Faculty of Electrical Technology and Engineering

DEVELOPMENT OF AN IOT-BASED SMART SHOPPING TROLLEY USING A MICROCONTROLLER

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Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours

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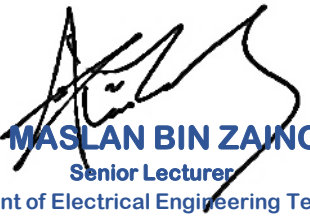
Signature : 

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DEDICATION

In heartfelt appreciation and profound gratitude, this work is dedicated to those whose unwavering support, encouragement, and love have been the guiding lights throughout this journey.

To my family, who have been the pillars of strength and the source of boundless love and encouragement. Your sacrifices, understanding, and enduring support have been the bedrock upon which this endeavour stands. This dedication is a tribute to the warmth of our home and the unbreakable bonds that fuel my aspirations.

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May this work be a humble offering, a reflection of the collective strength and inspiration drawn from each of you. With deepest appreciation, admiration, and love, this dedication stands as a token of gratitude for the invaluable contributions you have made to my life's journey.

ABSTRACT

This research project responds to the imperative for retail innovation through the implementation and evaluation of smart shopping trolley system. The background highlights the persistent inefficiencies in traditional retail checkout processes, necessitating a technological solution. The overarching problem lies in the need to enhance both operational efficiency and customer satisfaction within the retail landscape. The objectives of this study are threefold: firstly, to develop a hardware device that uses RFID technology on a shopping trolley for item detection. Next, is to create a user-friendly webpage that allows customers to view the items in their trolley and to enable staff to monitor the inventory database, and the last one is to analyse the effectiveness of the RFID technology in improving the retail industry. The methodology encompasses a comprehensive literature review to understand existing technologies, followed by the formulation and implementation of the RFID system. A flowchart is used to encapsulates the whole system, with clear functions and workflow of the system.The results indicate a significant reduction in checkout times, affirming the efficacy of the RFID-enabled smart shopping cart system. Volunteers feedbacks suggests a positive shift in satisfaction levels, signaling a potential transformation in the retail checkout experience. In conclusion, the integration of RFID technology holds substantial promise for optimizing retail checkout processes. Future directions involve refining the system based on feedback, exploring scalability for larger retail environments, and investigating potential integrations with e-commerce platforms. This research contributes valuable insights to the field of smart retail solutions, fostering continued advancements in enhancing the retail experience through technology.

ABSTRAK

Projek penyelidikan ini memberi respons terhadap keperluan inovasi dalam peruncitan melalui pelaksanaan dan penilaian sistem troli beli-beli pintar. Latar belakang menonjolkan ketidakcekapan berterusan dalam proses pembayaran tradisional di peruncitan, memerlukan penyelesaian teknologi. Masalah utama terletak pada keperluan untuk meningkatkan kecekapan operasi dan kepuasan pelanggan dalam industri peruncitan. Objektif kajian ini adalah tiga: pertama, untuk membangunkan peranti keras yang menggunakan teknologi RFID pada troli beli-beli untuk pengesanan item. Kedua, adalah untuk membuat laman web mesra pengguna yang membolehkan pelanggan melihat item dalam troli mereka dan membolehkan staf memantau pangkalan data inventori, dan yang terakhir adalah menganalisis keberkesanan teknologi RFID dalam meningkatkan industri peruncitan. Metodologi merangkumi kajian literatur menyeluruh untuk memahami teknologi sedia ada, diikuti dengan formulasi dan pelaksanaan sistem RFID. Carta alir digunakan untuk merangkumi seluruh sistem, dengan fungsi dan aliran kerja sistem yang jelas. Keputusan menunjukkan pengurangan yang ketara dalam masa pembayaran, mengesahkan keberkesanan sistem troli beli-beli pintar ber-RFID. Maklum balas sukarelawan menunjukkan pergeseran positif dalam tahap kepuasan, memberi isyarat kepada potensi transformasi dalam pengalaman pembayaran di peruncitan. Kesimpulannya, integrasi teknologi RFID menjanjikan untuk mengoptimumkan proses pembayaran di peruncitan. Hala tuju masa depan melibatkan penyempurnaan sistem berdasarkan maklum balas, meneroka skalabiliti untuk persekitaran peruncitan yang lebih besar, dan menyiasat integrasi potensi dengan platform e-dagang. Penyelidikan ini menyumbang wawasan berharga kepada bidang penyelesaian peruncitan pintar, memupuk kemajuan berterusan dalam meningkatkan pengalaman peruncitan melalui teknologi.

