depending on the store, it offers either to use mobile payment or, as in our case, payment via stationary checkout desks that need to scan a QR-Code on the phone's screen.

### **2.3.1<sup>1</sup> Types of Self-Checkout Systems**

There are a few different types of self-checkout systems that are used in retail stores or supermarkets (Schmidt et al., 2022).<sup>1</sup> Here are some of the most common types:

1. **Scan and Bag:** This is the most basic type of self-checkout system, where customers scan each item and then place it in a bag themselves. The system calculates the total cost of the purchase, which the customer pays using a payment terminal.
2. **Scan and Go:** In this type of system, customers use a handheld scanner to scan items as they shop. The system keeps a running total of the items scanned, and the customer pays at a self-checkout kiosk before leaving the store.
3. **Hybrid Self-Checkout:** This system combines traditional checkout lanes with self-checkout kiosks. Customers can choose to use a self-checkout kiosk or a cashier-assisted lane, depending on their preference.
4. **Mobile self-checkout:** This sort of self-checkout system permits clients to sweep and pay for items utilizing their cell phones. They can then skip the checkout line altogether and simply show their digital receipt to a store employee before leaving.

Each type of self-checkout system has its advantages and disadvantages, and the retailer's and customers' preferences will determine which system is best for them.

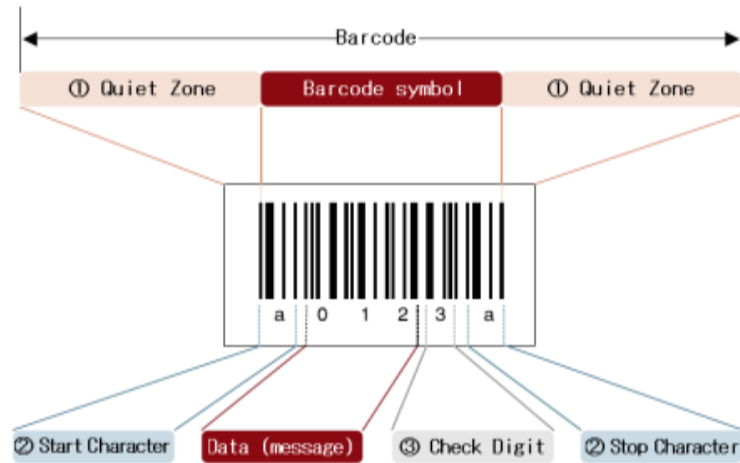
### 2.3.2 Advantages of Mobile Self-checkout Systems

Mobile self-checkout systems offer several advantages for retailers and customers alike. They eliminate the need for a physical cashier or checkout kiosk by allowing customers to scan and pay for their purchases on their own devices. This can provide a more convenient shopping experience by saving the customer time. Since customers can scan and pay for items on their own devices, the checkout process can be much faster than traditional checkout methods. (Schmidt et al., 2022)

<sup>1</sup> In addition, mobile self-checkout systems can help retailers reduce labor costs by requiring fewer cashiers or checkout assistants. This can be especially beneficial for smaller stores or those with limited staff. By providing real-time data on sales and inventory levels, they can help retailers improve their inventory management. This can help them make more informed decisions about restocking and pricing. They can also encourage customers to make more impulse purchases since they can quickly and easily scan and pay for items without having to wait in line. This can help increase sales and revenue for the retailer (Beck, 2022). Overall, mobile self-checkout systems offer a convenient, fast, and cost-effective way for retailers to improve the checkout process and enhance the customer experience. (Beck, 2022).

### 2.3.4 <sup>1</sup>Barcode

A barcode is a printed sequence of parallel bars or lines of varying widths (thickness and thinness) used to encode data in a pattern that can be seen and read by machines. It was invented by Noman Joseph Woodland and Bernard Silver in 1948 based on the vertical extension of the thin and thick bars in Morse code. The bars are typically dark on white, and their width and number change contingent upon the application. The binary digits 0 and 1 are represented by the bars, which can then be processed by a barcode reader to represent numbers from 0 to 9. As can be seen in figure 1, a barcode has three components. (Mathur, 2022).



**Figure 0.1: Barcode components (McCue, 2022).**

**1. Quiet Zone (margin):** It refers to the empty space at the barcode's left or right ends. A scanner has trouble reading barcodes if the quiet zone's width is too small.

**2. Start Character/Stop Character:** In the image above, they are the characters that represent the data's beginning and ending, respectively, and are highlighted in red. They differ, however, according to the kind of barcode.

**3. Check Digit (a symbol check character):** It is a digit that is used to check that the encoded barcode data is accurate.

Barcoding has been a part of everyday business transactions since 1970. Supermarkets and retail stores utilize the codes to acquire costs and other significant data about merchandise or items at the place to checkout by the consumer. Common product codes are broadly divided into the Universal Product Code, or UPC, and the European Article Number, or EAN, where the former is standardised in the US while the latter is in Europe. The EAN consists of either 13 or 8 digits in the standard and shorthand versions, while the UPC is 12 or 7 (Mathur, 2022).



**Figure 0.2 Barcode composition (McCue, 2022).**

Figure 2 shows the different elements of the UPC barcode. The number system digit represents the product category; for example, retail has 0 or 1, while pharmaceuticals and coupons have 3 and 5, respectively. The next part is the manufacturer code, which is assigned by the global standardization organization (GS1) that regulates UPCs. The next character represents the product code, which is given by the manufacturer, and the last character is the check digit, which confirms the accuracy of the data in the barcode and flags out any potential error. Scanners perform a calculation on the digits of the checksum, and you hear a beep to ensure the right result. (McCue, 2022)

#### 2.2.4.1 <sup>1</sup>Barcode Types

Barcode symbology differs in quality based on its size, capacity, material used, linearity, and requirement for a checksum. Based on their linearity, they are of two types.

1. **Linear/1D:** The linear or one-dimensional (1D) barcode is what we normally visualise when we picture barcodes. As noted in figure 3, they are regular black and white vertical bars. They can encode only 80 characters and are common on the products in our supermarkets, retail stores, libraries, and pharmacies. They tie the code to the product name, type, size, and image in the database. (McCue, 2022)





**Figure 0.3 1D barcode type (McCue, 2022)**

2. <sup>1</sup> **Data Matrix/2D:** As can be seen in figure 4, it is a two-dimensional barcode that can encode up to 2000 characters in a very small space. They are also called QR codes and can encode quantities, images, and URLs. They can render this information without any connection to the database. They require sophisticated scanners to take a picture and translate the entire image. (McCue, 2022)



**Figure 0.4 2D barcode type (McCue, 2022).**

#### 2.2.4.2 <sup>2</sup> Barcode Scanner

Barcode Scanner is an optical scanner device that can read printed barcodes and interpret information from the barcode to a computer. At a typical supermarket checkout counter, a barcode is used to quickly identify a product. A computer then takes the price of the item and enters it into the cash register, where it is added to the customer's bill.

Barcode scanners work by using a light source, usually a laser, to scan the barcode and convert the pattern of bars and spaces into a digital signal. The scanner emits a laser or LED light onto the barcode. The light reflects off the barcode and is captured by a photo sensor in the scanner. The photo sensor detects the amount of light that is reflected from the barcode, which corresponds to

the pattern of bars and spaces in the barcode. The scanner converts the pattern of bars and spaces into a digital signal that can be read by a computer or other electronic device. The digital signal is then sent to the computer or device that is connected to the scanner, which interprets the data and takes the appropriate action, such as adding an item to an inventory system or processing a transaction at a point-of-sale terminal (Jain, 2022).

Barcode scanners come in a variety of forms, such as handheld scanners, fixed-mount scanners, and mobile devices that include built-in scanners. The basic principle of using a light source to scan the barcode and convert the pattern of bars and spaces into a digital signal is the same for all types of barcode scanners (Jain, 2022).

#### **2.2.4.3 <sup>1</sup> Benefits of Barcode**

Barcodes have a proven track record for making business operations around the world more effective. The primary advantage of barcode systems is the real-time processing of data as soon as the barcode is scanned (McCue, 2022). In general, barcodes are:

1. **Efficient:** they allow more accurate and faster transfer of information, thereby ensuring the precise tracking and quicker transfer of assets and processes.
2. **Saves time:** depending on the use cases, the time savings can be significant. For instance, one SATO customer reduced his crew requirement from 25 to 4 and completed the inventory in just 5 hours once he implemented the barcode system.
3. **Reduce error:** data entry errors can lead to unhappy customers, a lot of time to find the problem, pharmaceutical inaccuracy, patient vulnerability, and irreversible damage to a business's reputation. However, using barcode printing and scanners, the error can go down to 1 error in every 36 trillion characters.

#### **<sup>4</sup> 2.2.5 Self-Checkout Adoption**

Prior studies on SC adoption are rather general, focusing on adoption alone without differentiating between device types and services models. Nonetheless, previous research brought insights about adopting factors that may be useful in understanding the newer generation of Scan and Go solutions. Most research on SC adoption uses the Technology Acceptance Model (TAM) (Davis, 1989), or adaptations of it (Cebeci et al., 2020). TAM's main dependent variable is intention to

use, a construct to measure the intended adoption. According to Fishbein and Ajzen (1977), it presents “the strength of one’s intention to perform a specific behavior”. Kaushik and Rahman (2015) adapt the TAM and add subjective norm and trust to build an alternative model to measure the intention to use. Although TAM has been used in the context of SSTs, there is no widely accepted adaptation of it (Kelly et al., 2016).

Our research adapts the pre-prototype version of TAM as this model enables to even interview inexperienced consumers (Davis and Venkatesh, 2004). Therefore, the basic suggestion is that perceived usefulness positively influences intention to use. Ease of use is not measured in the quantitative study as this cannot be interviewed without actual usage (Davis and Venkatesh, 2004). In line with prior research (Dabholkar, 1996; Meuter et al., 2005), we further differentiate between the three most-mentioned categories: technology-related, personality-related, and demographic factors.

#### **2.2.6 Technology-related Factors**

The usefulness of an ICT artifact is influenced by external factors (Davis and Venkatesh, 2004). Some studies (Dabholkar et al., 2003; Elliott et al., 2013; Marzocchi and Zammit, 2006; Weijters et al., 2007) suggest related items that have proven to influence usefulness of SC in the retail context. Dabholkar et al., (2003) found reliability, enjoyment and control (over the outcome of the process) to be factors positively influencing the usage of SCT. Besides, also speed (or time-saving) was investigated as an adoption factor. However, due to the year of publication, Dabholkar et al., (2003) were not able to differentiate between different schemes of SC. Nonetheless, SC was perceived to be the fastest option (Dabholkar et al., 2003). Similarly, Marzocchi and Zammit (2006) considered control to be one of the factors, influencing satisfaction and repurchase. Elliott et al., (2013) mention reliability to have a positive influence on the attitude towards SC. Moreover, they found that enjoyment positively influences the attitude. Fernandes and Pedroso (2017) work support those factors, finding that reliability is most important for the adoption of SC.

### **2.3 Review of Related Work**

The reviewed studies offer diverse insights into the realm of mobile self-checkout apps and their impact on the retail landscape. Smith (2021) delves into the transformative potential of these apps, aiming to assess their influence on the retail experience. Employing a mixed-methods approach,

Smith combines surveys with in-store observations to gauge user adoption rates, satisfaction levels, and operational efficiency. The findings underscore the positive correlation between mobile self-checkout apps and customer satisfaction, alongside a reduction in checkout time. Nevertheless, challenges related to app usability and security emerge as notable considerations, although the study's scope is constrained by a limited sample size and potential bias from self-reported data.