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LIST OF ABBREVIATIONS

RFID	-	Radio Frequency Identification
LF	-	Low Frequency
Wi-Fi	-	Wireless Fidelity
IoT	-	Internet of Things
IC	-	Internet Circuit
ID	-	Identification
BAP	-	Battery-Assisted Passive
EPC	-	Electronic Product Code
TID	-	Tag Identification
CPU	-	Central Processing Unit
ALU	-	Arithmetic-Logic Unit
PC	-	Program Counter
SP	-	Stack Pointer
ROM	-	Read-Only Memory
RAM	-	Random Access Memory
I/O	-	Input/Output
HTML	-	Hypertext Markup Language
DBMS	-	Database Management System
SQL	-	Structured Query Language
ANSI	-	American National Standards Institute
LCD	-	Liquid Crystal Display
IR	-	Infrared
PCB	-	Printed Circuit Board
UI	-	User Interface
SPI	-	Serial Peripheral Interface
QR	-	Quick Response Code

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CHAPTER 1

INTRODUCTION

1.1 Background

RFID (Radio Frequency Identification) technology has emerged as a promising solution to address these issues by automating the inventory management process and providing customers with a faster and more convenient checkout experience. RFID is a technology that uses radio waves for data collection and transfer, so data is captured efficiently, automatically and in real time without human intervention [1].

Smart shopping trolley with RFID technology have been developed to enable real-time tracking of items as they are added to the trolley, thereby automating the stock counting and replenishment processes. These smart shopping trolley can also provide customers with a more personalized shopping experience by displaying product information, promotions, and recommendations on a digital display.

Inventory management is a critical aspect of any retail business, as it directly impacts sales, profitability, and customer satisfaction. Traditional methods of inventory management, such as manual stock counting and replenishment, are often time-consuming, labour-intensive, and prone to errors. As RFID technology has the ability to provide the latest information about items, it can provide accurate information about inventory levels [2].

This project aims to develop a smart shopping trolley with RFID technology to improve customer service and inventory management in retail stores. The project will involve the design and development of the smart trolley, integration of RFID technology and software, and testing and evaluation of the system in a retail environment.

1.2 Problem Statement

The main intention of supermarkets is to provide availability of all the items and save the time of the purchaser but sometimes purchaser gets discontented while waiting in the queue at cash counter and sometimes they get frustrated while balancing the total price of all the products with the budget in the pocket before billing [3]. Hence, a shopping cart with item detection via RFID, with a billing system, needs to be developed to save time queuing and waiting.

Most systems rely on the actions of the personnel responsible for managing stock, who should be able to present the number of items located on the display shelves and in the stockroom. This information may become unreliable if incorrect information has been entered into the tracking system by the authorized personnel [4]. Therefore, there is a need to develop a more efficient and accurate inventory management system that can automate the stock counting, replenishment and provide customers with a faster and more convenient checkout experience. This project aims to develop a smart shopping trolley with RFID technology to address these issues and improve inventory management and customer service in retail stores.

1.3 Project Objectives

The main aim of this project is to design a shopping trolley that can improve the effectiveness of retail industry and inventory system. Stated below are the objectives of this project:

a) To develop a hardware device that uses RFID technology on a shopping trolley for item detection.

b) To create a user-friendly webpage that allows customers to view the items in their trolley and to enable staff to monitor the inventory database.

c) To analyse the effectiveness of the RFID technology in improving the retail industry.

1.4 Scope of Project

To ensure clarity and specificity in the project objectives, the scope of this project involves creating and designing a smart shopping trolley that utilizes RFID technology to enhance the inventory management and customer service in retail stores. To mitigate any potential issues arising from limitations and constraints, the following scope of work has been identified for the development of this project:

a) The project is consisting of microcontroller programming, and web development.

b) The system will only be functioning under Wi-Fi range of coverage.

c) This project is a small-scale prototype of a shopping trolley, hence LF-type RFID reader and tags will be used to describe the prototype.

d) User needs a smartphone to scan the QR to access the website.

e) Item billing with any real monetary transactions such as online banking & etc. will not be included. System speed will not be examined.

f) Auto-subtraction from trolley will not be included and tested in this project.

g) Inventory registration will only be done by manual listing as the main focus of this project will be on the trolley aspect.

1.5 Report Structure and Organization

The initial chapter sets the stage for the project by providing a comprehensive background of the RFID-enabled smart shopping cart system. The introduction outlines the context, significance, and objectives of the project, offering a clear understanding of the problem statement. Specific objectives are delineated to guide the research and serve as benchmarks for future reference.

In the second chapter, a meticulous literature review is conducted to assimilate knowledge and gain insights from prior research. The purpose is to build a solid foundation by understanding existing technologies and methodologies related to RFID-enabled smart shopping carts. This chapter aims to identify gaps, avoid redundancy, and critically analyze the strengths and weaknesses of various approaches used in similar projects.

The methodology chapter, comprising four distinct milestones aligned with the defined objectives, is presented in Chapter 3. Drawing on insights from the literature review, this chapter details the formulation of the system architecture. The selection of appropriate methods and components is discussed, with a focus on how these choices align with the objectives.

Next, the results and analysis chapter serve as a pivotal point in the report, showcasing the results achieved through the systematic testing of the RFID-enabled smart shopping cart system. These results, derived from basic component testing, are analyzed, and discussed in-depth. This chapter provides valuable insights that will guide future work and development in the subsequent phases of the project. The discussion delves into the implications of the results, addressing potential challenges and opportunities for refinement.