In contrast, Garcia and Lee (2019) offer a practical roadmap for the development of smartphone-based self-checkout apps. Their descriptive study draws from expert opinions and industry best practices to outline detailed steps encompassing platform selection, integration considerations, and feature prioritization. However, the absence of empirical validation casts a shadow over the recommendations' universal applicability, as contextual variations may impact their efficacy.

Chen and Wang's (2018) exploration of self-checkout benefits for retailers' sheds light on the broader advantages of adopting such systems. Through a combination of literature review and case studies, they unveil benefits ranging from reduced labor costs to enhanced customer experience and increased revenue. Yet, the study's narrow focus on benefits overlooks potential drawbacks like theft and technical glitches, warranting a more comprehensive examination.

Brown and Johnson (2020) pivot towards practical application by endeavoring to develop a full-stack mobile self-checkout app for a hypothetical supermarket. Employing an agile development process, they successfully engineer an app equipped with barcode scanning, payment processing, and user authentication functionalities. Nonetheless, the prototype's testing within a controlled environment raises concerns about real-world scalability and security, necessitating further scrutiny in these domains.

Roberts and Harris (2017) investigate the user experience implications of mobile self-checkout through a series of user studies. Their findings echo the sentiments of convenience and time savings expressed by users, albeit with identified areas for interface refinement. Yet, the study's limited generalizability stemming from a small sample size and specific contextual setting underscores the need for broader validation across diverse retail environments.

Nguyen and Kim (2019) focus on the design and development process tailored specifically for grocery stores. Through a case study approach, they demonstrate the successful reduction of checkout time, enhancement of customer satisfaction, and operational efficiency. However, the study's applicability beyond the grocery store context remains unexplored.

Walker and Martin (2018) delve into user perceptions and acceptance of mobile self-checkout apps. Employing a mixed-methods study, they uncover positive user attitudes towards convenience and flexibility, juxtaposed with concerns regarding security and usability. Yet, the study's sample bias and uncertainty in generalizability across diverse user groups warrant further investigation.

Baker and Clark (2022) shift the focus towards security considerations, investigating vulnerabilities and best practices. Their thorough analysis reveals risks such as data leakage and payment fraud, accompanied by recommendations for secure app design. However, the study's narrow focus on technical aspects neglects organizational and human factors crucial for holistic security enhancement.

Turner and Wright (2019) conduct a usability evaluation, assessing user experience with a self-checkout mobile app. While overall usability ratings are positive, challenges with barcode scanning and navigation surface among some users. Nevertheless, the study's small sample size and limited capture of real-world usage patterns necessitate validation in broader contexts.

Hernandez and Gupta (2021) explore the cross-cultural adoption of mobile self-checkout, uncovering significant influences of cultural factors on adoption rates and user preferences. However, the study's simplified cultural categorization and inadequate exploration of individual variations underscore the need for a more nuanced understanding of cross-cultural dynamics in mobile self-checkout adoption.

Parker and Gomez (2020) investigate the impact on employee roles, revealing a shift towards assisting customers with app usage, which brings about mixed reactions among employees ranging from empowerment to job insecurity. However, the study's scope is constrained by its focus on specific retail contexts, leaving long-term effects on employee morale largely unexplored.

Adams and White (2017) explore the relationship between mobile self-checkout adoption and traditional checkout lanes, finding reduced queue lengths at traditional lanes alongside some lanes

being repurposed for other services. Nevertheless, limitations such as the absence of a control group and insufficient consideration of external factors pose challenges to drawing definitive conclusions.

Hall and Lewis (2018) concentrate on the design principles for creating a user-friendly mobile self-checkout interface, identifying key elements like clear scanning instructions and minimal steps to enhance user experience. Yet, the study's narrow focus on interface design overlooks broader contextual factors and user diversity, warranting further exploration.

Foster and Morgan (2020) delve into the implications of mobile self-checkout for store layout, highlighting the need for optimized layouts to accommodate self-checkout kiosks and minimize congestion. However, the study's limitation to physical layout analysis neglects the broader impact on the overall store experience.

Ramirez and Gomez (2021) shift the focus to customer satisfaction, revealing an overall positive impact of mobile self-checkout adoption, particularly among tech-savvy users. Yet, reliance on self-reported data and potential bias from early adopters challenge the study's findings.

## **2.4 Summary**

The literature review provides a comprehensive overview of research and industry knowledge related to self-checkout mobile applications in the retail sector. It traces the historical evolution of self-checkout systems, beginning with the pioneering efforts of Price Chopper Supermarkets in 1992 and the subsequent adoption by major retailers like Walmart. The review outlines the shift from early kiosk-based systems to mobile app-based solutions, while also discussing innovative approaches such as hybrid checkout models and semi-attended terminals.

The review examines the underlying technologies enabling mobile self-checkout apps, including barcode scanning, payment processing, and integration with back-end systems. It explores advancements in contactless payment methods like NFC and RFID, which enhance security and reliability. Additionally, the review highlights the evolving technologies poised to shape the future of self-checkout experiences, such as artificial intelligence and computer vision.

Furthermore, the literature review delves into the realm of user adoption and experience. It analyzes theories and models for technology acceptance, like the <sup>12</sup>Technology Acceptance Model (TAM), and <sup>12</sup>investigates factors influencing adoption, such as perceived usefulness, ease of use, and <sup>12</sup>trust. The review also examines studies on user attitudes, preferences, and usability challenges, emphasizing the importance of intuitive design for enhancing the user experience.

Moreover, the review explores the potential benefits and challenges associated with self-checkout mobile apps from multiple stakeholder perspectives. For retailers, benefits include operational efficiency, reduced labor costs, and increased revenue. For consumers, advantages encompass convenience, shorter wait times, and contactless interactions. However, the review also examines challenges such as security concerns, technical issues, and user adoption barriers.

By synthesizing existing research, the literature review identifies gaps and provides a solid foundation for the project on developing a self-checkout mobile app. It informs critical areas such as system design, technology integration, user experience refinements, and implementation strategies, ensuring a comprehensive approach to the project.

2.4 <sup>51</sup>Summary of Related Work

Table 2.1: Summary of Related Work

Related Work	Method/Approach	Strengths	Weaknesses
Price Chopper Supermarkets (Inman & Nikolova, 2017)	<sup>30</sup> Introduced the first self-checkout system in 1992. <sup>30</sup> Customers scan, bag, and pay for their purchases independently.	<ul style="list-style-type: none"><li>▪ Pioneered self-checkout technology.</li><li>▪ Reduced labor costs and increased operational efficiency.</li></ul>	<ul style="list-style-type: none"><li>▪ Significant hardware and maintenance costs.</li><li>▪ Required floor space for dedicated kiosks.</li></ul>
Wal-Mart Pilot Program (Walker & Martin, 2018)	Adopted self-checkout systems in select stores starting in 1994.	<ul style="list-style-type: none"><li>▪ Validated the viability of self-checkout in large-scale retail.</li></ul>	<ul style="list-style-type: none"><li>▪ Early systems were still kiosk-based, leading to high setup costs.</li></ul>

Mobile-based Self-Checkout Solutions (Brown et al., 2020)	Used mobile applications for self-checkout, leveraging the BYOD (Bring Your Own Device) principle.	<ul style="list-style-type: none"> <li>▪ Eliminated hardware costs.</li> <li>▪ Increased flexibility and convenience for customers using their own devices.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Depended on reliable internet connectivity.</li> <li>▪ Faced challenges with user adoption and payment methods.</li> </ul>
NFC and RFID Payment Methods (Lee et al., 2018)	Implemented <sup>54</sup> Near Field Communication (NFC) and Radio Frequency Identification (RFID) payments to improve reliability.	<ul style="list-style-type: none"> <li>▪ Enhanced security and efficiency.</li> <li>▪ Did not rely on internet connectivity, improving payment reliability.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Required investment in NFC/RFID technology.</li> <li>▪ Limited to customers with compatible devices.</li> </ul>
Semi-Attended Customer Activated Terminals (SACAT) and Hybrid Models (Roberts et al., 2019)	<sup>1</sup> Combined traditional checkout lanes with self-checkout kiosks.	<ul style="list-style-type: none"> <li>▪ Catered to diverse customer preferences.</li> <li>▪ Allowed smooth transition to self-checkout systems.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Required significant infrastructure for hybrid models.</li> <li>▪ Ongoing need for cashier support in some cases.</li> </ul>
Scan & Go Mobile Apps (Roqqio, Snabble, 2021)	Customers use retailer-provided mobile apps to scan items and pay using their smartphones.	<ul style="list-style-type: none"> <li>▪ Improved service quality with real-time scanning and payments.</li> <li>▪ Reduced need for physical kiosks.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Some customers faced difficulties using the app.</li> <li>▪ Still required QR-code scanning at checkout in some stores.</li> </ul>
Self-Checkout Adoption (NCR, 2014)	Survey of 2,800 respondents showing 90% adoption of <sup>75</sup> self-checkout systems in stores.	<ul style="list-style-type: none"> <li>▪ Highlighted the widespread acceptance and satisfaction with</li> </ul>	<ul style="list-style-type: none"> <li>▪ Focused only on kiosk-based systems, lacking insights on mobile app-based <sup>2</sup> self-checkout systems.</li> </ul>



		self-checkout systems.	
Traditional Self-Checkout Systems (Garcia & Chen, 2019)	Early systems relied on hardware-heavy, kiosk-based setups that customers interacted with to check out independently.	<ul style="list-style-type: none"> <li>Reduced the need for cashiers and labor costs.</li> <li>Improved customer satisfaction with shorter wait times.</li> </ul>	<ul style="list-style-type: none"> <li>High investment in hardware and maintenance.</li> <li>Issues related to space requirements and scalability.</li> </ul>
Bring Your Own Device (BYOD) Principle (Brown et al., 2020)	Shifted to mobile-based self-checkout, allowing customers to use their smartphones for scanning and paying for items.	<ul style="list-style-type: none"> <li>Reduced hardware costs significantly.</li> <li>Allowed greater flexibility for customers using personal devices.</li> </ul>	<ul style="list-style-type: none"> <li>Depended on stable internet connectivity.</li> <li>User adoption and payment processing issues still persisted.</li> </ul>
Alternative Payment Methods (Lee et al., 2018)	Introduced NFC and RFID-based payment systems to mitigate internet connectivity issues during checkout.	<ul style="list-style-type: none"> <li>Improved checkout reliability by eliminating reliance on internet.</li> <li>Enhanced security in transactions.</li> </ul>	<ul style="list-style-type: none"> <li>Required customers to have NFC/RFID-enabled devices.</li> <li>Investment in new technology infrastructure needed.</li> </ul>
Mobile Self-Checkout Systems (Schmidt et al., 2022)	Focused on mobile self-checkout systems where customers scan and pay using their smartphones, bypassing physical checkouts.	<ul style="list-style-type: none"> <li>Streamlined the checkout process, allowing faster transactions.</li> <li>Reduced labor costs for retailers.</li> </ul>	<ul style="list-style-type: none"> <li>Some customers struggled with app usability.</li> <li>Dependent on stable mobile networks and device compatibility.</li> </ul>
Retailer-Provided Mobile Apps (Roqqio, Snabble, 2021)	Mobile apps provided by retailers allow customers to scan products and pay via their smartphones.	<ul style="list-style-type: none"> <li>Enhanced convenience for customers.</li> <li>Improved service quality and</li> </ul>	<ul style="list-style-type: none"> <li>QR-code scanning still needed at the store exit.</li> <li>User difficulties with app interface in some cases.</li> </ul>

		operational efficiency retailers.	for	
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## CHAPTER THREE

### REQUIREMENT, ANALYSIS AND DESIGN.

#### 3.1 Overview

This chapter describes the methodology used in the study, including the Adopted Methodology, tools and techniques, ethical considerations, requirement analysis, requirement specification, system design, and summary.

#### 3.2 Adopted Methodology

The adopted methodology for this project is the waterfall model. This approach is straightforward and easy to comprehend because each step has a distinct deliverable and review procedure, and each phase is completed one at a time. The project's operations are structured in phases once more, and the sequential pattern of the job makes it easier to handle. Using this approach makes it easy because it provides clear step-by-step instructions.

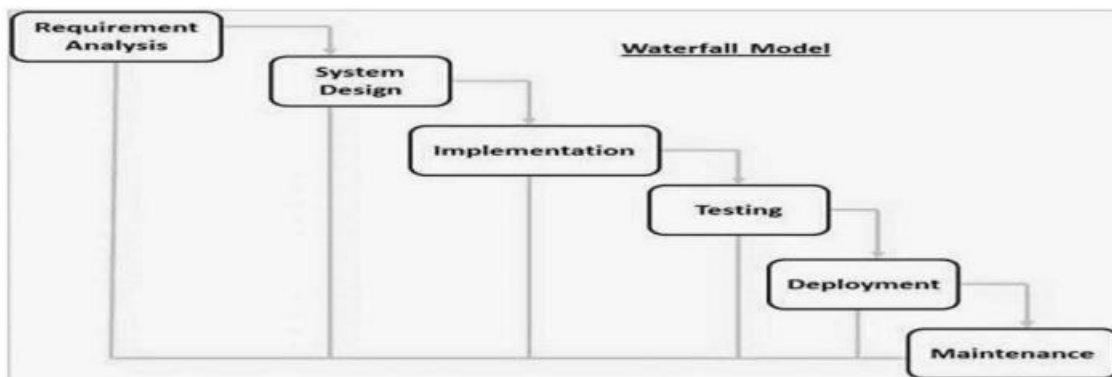


Figure 0.1 Waterfall Model Source: (Wikipedia,2011)

#### 3.3 Tools and techniques

1. **React Native** is a framework that allows you to create real mobile applications identical to an application built using Swift or Java. The same fundamental UI building blocks used by iOS and Android are used by React Native. These building blocks are just put together using JavaScript and React.

2. **Firebase** was chosen as the back-end service for this project due to its real-time database, which allows for instant synchronization between the mobile app and the store's inventory system.

3. **Firebase** was chosen for the database.
4. **Expo** was chosen as the framework for react native
5. **Vs code** as the code editor.

### **3.5 Ethical Consideration**

Self-checkout app that is respectful of user rights, fair, secure, and socially responsible. The primary consideration is to focus on the of the functionality, which is of utmost importance. The goal is to help users concentrate on relevant information without distracting them. Here are some of the most common examples:

1. Privacy and Data Security
2. Accessibility
3. Fairness and Equity
4. User Autonomy
5. Security
7. User Experience and Satisfaction

### **3.6 REQUIREMENT ANALYSIS**

#### **3.6.1 SOFTWARE REQUIREMENTS**

1. Operating System: Windows
2. Database: Firebase
3. Application Program: VS code
4. React Native
5. Back-end: Firebase

3.7 Requirements Specifications

Table 3.1: Functional Requirement Specifications

Req. No.	Description
FR1	Product Scanning. Users should be able to securely log in and authenticate their identity using methods such as email/password, biometric authentication, or social media accounts.
FR2	Price Display and Calculation; This app displays the price of a scanned item and calculates the total cost.
FR3	Digital Receipts; After a successful transaction, the app provides a digital receipt that users can view, save, or email.
FR4	Notification and Alerts: The app should allow Users receive notifications and alerts for order updates, promotions, and important information.
FR5	Fraud Prevention and security monitoring: This app includes measures to detect and prevent fraudulent activities, ensuring secure transactions.
FR6	Data Privacy and Security: The app includes measures to detect and prevent fraudulent activities, ensuring secure transactions and user protection.

7 Table 3.2: Non-Functional Requirement Specifications

Req. No.	Requirement Description
NFR1	37 Performance and Responsiveness: The app must load quickly and respond promptly to user interactions, ensuring a seamless and efficient checkout process.
NFR2	48 Reliability and Availability: The app must be highly reliable and available, with minimal downtime to ensure users can always complete their transactions
NFR3	33 Scalability: The app should be able to handle an increasing number of users and transactions without performance degradation, especially during peak hours.
NFR4	24 Compliance with Standards: The app must comply with industry standards and best practices for software development, security, and data privacy.
NFR5	25 Error Handling and Robustness: The app should handle errors gracefully, providing clear error messages and recovery options to ensure a smooth user experience

## 3.8 SYSTEM ARCHITECTURE

### 3.8.1 Application Architecture

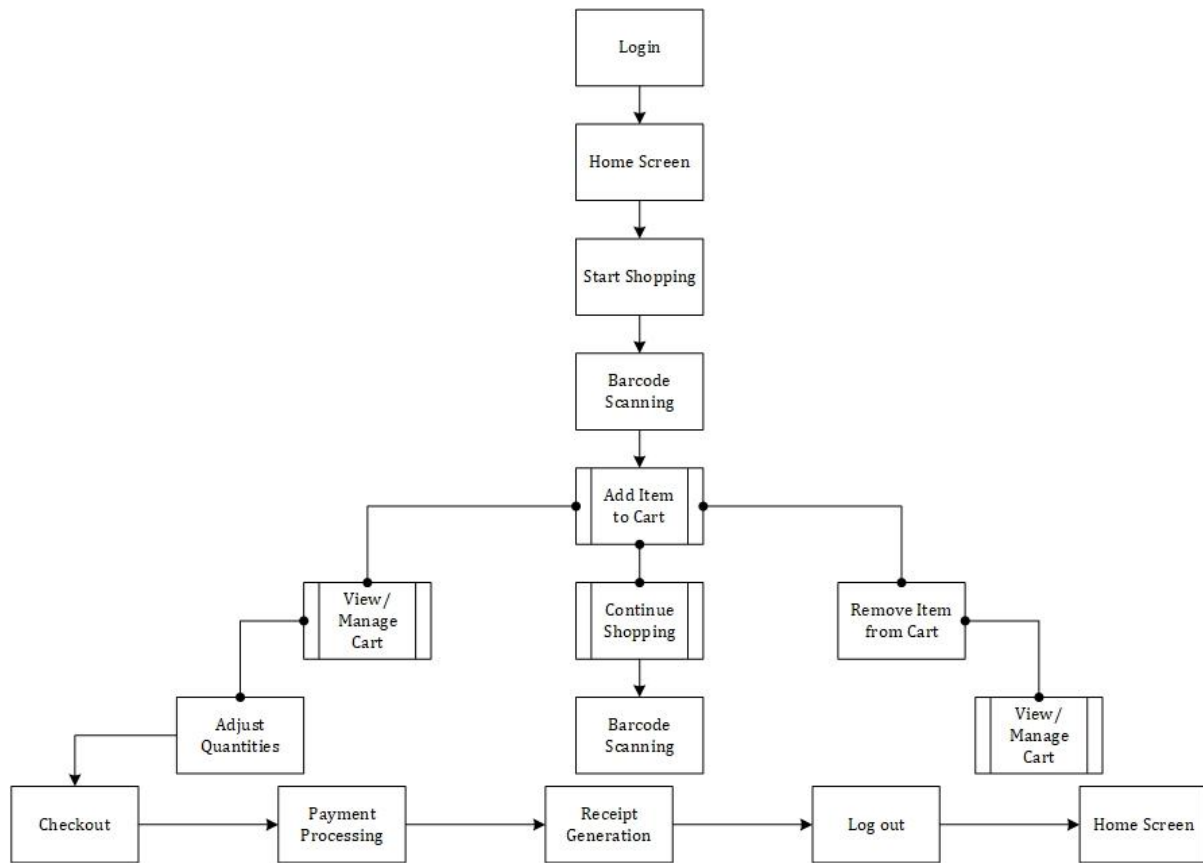
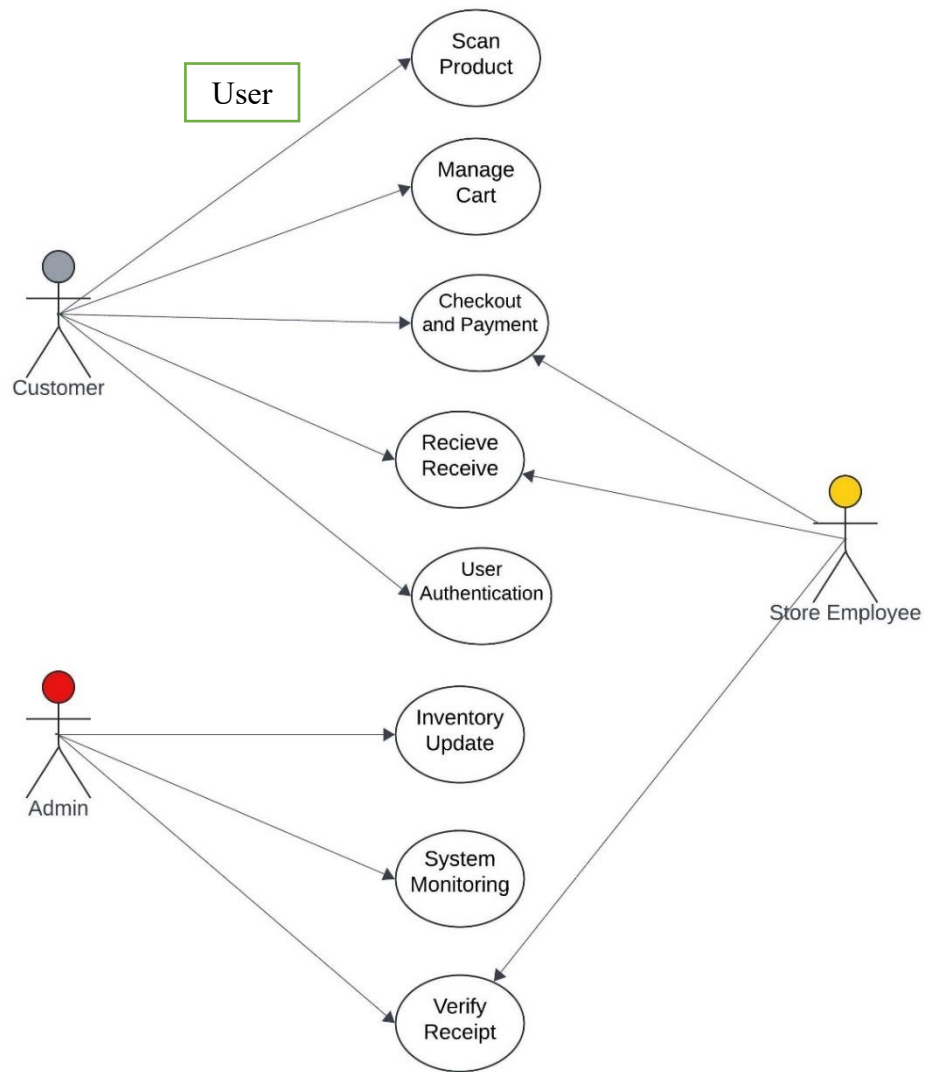