The final chapter, Chapter 5, synthesizes the entire study. It encapsulates the key findings, implications, and contributions of the project. The conclusion chapter also outlines any limitations encountered during the study and offers recommendations for future

research. By drawing connections between the objectives, methodology, and results, this chapter provides a conclusive and reflective summary of the RFID-enabled smart shopping cart project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Technology has become crucial for shopping experiences in the ever-changing retail industry. Modern shopping has evolved into a multi-dimensional ecology that seamlessly combines the physical and digital world, and is no longer limited to brick-and-mortar establishments. Technology advances have made this integration possible, revolutionising how consumers browse, choose, and buy things.

The project's overall concept and theory utilising the Internet of Things (IoT) are reviewed and summarised in this chapter. Explaining previous and present research was the chapter's key recommendation. This chapter covered the theory and concepts applied to resolve the project's problem. Journals and papers are the primary information sources; they were picked because they closely match the project's objectives.

This chapter will first discuss the overview of the project, which is the creation of a smart shopping trolley. All components and elements involved in the creation of this project will be covered in this topic.

Next, few studies regarding this project will be included in this report to educate the community about the technologies that will be used in this project. This will include the studies of RFID, microcontroller, and website development.

After discussing the previous subtopic, a few chosen research papers will be included in this report to give readers a thorough comprehension of the knowledge, perceptions, and conclusions that have been made in relation to the theme or issue under investigation. We will compare the studies to broaden our perspectives, assess the quality of the research,

support our claims, spot gaps, suggest new lines of inquiry, and promote critical thinking in the subject of study.

At the conclusion of Chapter 2, this subject will be summarised and concluded.

2.2 Internet of Things

The Internet of Things (IoT) is a network of interconnected devices with unique identifiers that can communicate without human intervention [5]. This system includes computing devices, machines, and sensors capable of sensing their surroundings and exchanging data intelligently. The underlying technology that enables this network is RFID. In the IoT, objects are equipped with labels or RFID tags connected to a network through the electronic product code (EPC) or Internet Protocol (IP). These objects contain embedded sensors and actuators, allowing them to interact with the network wirelessly or through cables, often using IP protocols. This integration enables real-world objects to be connected to and accessed through the Internet. The availability of small-sized, affordable microprocessors, communication modules, and electronic components has facilitated their integration with everyday objects, contributing to the growth of the IoT [6].

2.3 Overview of Smart Shopping Trolley

Humans nowadays invariably choose technology that benefits them, and they have always imagined a technology that can support their desires. Humans want to reduce tasks in various industries by applying technology faster and more easily. Shopping is a major activity in which people spend most of their time. According to surveys, humans spend 1 to 1.5 hours shopping, and most customers will invariably avoid long lines. [7]. Customers must proceed to checkout at the billing counter when shopping is done. This billing process

is quite time-consuming, and we must employ more human resources in the billing section. [8].

As we are all aware, there are two types of shopping: traditional in-person shopping and online shopping. Online shopping is considered the most convenient method of purchasing since it eliminates the need to physically visit a store or mall. On the other hand, traditional shopping requires individuals to go to a physical location and often involves waiting. Nowadays, supermarkets and malls provide shopping carts and baskets for customers to store their purchased items. Upon completing their shopping, customers are required to proceed to the checkout counter. This checkout process can be time-consuming and necessitates additional staff in the billing section. [7].

The conventional trolley differs from a smart trolley in several ways. While the traditional trolley is easily accessible in most supermarkets and comes at an affordable price, the smart trolley is more advanced, costly, and limited in quantity due to its higher manufacturing expenses. The smart trolley stands out for its speedy accounting process compared to the traditional method. Additionally, it offers superior service by reducing congestion at the cashier counter and minimizing the time and effort required during the accounting process. [9]. Figure 2.1 shows modern shopping cart with integration of mobile application.

Figure 2.1 Smart shopping cart application

2.4 Inventory system

Effective inventory management plays a crucial role in guiding decision-making within a company. It encompasses various aspects, including determining appropriate actions, establishing inventory management policies, and implementing procedures to handle inventory. The objective is to ensure that each item in the warehouse is consistently maintained at the desired quantity, thus providing optimal care for inventory items [10].

Inventory control is recognized as a fundamental management function within an organization due to its significant impact. It aids internal operations by enabling uninterrupted production, optimizing efficiency, and enhancing customer service. To effectively manage their inventory, companies employ inventory control systems, software programs designed to oversee every aspect of their inventory as products progress through manufacturing and sales processes. [11].

The existing inventory management system needs to be more efficient and accurate due to its manual nature when tracking the store's stock of goods. The sales staff are burdened with the responsibility of monitoring the stock levels of each item as part of the inventory update process. A purchase order is generated whenever the stock level reaches an unacceptably high or low point, or stock status reports are compiled. This manual method results in time wastage, challenges in calculating the total number of items sold, excessive paperwork, vulnerability to errors, and difficulties updating the system whenever changes are made. Consequently, automating the inventory system becomes imperative to address these issues. [11]. Figure 2.2 shows an example of inventory management site of Sangkemi Global Nig. Ltd.