Figure 0.2 Application Architecture

### 3.8.2 Use Case diagram.



**Figure 0.3 Use Case diagram**



### 3.8.3 Use case description

Table 3.3: Use case Description for Login/Register

15 Use Case:	Register New User/Login	
Description	This use case describes process of registering new users and logging in existing users by providing details such as email, password, or social media login credentials.	
Actors:	User	
Stakeholders:	Customers, Retailers.	
Preconditions:	None	
Postconditions:	If registration is successful, Users are registered and can be logged in.	
Main flow	24 User: 1. User selects the register option. 2. If the user selects register, the user provides their credentials.	36 System: 3. The system validates the provided credentials. 4. If the validation is successful, the user is logged into the application. 5. Use case ends
Exception Condition:	68 If the login credentials are incorrect, an error message will appear. The user then has the option to retry entering correct credentials or cancel which will end the current process	

5 Table 3.4: Use Case Description for Admin

Use Case:	Admin
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Description	This use case describes process of managing the inventory, transactions, managing user data and system maintenance by the Administrator.	
Actors:	Admin, system	
Stakeholders:	Customers, Retailers.	
Preconditions:	Admin is logged into the application.	
Postconditions:		
Main flow	Admin: <ol style="list-style-type: none"> <li>The admin updates the inventory as needed (add, remove or edit items).</li> <li>The admin accesses the transaction history</li> <li>The admin removes or updates users information.</li> <li>The admin performs routine checks or troubleshooting.</li> </ol>	System: <ol style="list-style-type: none"> <li>The system saves the changes and update inventory database.</li> <li>The system displays list of transactions.</li> <li>The system saves the changes and updates the database.</li> <li>The system executes maintenance tasks and logs the actions.</li> </ol>
Exception Condition:	None	

5

Table 3.5: Use Case Description for Scanning Barcode

Use Case:	Scanning Barcode	
Description	This use case describes how users scan product barcodes using their mobile device's camera to add items to their cart.	
Actors:	User, system	
Stakeholders:	Customers, Retailers.	
Preconditions:	User is logged into the application and has scanned product barcode.	
Postconditions:	None	
Main flow	User: 1. User opens camera and scan product barcode.	System: 5. System fetches the product information and displays it on screen.
Exception Condition:	None	

5

Table 3.6: Use case description for Viewing Cart.

Use Case:	View Cart
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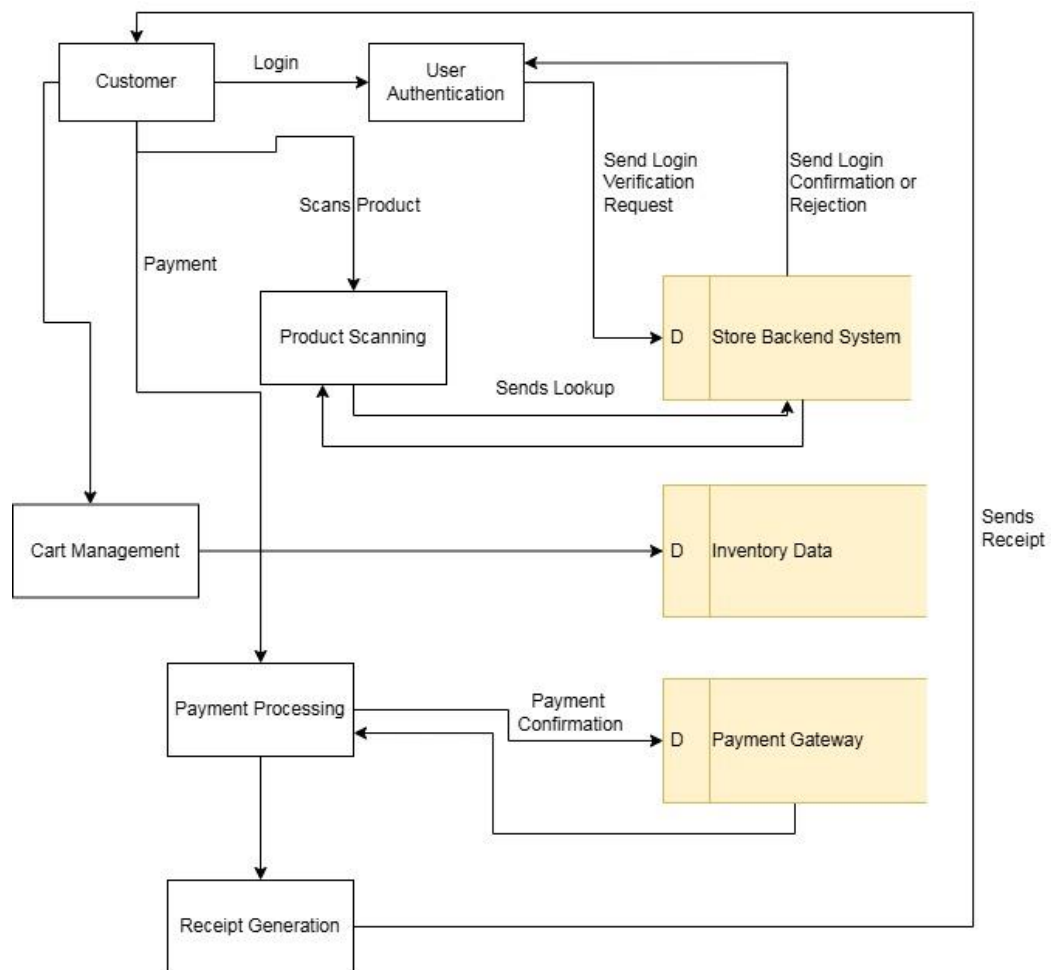
Description	This use case describes how users view and manage items in their cart.	
Actors:	User, system	
Stakeholders:	Customers, Retailers.	
Preconditions:	User is logged into the application and can smoothly view their cart and proceed to checkout.	
Postconditions:	User has all the necessary information and options to proceed with their purchase.	
Main flow	User: 1. User adds items to cart and taps the cart icon to navigate to the cart section.	System: 2. System fetches cart details and display all items in the cart, along with their prices, quantities and total amount.
Exception Condition:	None	

5 Table 3.7: Use case description for Checkout

Use Case:	Checkout
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Description	This use case describes how users can proceed to checkout where they will select payment methods such as credit/debit card, mobile wallets.	
Actors:	User, system	
Stakeholders:	Customers, Retailers.	
Preconditions:	User can successfully complete the checkout process..	
Postconditions:	User is informed about their purchase and the system is updated accordingly.	
Main flow	User: <ol style="list-style-type: none"> <li>1. User taps on the checkout button.</li> <li>2. Users select the payment method and confirm the purchase.</li> </ol>	System: <ol style="list-style-type: none"> <li>3. System navigates to payment option , processes the payment, confirms the order and provides summary and receipt.</li> </ol>
Exception Condition:	None	

### 3.8.3 Data Flow Diagram <sup>13</sup>



**Figure 0.4 Data Flow Diagram**

### 3.8.4 Entity Relationship Diagram (ERD)

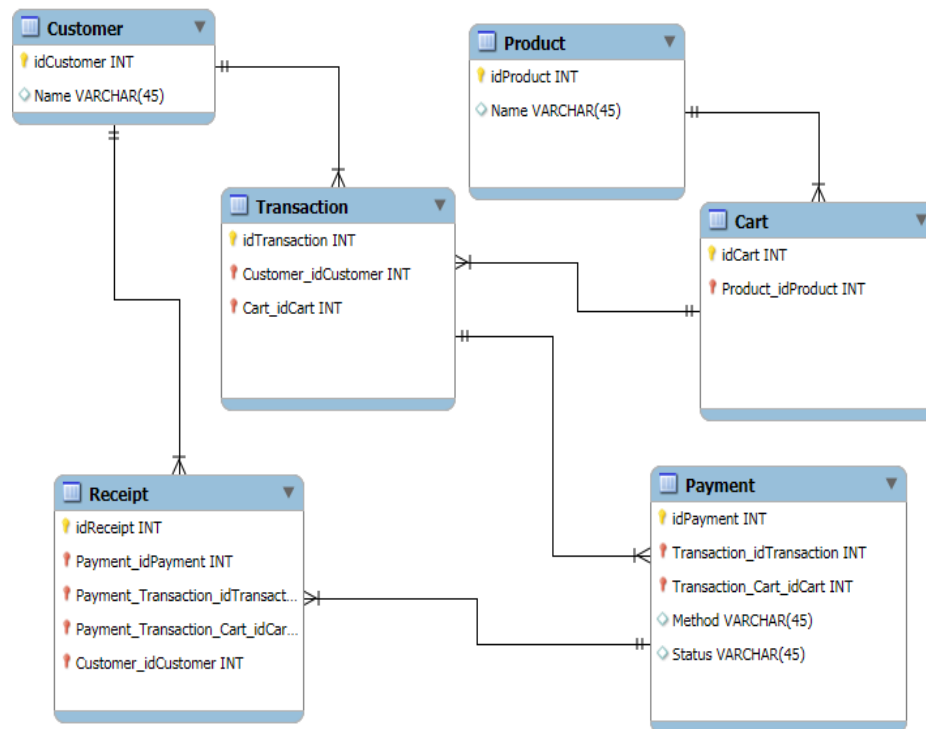
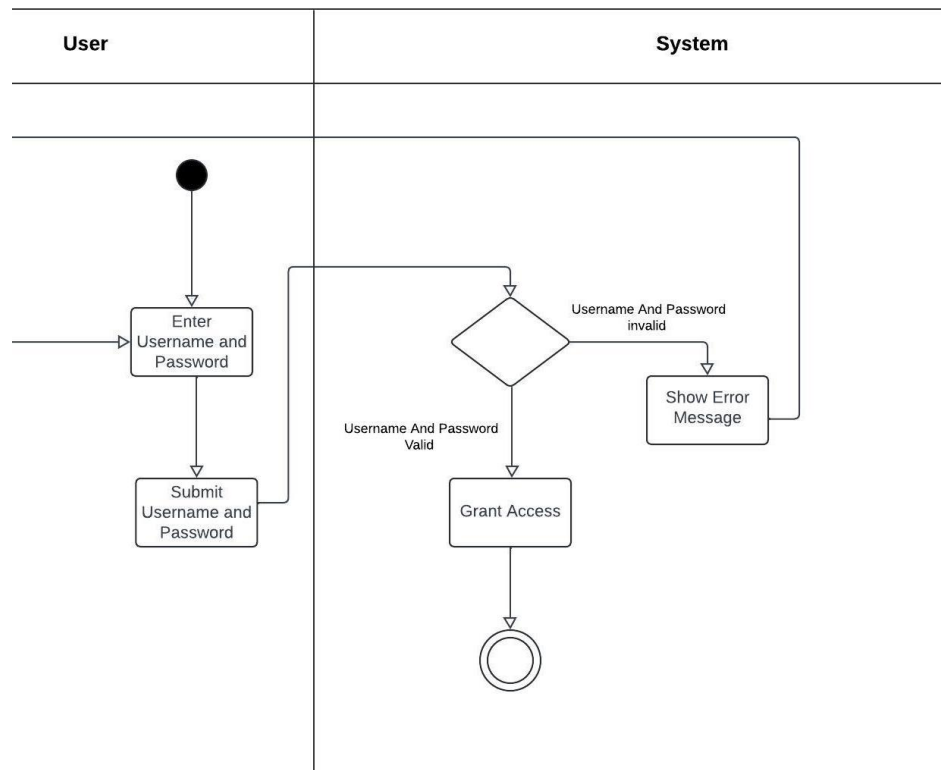