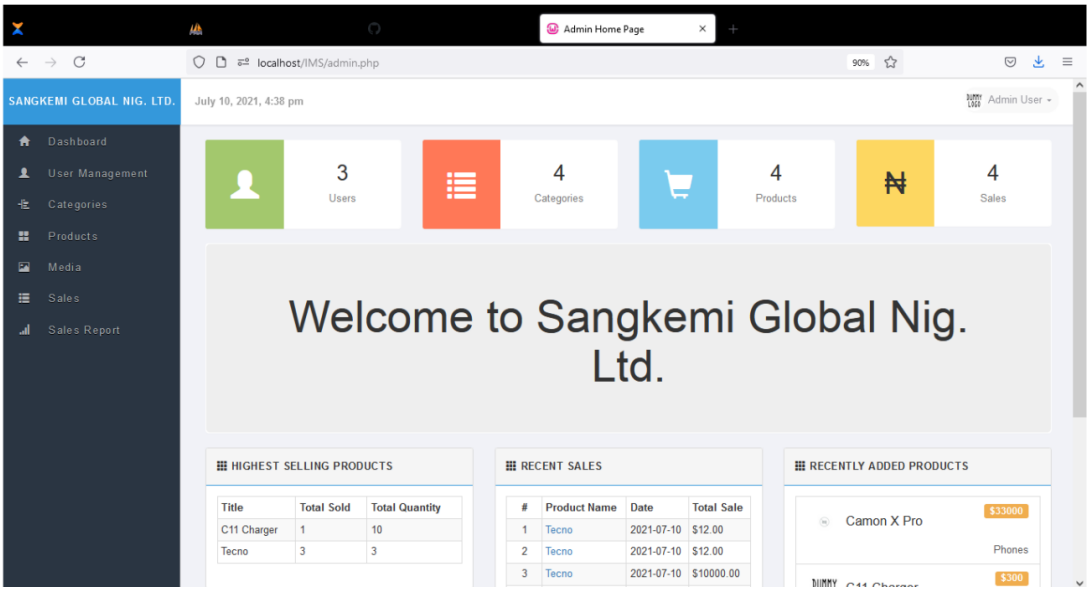

Figure 2.2 Example of inventory management interface

2.5 Radio Frequency Identification (RFID)

RFID has come a long way from its first application of identifying airplanes as friend or foe in World War II. Not only does the technology continue to improve year over year, but the cost of implementing and using an RFID system continues to decrease, making RFID more cost-effective and efficient [12].

RFID is a computing method that relies on radio waves to wirelessly transmit and receive data between a reader and a movable item. This technique allows for the identification, categorization, and tracking of items without the need for physical contact. [13]. RFID technology is employed to capture data from an RFID tag. It is accomplished by utilizing radio frequency waves to transmit the information from the tag to a reader. For effective communication, the RFID tag needs to be within the range of an RFID reader. RFID technology enables efficient and speedy searching of multiple objects, making it possible to swiftly detect a specific product even when numerous other items surround it [14].

2.5.1 RFID Reader

An RFID reader is the brain of the RFID system and is necessary for any system to function. Readers, also called interrogators, are devices that transmit and receive radio waves in order to communicate with RFID tags. RFID readers are typically divided into two distinct types – Fixed RFID Readers and Mobile RFID Readers. Fixed readers stay in one location and are typically mounted on walls, desks, portals, or in other stationary locations. A typical subset of fixed readers is integrated readers. An integrated RFID reader has a built-in antenna that typically includes one additional antenna port to connect an optional external antenna. Integrated readers are usually aesthetically pleasing and designed for indoor applications without high tagged item traffic. Mobile readers are handheld devices that allow for flexibility when reading RFID tags while still being able to communicate with a host computer or smart device. Figure 2.3 shows different types of RFID readers.

Figure 2.3 Different types of RFID readers

There are two primary categories of Mobile RFID readers – readers with an onboard computer, called Mobile Computing Devices, and readers that use a Bluetooth or Auxiliary connection to a smart device or tablet, called Sleds. Fixed RFID Readers typically have external antenna ports connecting anywhere from one additional antenna to up to eight antennas. With the addition of a multiplexer, some readers can connect to up to 32 RFID antennas. The number of antennas connected to one reader depends on the area of coverage

required for the RFID application. Some desktop applications, like checking files in and out, only need a small coverage area, so one antenna works well. Other applications with a larger area of coverage, such as a finish line in a race timing application, typically require multiple antennas to create the necessary coverage zone [12].

2.5.2 RFID Tag

In its simplest form, an RFID tag consists of two essential components: an antenna for transmitting and receiving signals and an RFID chip (also known as an integrated circuit, IC) that stores the tag's ID and other relevant information. These RFID tags are attached to items to enable their tracking using an RFID reader and antenna. RFID tags use radio waves to transmit data about an item to the reader/antenna combination. Unlike Active or Battery Assisted Passive (BAP) tags, most RFID tags do not have a built-in battery. Instead, they rely on the energy generated by the reader's radio waves to power their operation. When the tag receives the transmission from the reader/antenna, the internal antenna of the tag allows the energy to flow through to the chip. This energy activates the chip, modulating the energy with the desired information and transmitting a signal to the antenna/reader [12]. Figure 2.4 shows different types of RFID readers.