Figure 0.5 ERD Diagram

### 29 3.8.3 Activity Diagram for user and Authentication



**Figure 0.6 Activity diagram for user and authentication.**



### 3.8.6 Activity Diagram for Product scanning

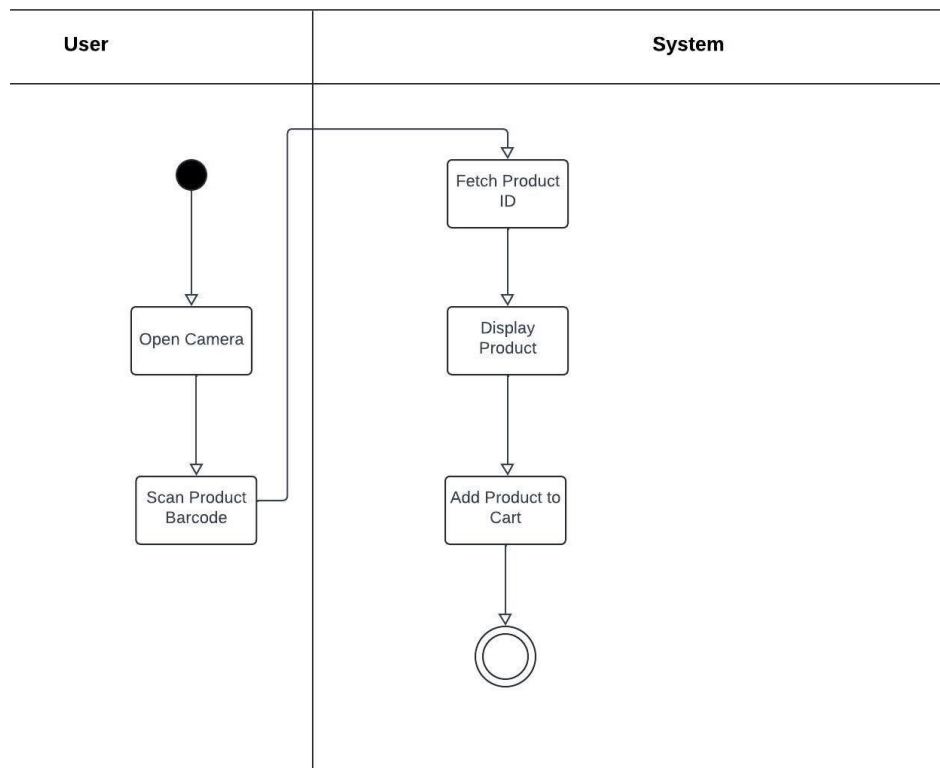
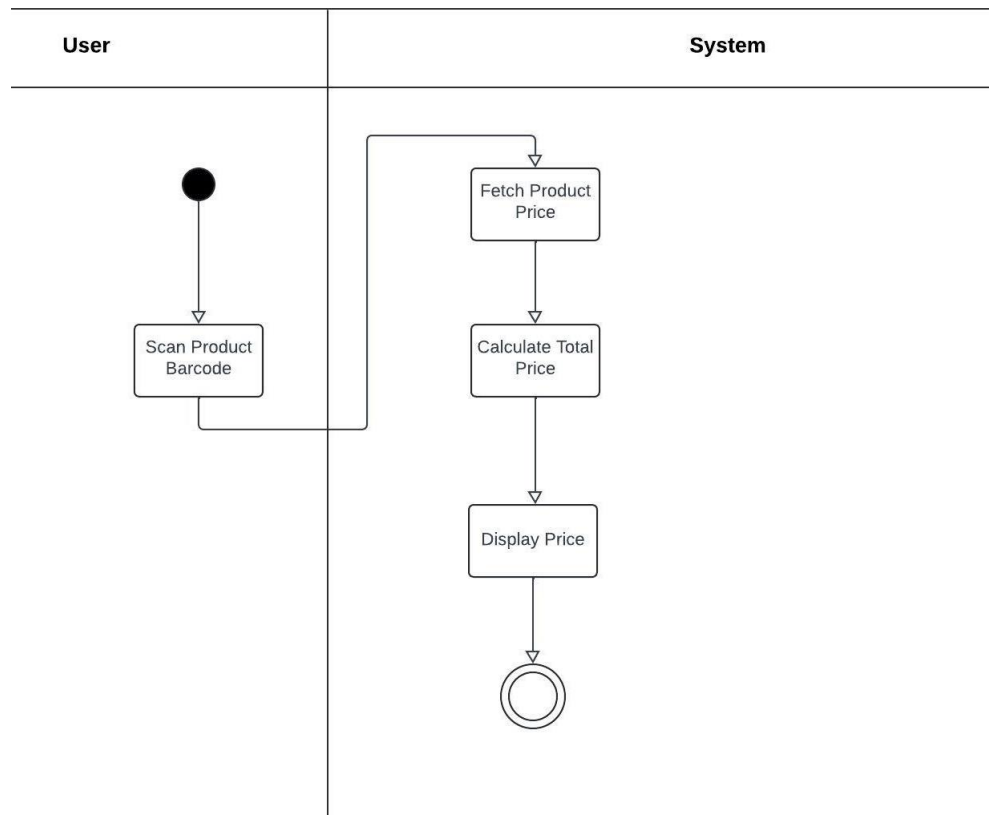


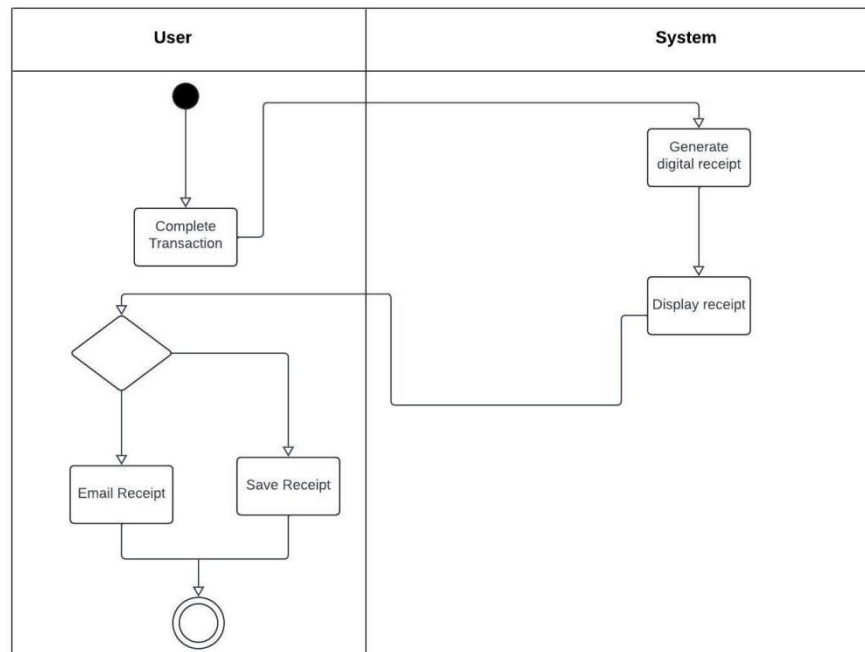
Figure 6.7 <sup>23</sup> Activity Diagram for Product scanning

### 3.8.7 Activity diagram for Price Display and calculation



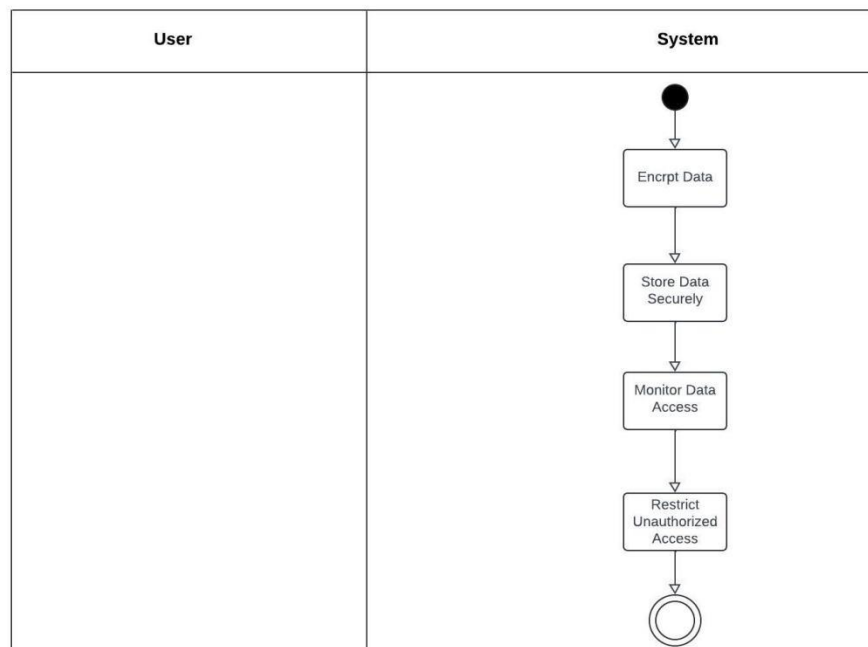
**Figure 0.8 Activity diagram for Price Display and calculation**

### 3.8.8 Activity Diagram for Digital Receipt



**Figure 0.9 Activity Diagram for Digital Receipt**

### 3.8.9 Activity Diagram for Data Privacy and security



**Figure 0.10 Activity Diagram for Data Privacy and security**

## CHAPTER FOUR

### IMPLEMENTATION AND TESTING

#### 4.1 Overview

This chapter presents the comprehensive process involved in the implementation and testing of the self-checkout mobile application for retail stores. The chapter outlines the main features of the application, the challenges faced during the implementation phase, and the strategies employed to overcome these issues. Furthermore, it discusses the testing methodologies applied to validate the application and ensure its functionality, reliability, and user-friendliness. Finally, the chapter provides a usage guide for end-users and concludes with a summary of key points.

#### 4.2 Main Features

The self-checkout mobile application was developed with several core features aimed at enhancing the user experience and addressing traditional checkout challenges. These features were designed to streamline the shopping process, reduce wait times, and provide a seamless and secure checkout experience. The primary features include:

1. **Barcode Scanning:** Users can scan the barcode of products using their mobile phone's camera. The scanned items are automatically added to the virtual shopping cart, and the app provides real-time pricing information.
2. **Payment Gateway Integration:** The application integrates with multiple payment gateways, allowing users to pay using credit/debit cards, mobile wallets (Apple Pay, Google Pay), and Near Field Communication (NFC) methods. This provides flexibility and convenience for completing transactions.
3. **Inventory Tracking:** The app is connected to the store's inventory management system, which ensures that users are notified if an item is out of stock. This feature prevents over-purchasing and enhances the shopping experience by providing real-time product availability.
4. **User Authentication:** The app includes secure user authentication using OAuth 2.0, ensuring that user data is protected. Users can log in through social media platforms (e.g., Google, Facebook) or create a dedicated account for the app.

5. **Receipt Generation:** After completing a transaction, the app generates a digital receipt, which can be saved or shared via email. The receipt serves as proof of purchase and can be shown to store personnel before exiting.

#### 21 4.3 Implementation Problems

During the implementation process, several challenges were encountered. These issues ranged from technical difficulties to integration problems and posed significant roadblocks to the timely completion of the project. The main problems included:

1. **Barcode Scanner Accuracy:** Ensuring the barcode scanner accurately recognized various product barcodes under different lighting conditions proved to be a technical challenge. Variations in barcode formats and types further complicated this issue.
2. **Payment Gateway Integration:** While integrating multiple payment gateways, inconsistencies were observed in transaction processing times, especially with NFC-based payments. Additionally, some gateways had stringent security protocols that required extensive configuration.
3. **Backend System Integration:** Integrating the app with the store's existing inventory management system was complex. The backend system used older technology, and compatibility issues arose during data synchronization processes.
4. **Security Concerns:** Ensuring the security of user data, particularly during payment processing and authentication, required the implementation of advanced encryption techniques. However, this created performance bottlenecks, especially on older mobile devices.
5. **Device Compatibility:** The app was designed to work across a wide range of mobile devices and operating systems (iOS and Android). However, differences in hardware specifications led to performance issues on lower-end devices.

#### 7 4.4 Overcoming Implementation Problems

To address the challenges encountered during the implementation phase, several strategies were employed:

1. **Barcode Scanner Optimization:** The barcode scanning functionality was improved by incorporating machine learning algorithms to enhance image recognition under varied lighting conditions. In addition, multiple barcode formats were supported to ensure compatibility with different product labels.
2. **Payment Gateway Configuration:** To tackle payment gateway issues, redundant fallback mechanisms were implemented. If a transaction failed using one gateway, the app automatically switched to an alternative gateway. Extensive performance testing was also conducted to ensure that real-time payment processing was reliable.
3. **Backend System Compatibility:** To resolve integration issues with the store's legacy backend system, middleware was introduced to facilitate smooth communication between the app and the backend. APIs were developed to synchronize inventory data in real time, ensuring accurate stock levels within the app.
4. **Security Enhancements:** To mitigate security concerns, the app utilized end-to-end encryption for all transactions and sensitive data. Additionally, two-factor authentication was introduced to provide an extra layer of security during user login and payment processes.
5. **Performance Optimization for Lower-end Devices:** The app was optimized to run more efficiently on lower-end devices by reducing the complexity of graphical elements and optimizing background processes. This ensured that the app performed consistently across a wide range of devices.

## 4.5 Testing

Testing was a critical phase in ensuring the functionality, reliability, and security of the self-checkout mobile application. Both functional and non-functional testing methodologies were applied to validate the system.

### 4.5.1 Test Plans

The following test plans were developed to evaluate different aspects of the application:

Table 4.1: Test Plans

Test Area	Test Type	Objective
<b>Barcode Scanning</b>	Functional Testing	Ensure that the app accurately scans and identifies barcodes.
<b>Payment Processing</b>	Security Testing	Validate secure and successful completion of payment transactions.
<b>Inventory Synchronization</b>	Integration Testing	Verify real-time synchronization of stock availability.
<b>User Authentication</b>	Security Testing	Ensure secure login and data encryption during user authentication.
<b>Performance</b>	Load Testing	Measure app performance under different load conditions (e.g., multiple users).
<b>User Interface</b>	Usability Testing	Test the app's user interface for intuitiveness and ease of use.

4.5.2 Test Case

55 Table 4.2: Test Case for user authentication

Test Case	
Description	Validate user authentication using email and password
Test Type	Security Testing
Preconditions	User has an account with email and password
Test procedure	1. Open the app. 2. Select "Login with Email". 3. Enter correct email and password.
Expected Result	User should be logged in successfully and granted access to the app's features.
Status	Pass

Table 4.3: Testing for barcode scanning



<b>Test Case Description</b>	Verify bar-code scanning functionality
<b>Test Type</b>	Functional Testing
<b>Preconditions</b>	App is installed and running
<b>Test procedure</b>	<ol style="list-style-type: none"> <li>1. Open the app.</li> <li>2. Select "Scan" option.</li> <li>3. Scan a product bar-code.</li> </ol>
<b>Expected Result</b>	The app should accurately scan the bar-code and display the correct product details (e.g., name, price, availability).
<b>Status</b>	Pass

Table 4.4: Testing for Adding/Removing items from cart

<b>Test Case Description</b>	
------------------------------	--

	Test app usability for adding/removing items from cart
<b>Test Type</b>	Usability Testing
<b>Preconditions</b>	User is logged in and has items in the cart
<b>Test procedure</b>	<ol style="list-style-type: none"> <li>1. Scan multiple items to add them to the cart.</li> <li>2. Remove some items from the cart.</li> </ol>
<b>Expected Result</b>	Items should be added and removed from the cart accurately, and the cart's total price should update in real-time.
<b>Status</b>	Pass

Table 4.5: Testing for Payment encryption

<b>Test Case Description</b>	Validate secure payment encryption
<b>Test Type</b>	Security Testing

<b>Preconditions</b>	User is logged in and attempting a payment
<b>Test procedure</b>	1. Complete a transaction using any payment method.
<b>Expected Result</b>	Payment data should be encrypted during transmission, and no sensitive information should be exposed in logs or network
<b>Status</b>	Pass

Table 4.6: Testing for Digital receipt generation

<b>Test Case Description</b>	Validate digital receipt generation after payment
<b>Test Type</b>	Functional Testing

<b>Preconditions</b>	User has completed a payment
<b>Test procedure</b>	1. Complete a purchase using any payment method.
<b>Expected Result</b>	A digital receipt should be generated and displayed and should be shareable via email.
<b>Status</b>	Pass

Table 4.7: Testing for Logout

<b>Test Case Description</b>	Verify customer logout functionality
<b>Test Type</b>	Functional Testing
<b>Preconditions</b>	User has logged in.

<b>Test procedure</b>	1. Open the settings menu. 2. Select "Logout".
<b>Expected Result</b>	The user should be logged out, and the app should return to the login screen.
<b>Status</b>	Pass

Table 4.8: Testing for Payment through Credit card.

<b>Test Case Description</b>	Validate payment through credit card
<b>Test Type</b>	Payment Testing
<b>Preconditions</b>	User is logged in and has items in the cart
<b>Test procedure</b>	1. Proceed to checkout. 2. Choose "Credit Card" as payment method. 3. Enter valid credit card details. 4. Confirm payment.
<b>Expected Result</b>	Payment should be processed successfully, and a confirmation screen with a digital receipt should be sent to your email.
<b>Status</b>	Pass

### 4.5.3 Manual Testing

Manual testing was employed to evaluate the app's functionality from an end-user perspective. Testers performed various tasks, such as scanning items, adding to the cart, processing payments,

and checking out, to identify any potential issues. The following steps were part of the manual testing process:

1. **Barcode Scanning:** Testers used different mobile devices to scan a variety of products in various lighting environments to ensure consistent performance.
2. **Payment Processing:** Multiple payment methods were tested, including credit cards, mobile wallets, and NFC payments, to ensure transactions were processed successfully.
3. **User Authentication:** Testers attempted to log in via different authentication methods (social media, email, and password) and evaluated the response time and security features.
4. **Inventory Tracking:** Testers selected items that were low in stock to ensure the app accurately notified users when an item was unavailable or running out.
5. **User Interface:** Testers navigated the app to assess the intuitiveness of the interface, reporting any usability issues or areas for improvement.

## 4.6 User Guide

The following is a brief guide for users on how to navigate and use the self-checkout mobile application:

1. **Registration/Login:** Users can register by creating a new account or log in using their existing social media accounts (Google, Facebook). Two-factor authentication is optional but recommended for enhanced security.
2. **Scanning Items:** Users can scan product barcodes using their smartphone's camera. Scanned items are displayed in the virtual shopping cart, along with their prices and quantities.
3. **Managing the Cart:** <sup>31</sup>Users can view and manage the contents of their shopping cart by adjusting quantities or removing items.
4. **Payment:** Once shopping is complete, users can proceed to the checkout. <sup>53</sup>The app provides multiple payment options, including credit/debit cards, mobile wallets, and NFC payments.
5. **Digital Receipt:** After payment is successful, a digital receipt is generated. This receipt can be shown to store employees when exiting the store.
6. **Language Settings:** Users can change the app's language by navigating to the settings and selecting their preferred language.

## <sup>10</sup>4.7 User Interface Design

<sup>10</sup>The user interface design of the Application is vital for providing a smooth and intuitive user experience. The UI design process was centered around users, integrating their feedback and conducting usability tests to develop an interface that is both accessible and visually attractive.

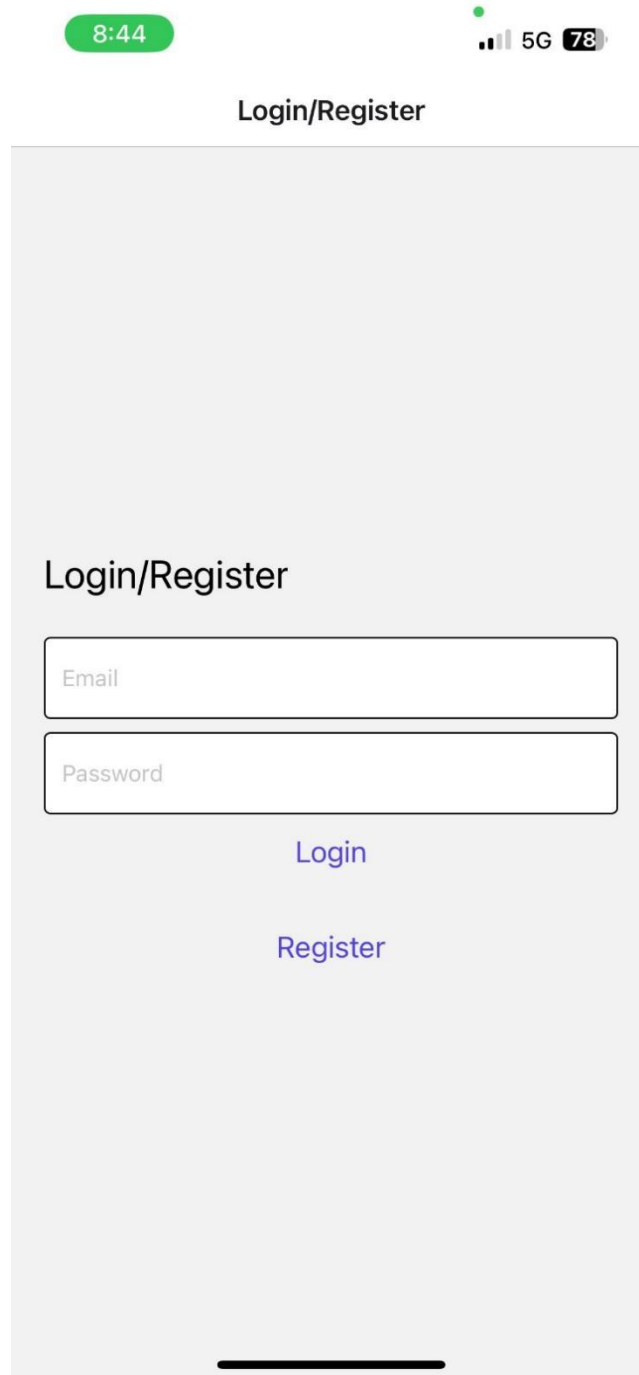


Figure 4.1: login/Register page

The login/Register page allows users to either access their existing accounts or create new ones. For existing users it provides a secure way to enter their credentials and access the app features.



For new users it facilitates the account creation by collecting necessary information like email, password and other relevant data.