Figure 2.4 Various kind of RFID tag

The chip on the RFID tag typically contains four memory banks: Electronic Product Code (EPC), Transponder ID (TID), User, and Reserved. Each memory bank holds specific information about the tagged item or the tag itself, depending on the bank and its purpose. A wide variety of RFID tags come in various shapes, and sizes and with specific features and options tailored to different environments, surface materials, and applications [12]. Table 2.1 below shows various types of RFID tags, with various ranges of frequency.

Table 2.1 Types of RFID tags specifications

Types of RFID tags	Range of frequency	Typical frequency
Low frequency (LF)	30k to 300kHz	125kHz – 134kHz
High frequency (HF)	3M to 30MHz	~13.5MHz
Ultra-High Frequency (UHF)	300MHz to 3GHz	865MHz – 956MHz

2.5.3 Item detection by using RFID

Radio waves capture RFID tags, and the collected data is stored in a database. RFID is an IoT technology that is versatile and user-friendly. These RFID tags are commonly employed to identify products by utilizing radio waves. The popularity of RFID sensors stems from their efficient operation, faster scanning, and detection capabilities. One significant advantage of RFID over barcode scanning is that RFID does not require a line-of-sight connection during scanning, as the object only needs to be positioned within range of an RFID reader. Additionally, the scanning distance of RFID can be adjusted according to specific requirements. [15].

Integrating these technologies in smart trolley system brings about many advantages for both customers and retailers. Customers can relish in the convenience of faster shopping

experiences by avoiding lengthy queues at the billing counter. On the other hand, retailers can benefit from increased efficiency while reducing labour demands. [16].

2.6 Barcode

Barcode technology offers a cost-effective and straightforward method for encoding text information that affordable electronic readers can easily read. It enables swift and highly accurate data collection. Barcoding involves a computer-assisted process of generating encoded information, which is subsequently printed on predefined stationery, often in the form of self-adhesive labels, for various future applications.

A barcode consists of parallel bars and spaces positioned in specific patterns. These predefined patterns, known as "symbologies," convert small character data strings into a printed symbol. A barcode reader interprets the barcode by scanning a light source across it and measuring the intensity of light reflected by the white spaces. The pattern of reflected light is detected by a photodiode, which generates an electronic signal that matches the printed Barcode pattern precisely. This signal is then decoded back into the original data using affordable electronic circuits [17]. Figure 2.5 below shows components of a barcode, and Table 2.2 below shows the comparison of RFID and barcode.

Figure 2.5 Components of a barcode

Table 2.2 Table of comparison between RFID and barcode

RFID	Barcode
Requires line of sight to be read	Can be read without line of sight
Can be read individually	Multiple tags can be read simultaneously
Requires manual tracking, prone to human errors	Can be automatically tracked, less prone to human error
Can't be read if damaged/dirty	Can cope with harsh environment

2.7 Microcontroller

A microcontroller is a programmable digital processor that includes essential peripherals. Both microcontrollers and microprocessors are sophisticated sequential digital circuits designed to execute tasks based on programmed instructions. Sometimes, a microcontroller circuit incorporates an analogue input/output interface, resulting in a mixed-mode nature that encompasses both analogue and digital functionalities. [18].

A microcontroller can be likened to a Swiss knife integrating multiple functions within a single IC. Its design incorporates all the essential features of a microprocessor's Central Processing Unit (CPU), including the Arithmetic-Logic Unit (ALU), Program Counter (PC), Stack Pointer (SP), and registers. Additionally, it encompasses other crucial elements necessary to form a complete computer system, such as Read-Only Memory (ROM), Random Access Memory (RAM), parallel input/output (I/O), serial I/O, counters, and clock circuits. Like a microprocessor, a microcontroller is a versatile device. However, its primary purpose is to read data, perform limited calculations on that data, and control its environment based on those calculations. A microcontroller's primary use is to govern a machine's operations using a fixed program stored in ROM, which remains unchanged

throughout the system's lifespan. [18]. Figure 2.6 below shows two different types of microcontrollers.

Figure 2.6 Examples of microcontrollers

2.8 Webpage

Affordable and widespread internet access has transformed the World Wide Web into a valuable information resource. Consequently, establishing a robust online identity has become a crucial marketing strategy for any organization. Creating a solid web presence entail developing an official website, managing social media accounts, and utilizing other relevant platforms. It is essential to carefully design, structure, implement, and maintain these channels to uphold a positive business reputation and attract a substantial number of visitors. [19].

"Web development" is creating awareness among individuals or companies about the products or services they offer and helping them understand the importance and relevance of those offerings. Utilizing suitable web development technology can significantly enhance a website's effectiveness. Web development encompasses various non-design elements involved in building a new website. In larger businesses and organizations, web development teams may consist of multiple individuals and employ established practices such as agile methodologies for website development. [20]. Web technology encompasses the methods by which devices or computers communicate with each other

using markup languages. It facilitates communication over the web and involves creating, delivering, and managing web content using HTML (Hypertext Markup Language) [20].

2.8.1 Front-end development

Front-end developers specialize in crafting the visual presentation of websites using front-end programming languages. They are responsible for shaping a website's aesthetics, including fonts, colours, layout, and graphics. The visual aspect of a website is brought to life through the skills and expertise of front-end development [21].

2.8.2 Back-end development

Back-end developers are responsible for constructing the framework or functionality of a website using server-side programming languages. They write code that enables the website to execute the instructions provided by front-end programming languages, bringing the website to life. The work of back-end developers involves creating the behind-the-scenes logic that drives the website's functionality [21].

2.9 Database

A database is a structured collection of information or data that is organized and typically stored electronically in a computer system. The management and control of a database are typically facilitated by a database management system (DBMS). The combination of the data, the DBMS, and the associated applications is commonly referred to as a database system, often simply referred to as a database. [22].

In the prevailing types of databases used today, data is commonly organized in tables consisting of rows and columns. This tabular structure enables efficient processing and querying of data. This format allows data to be conveniently accessed, managed, modified,

updated, controlled, and organized. The majority of databases utilize structured query language (SQL) as a means for writing and querying data. [22].

2.10 Previous Research

In this subtopic, previous studies or articles are revised before the future development of the smart shopping trolley. The major purpose of evaluating previous research is to investigate the ideas and concepts used to address the issues encountered throughout project development. The articles were chosen because they were pertinent to the project's objectives. Only a part of the entire research paper was included in each comparison.

2.10.1 Smart Shopping Trolley & Stock Management System [23]

Over the years, technology has revolutionized the way people shop, prompting retailers to seek ways to enhance the shopping experience constantly. To achieve this, supermarkets have introduced RFID-based shopping baskets that utilize UHF RFID technology to tag and track each item's price accurately. This paper presents a smart trolley concept that aims to integrate various components, such as the reader, antennas, and user interface, directly into the shopping cart at a lower cost. Communication is facilitated through low-power Bluetooth, offering extended battery life compared to Zigbee. The items in the cart are equipped with UHF RFID tags featuring unique identification codes. The smart trolley incorporates a self-checkout system, enabling real-time tracking of product stock and providing consumers with item-level information. Additionally, distributors receive purchase order notifications when item counts reach zero. Figure 2.7 shows the flowchart of the project.

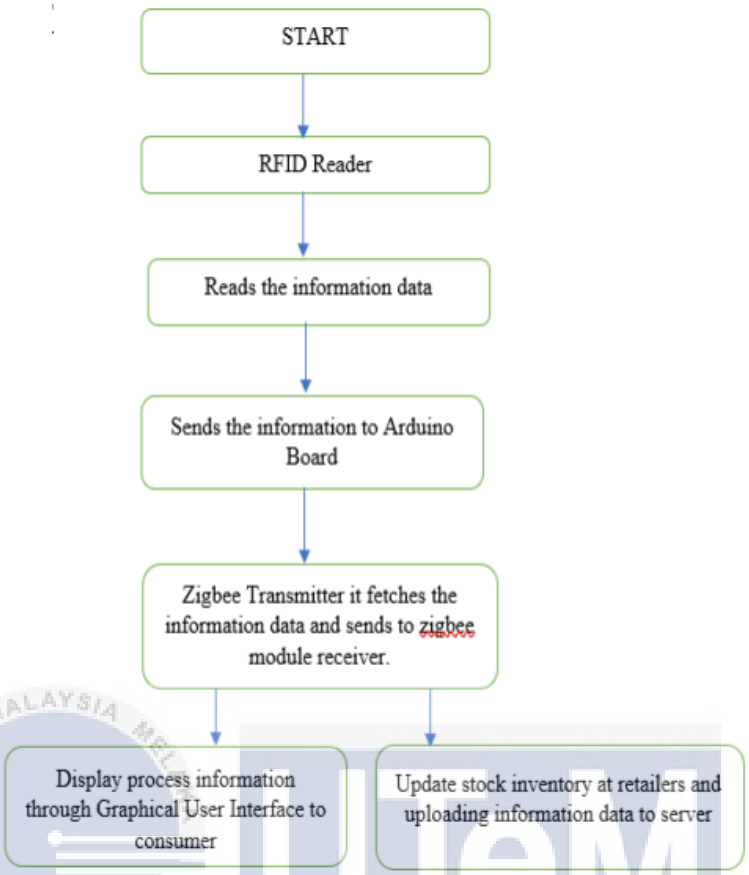

Figure 2.7 Flowchart of the project

2.10.2 Development of an IoT-Based Shopping Trolley [7]

This project focuses on implementing a system to enhance the shopping experience by reducing the time spent during the purchase process. The primary goal is to develop a technology-driven, cost-effective, scalable, and durable system to assist individuals in in-person shopping activities. Additionally, data analysis is being incorporated into the project. The system identifies their preferences and suggests similar offers as customers place items into their shopping carts. Indoor navigation is available to help locate specific products on the shopping list. Anti-theft protection measures have also been implemented. The key to success is understanding the innovation and various components to minimize potential

issues. It is time for industries to embrace technologies like RFID in diverse applications. To avoid overwhelming customers with excess baggage, the project simultaneously restricts the number of items placed in the cart. By employing barcode scanners and enabling self-checkout, the Intelligent Shopping Basket developed in this project effectively reduces or eliminates the time spent at supermarket billing counters, enhancing productivity. Considering the evolving trends in retail shopping, the Intelligent Shopping Basket project is undoubtedly essential for the retail marketing industry to update their offerings, adapt to technological advancements, and save time and staffing. Figure 2.8 shows the flowchart of this project.