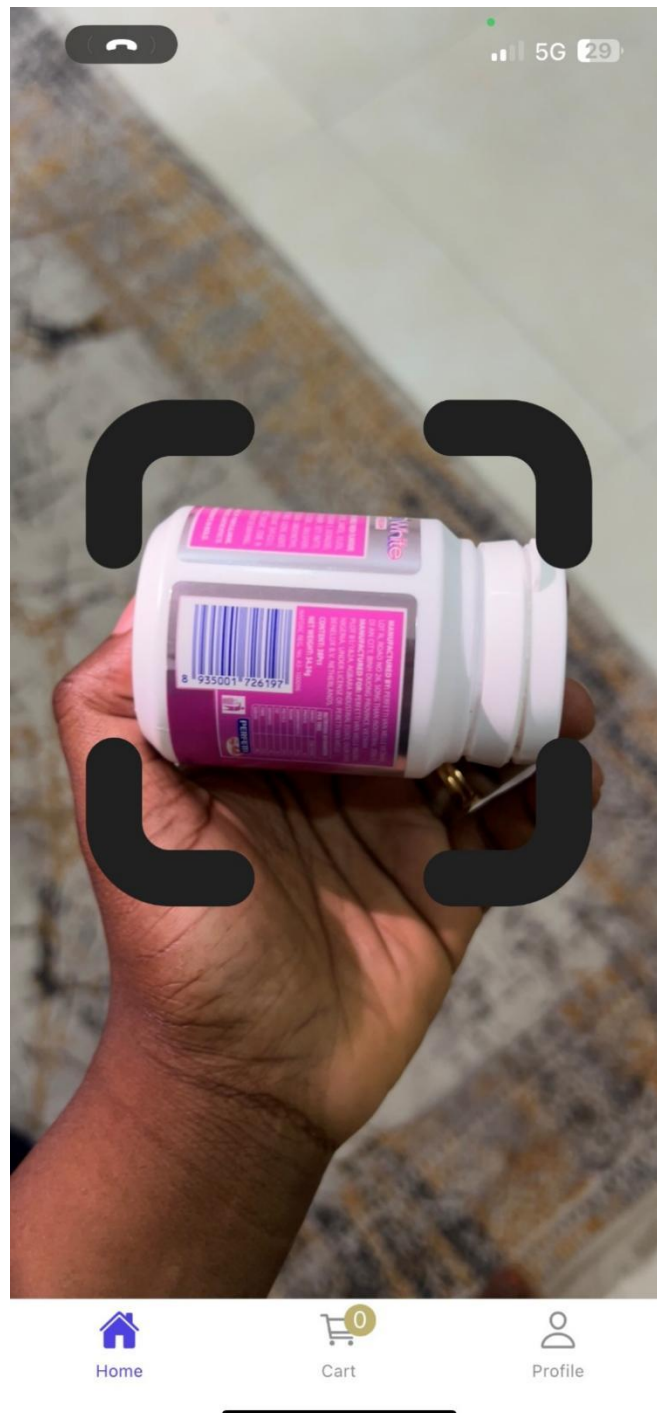


Figure 4. 2: Scanning product Barcode

Scanning product barcode<sup>22</sup> allows users to quickly and easily add items to their Shopping cart. By using the phone's camera, the App reads the barcode on a product, retrieves its information from the database and displays it on the screen.

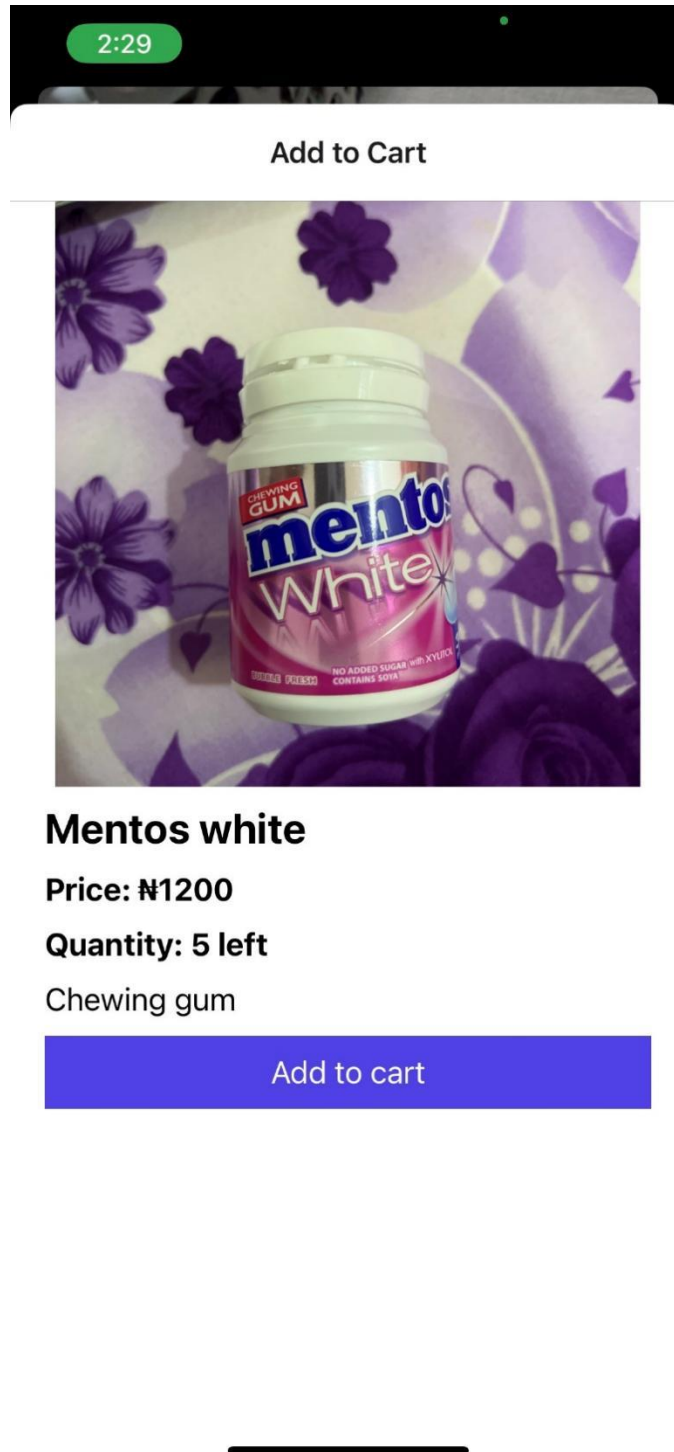


Figure 4. 3: Information about Product scanned



Figure 4. 4: Shopping Cart

The shopping cart serves as a virtual basket where users can see items they have scanned and added. It displays the product name, quantities and prices. This feature ensures that users have a clear overview of their purchases before Checking out.

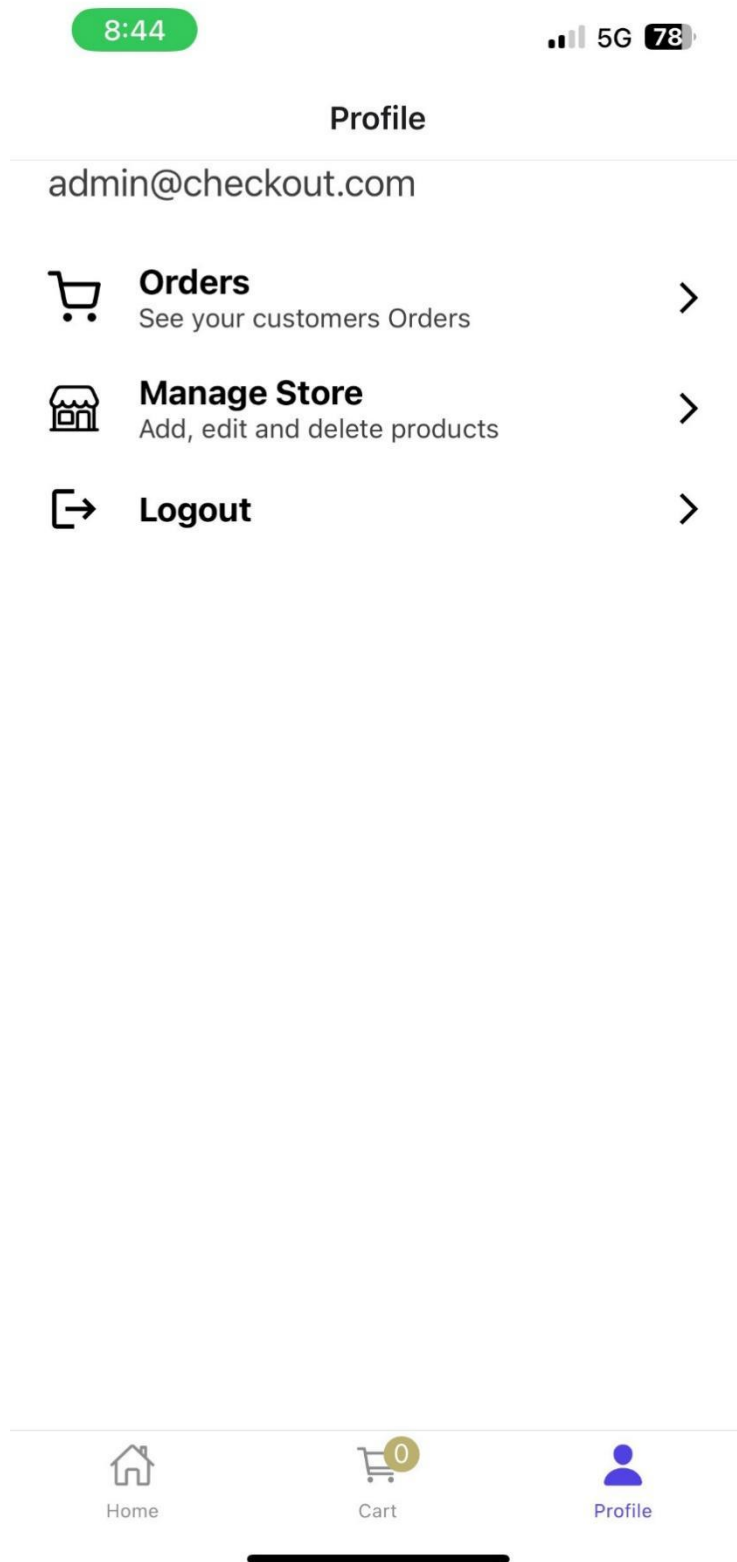


Figure 4. 5: Admin's Page

The Admin's page is where the administrators can manage the store. This includes adding or removing products, updating prices, and managing user accounts and orders.

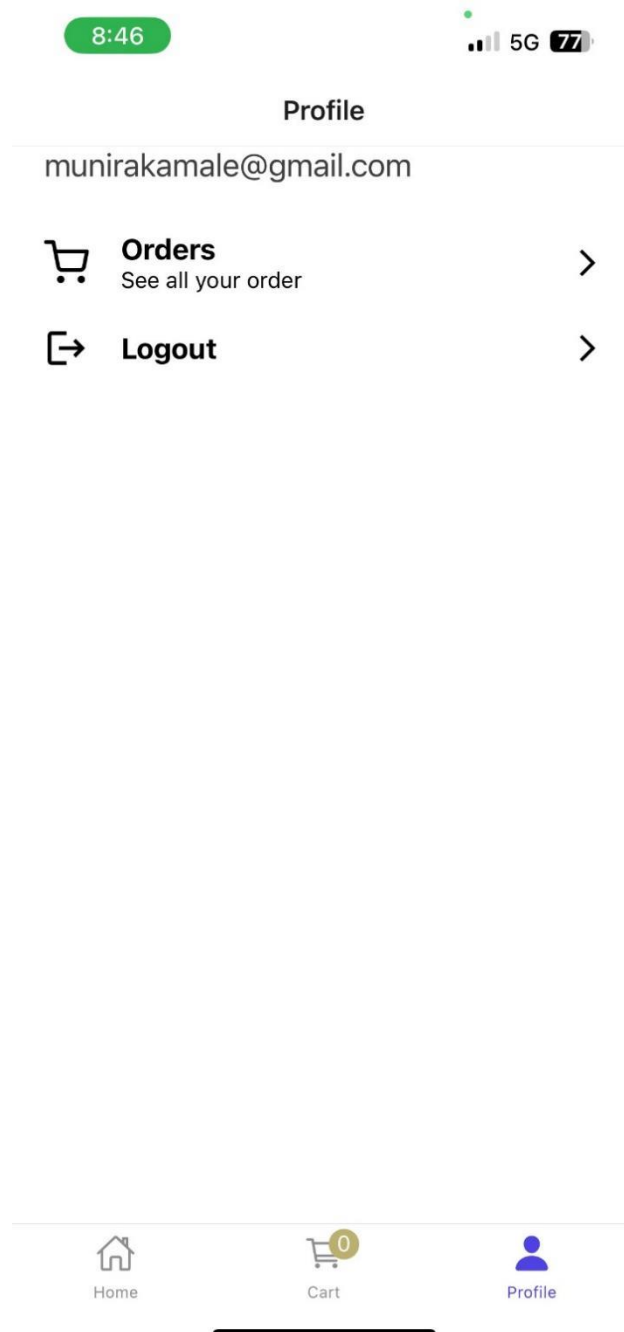
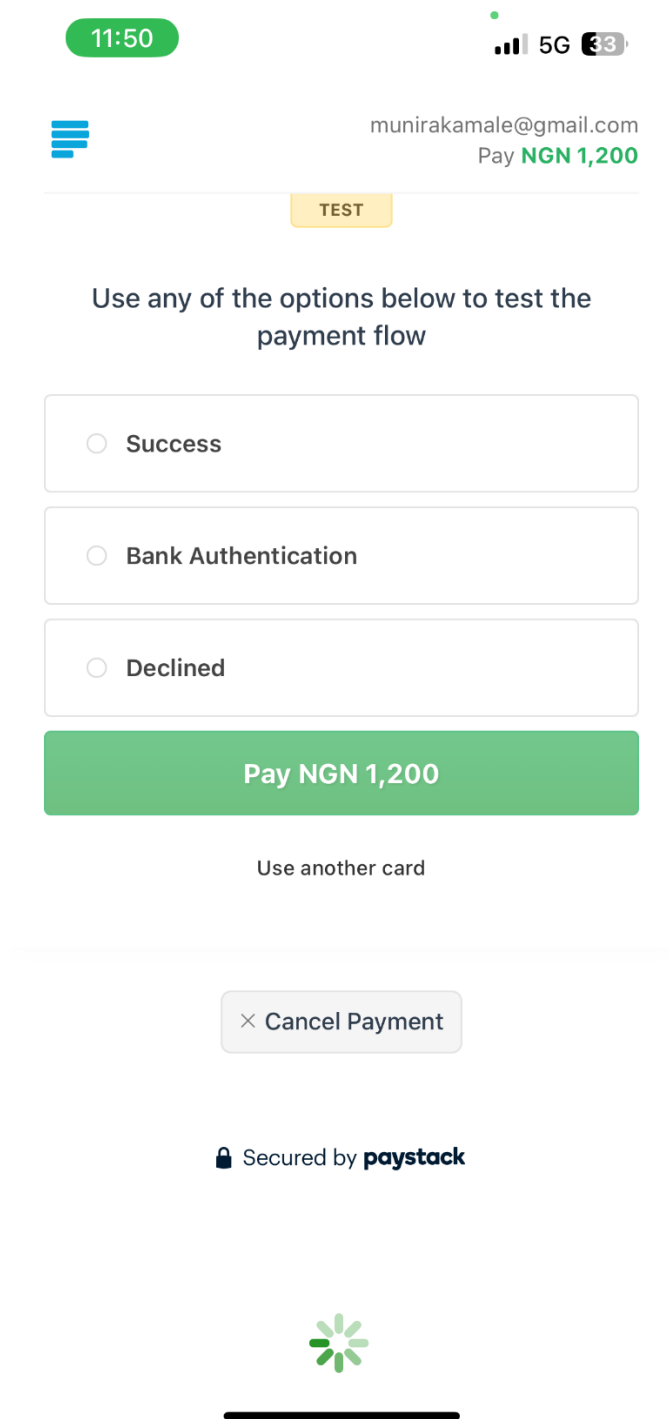


Figure 4. 6: User's page

The user's page is where you see all orders and history of orders.



The image shows a mobile application interface for a payment screen. At the top, there is a status bar with the time 11:50, 5G signal, and a battery icon at 33%. Below the status bar, on the left, is a blue hamburger menu icon. On the right, the email address munirakamale@gmail.com is displayed, followed by the text 'Pay NGN 1,200'. A yellow 'TEST' button is centered below the email. The main heading reads 'Use any of the options below to test the payment flow'. There are three radio button options: 'Success', 'Bank Authentication', and 'Declined'. Below these is a large green button labeled 'Pay NGN 1,200'. Underneath the green button is the text 'Use another card'. At the bottom, there is a grey button with a close icon and the text 'Cancel Payment'. Below the button is a security notice: 'Secured by paystack' with a padlock icon. At the very bottom, there is a green loading spinner icon and a thick black horizontal bar.

11:50 5G 33

munirakamale@gmail.com  
Pay NGN 1,200

TEST

Use any of the options below to test the payment flow

☐ Success

☐ Bank Authentication

☐ Declined

Pay NGN 1,200

Use another card

× Cancel Payment

Secured by **paystack**




Figure 4. 7: Payment page

The payment page allows users to make payments after checking out using various payment methods. This could include options like credit/debit cards, mobile wallets.

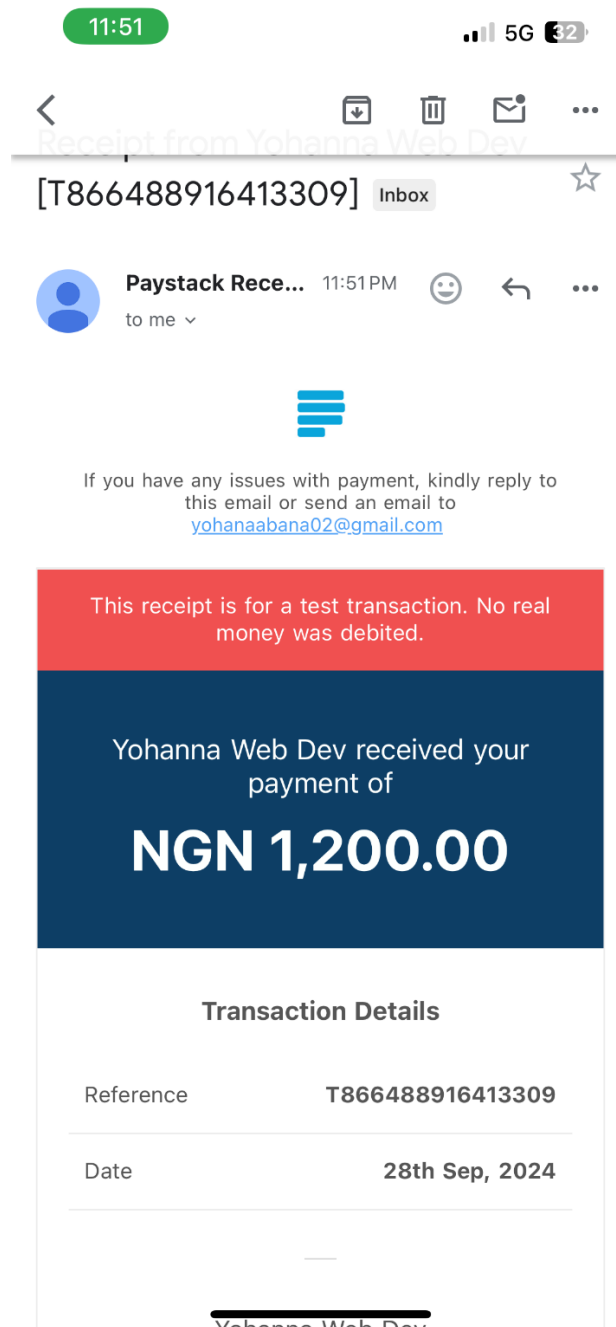


Figure 4. 8: Digital Receipt



42

After a successful transaction, a digital receipt will be sent to your email and you can just walk out of the store.

## 4.8 Summary

23

In this chapter, the implementation and testing phases of the self-checkout mobile application were discussed in detail. The development of the app involved several core features aimed at improving the checkout experience for users. However, various implementation challenges were faced, such as barcode scanner accuracy, payment integration issues, and security concerns. These challenges were addressed through optimization techniques, middleware solutions, and enhanced security protocols.

2

The testing phase involved a combination of functional, security, and usability tests to ensure the application met the required standards for performance, reliability, and user-friendliness. Finally, a user guide was provided to assist end-users in navigating the app and using its features effectively.

Through meticulous planning and execution, the self-checkout mobile application was developed to meet the needs of both customers and retailers, offering a seamless and efficient shopping experience.

## CHAPTER FIVE

### SUMMARY, CONCLUSION AND RECOMMENDATION

#### 5.1 Summary

The self-checkout mobile application developed for retail stores demonstrated significant improvements in operational efficiency and user satisfaction. It integrates key features such as barcode scanning, secure payment processing, inventory synchronization, and user authentication. Testing phases, including unit and integration testing, showed the application's seamless interaction with the store's back-end system, ensuring real-time data updates and secure transaction handling. The application was also designed with a user-friendly interface that prioritizes ease of use and clear navigation to enhance customer experience.

User testing indicated high satisfaction, with positive feedback on the app's functionality, especially in terms of reducing checkout times and improving the convenience of in-store shopping. Challenges such as initial adoption hurdles and the need for clear user instructions were noted, but the system overall proved effective in addressing key problems associated with traditional checkout methods.

#### 5.2 Conclusion

In conclusion, the self-checkout mobile application offers a robust solution to the inefficiencies of traditional checkout systems in retail environments. By allowing customers to manage the scanning and payment process through their own devices, the app significantly reduces wait times and operational costs for retailers while providing a more hygienic and efficient shopping experience. The system's integration with the store's inventory management ensures real-time synchronization, improving stock visibility for customers.

The success of the app lies in its focus on user-centric design, security, and adaptability across various retail settings. While challenges such as technological adoption and security risks remain, the overall benefits outweigh the limitations. Continuous improvements and the inclusion of features like personalized offers and loyalty programs will further enhance the customer experience and ensure sustained relevance in the evolving retail landscape.

### **5.3 Recommendations**

1. Further improve the app's user interface to ensure clearer instructions for first-time users.
2. Integrate additional features like loyalty programs and personalized offers to increase customer engagement.
3. Explore integration with more payment gateways to increase flexibility for users.
4. Enhance offline functionality to ensure seamless transactions in areas with poor connectivity.
5. Provide regular training and support for retail staff to ensure smooth implementation.
6. Continue monitoring user feedback for ongoing improvements in usability and functionality.

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