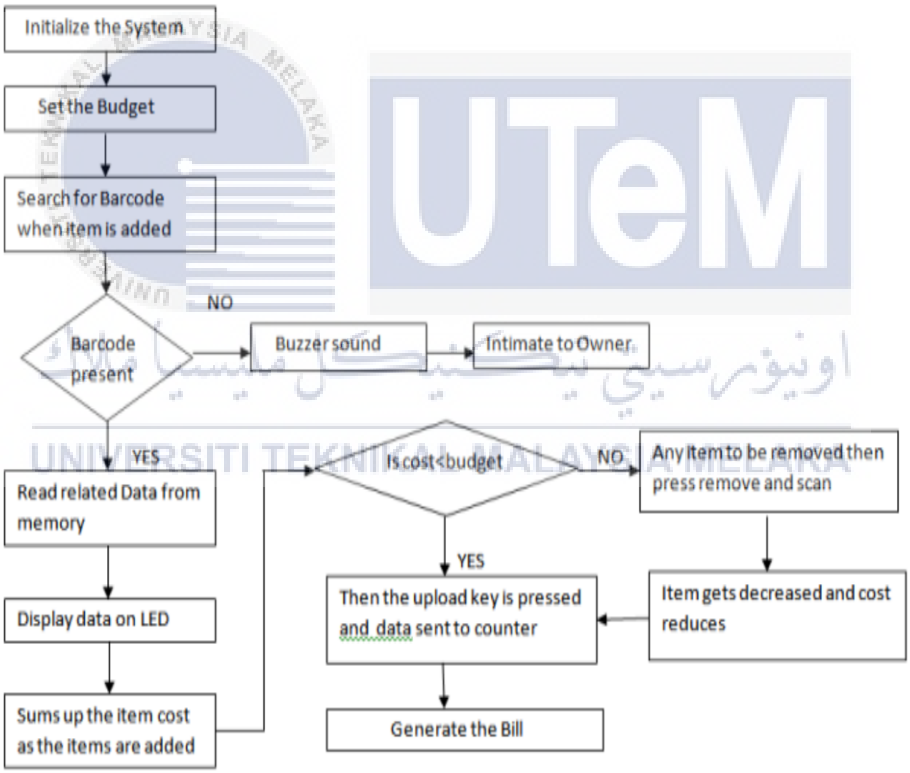

Figure 2.8 Project's flowchart

2.10.3 Smart Trolley Billing System [24]

In the proposed system, the customer follows a specific process after purchasing a product. Firstly, they scan the RFID tag of the product using an RFID reader and place it in the trolley. The system captures the product's price and stores it in its memory during the scanning process. If a match is found, the Liquid Crystal Display (LCD) have the corresponding product name and costs. Simultaneously, the system processor sends this information to the computer for billing purposes using the RS232 protocol. To ensure security, an infrared (IR) sensor is utilized to count the products. This ensures that only the scanned products are included in the final bill, preventing additional costs. If any unwanted product is removed from the trolley, the system adjusts the count in the bill accordingly and recalculates the total amount. The RFID technology enables quick and efficient scanning without human labour. The controller processes the information and displays the product name and price on the smart trolley's LCD screen. Figure 2.9 below shows the working steps for the project:

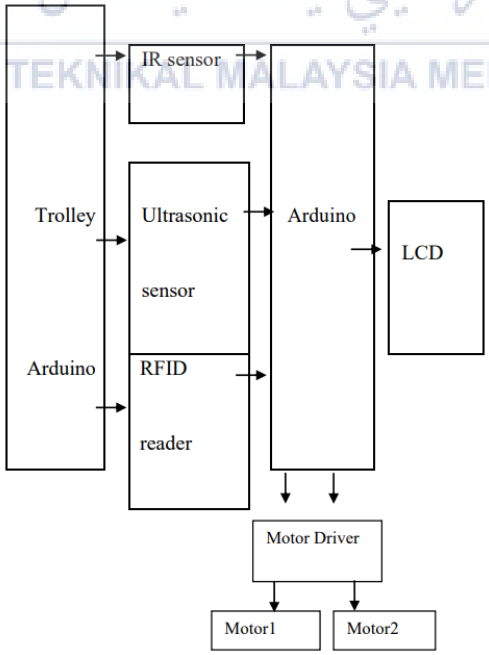

Figure 2.9 Working steps for smart billing trolley system

2.10.4 IoT-Based Advanced Smart Shopping Cart using Arduino and RFID[15]

The design of the Smart Shopping System considers various scenarios and aims to automate the process. Each cart has an RFID reader, which is essential for the system's functionality. A camera barcode scanner is also integrated into the design, mounted on the cart. The RFID reader retrieves product information from the database, stored in the Base Station at the payment counter. The database includes barcodes, product names, prices, and weights.

To prevent fraud, a weight sensor in a load cell is implemented to cross-verify the product's identity. The load cell output is used in the cart's decision-making process. If the weight estimated by the load cell does not match the expected weight of the product, it indicates a mismatch.

Image processing is incorporated as a third level of control to enhance the decision-making process. After scanning the RFID tag, the camera captures an image of the product. This allows for comparison and verification if someone attempts to replace the scanned product with a more expensive one. A sheet is provided on top of the cart for placing the products, eliminating the need for the buyer to place them manually. Another image is taken just before the product is placed in the cart. Both images are stored locally in the cart's system. An image comparison algorithm is applied to determine if the products are identical. If a discrepancy is detected, it is considered a case of divergence. After the algorithm's results are obtained, both images are deleted from the cart's memory to manage memory consumption effectively. Figure 2.10 below shows the flowchart of an overview of the project, and Figure 2.11 shows the flowchart of the mobile interface.

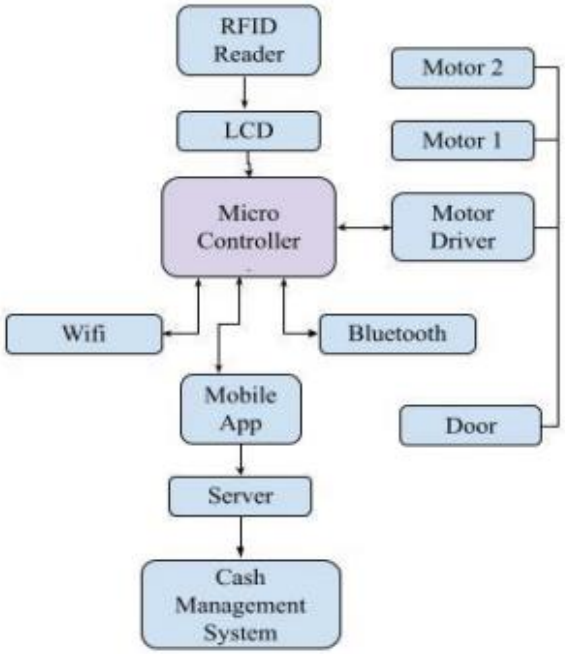

Figure 2.10 Overview of the system

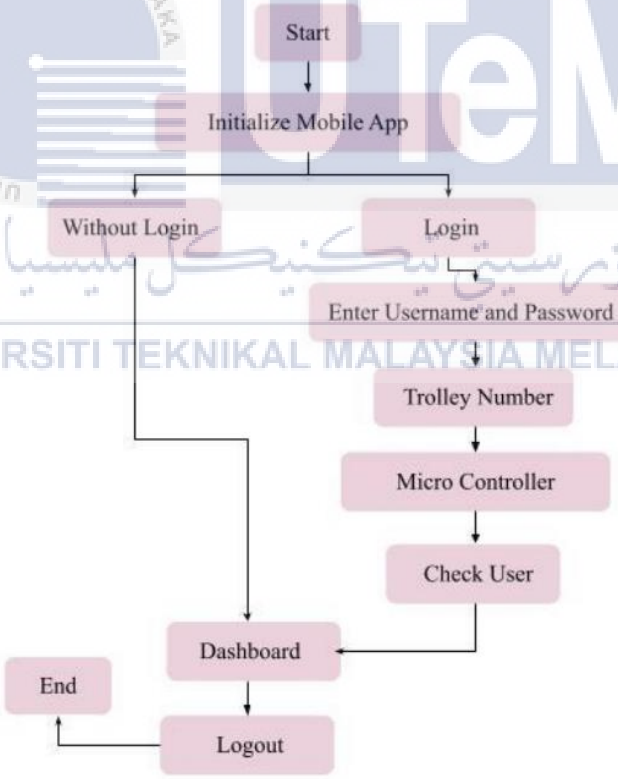

Figure 2.11 Flowchart of the mobile interface

2.11 Research Comparison

Table 2.3 Comparison of all four research papers

Project (Year)	Title	Technology Used	Functions
2.10.1 2019	Smart Shopping Trolley & Smart Management System [23]	- UHF RFID - Low-powered Bluetooth	- UHF RFID-based smart trolley with self-checkout system - Purchase order notifications for distributors
2.10.2 2019	Development of an IoT-Based Shopping Trolley [7]	- RFID - Barcode scanners - Data analysis - Self-checkout	- RFID-based system to enhance shopping experiences. - Indoor navigation, anti-theft protection, suggestions of similar items.
2.10.3 2020	Smart Trolley Billing System [24]	- RFID - LCD - IR sensor	- RFID-enabled trolley with scanning and billing functionality - Adjusting bill based on product removal
2.10.4 2022	IoT-Based Advanced Smart Shopping Cart using Arduino and RFID [15]	- RFID - Camera barcode scanner - Weight sensor - Image processing	- Smart shopping system with RFID reader, barcode scanner, and weight sensor - Image processing for verification and comparison - Weight sensor to detect fraud

Based on the comparison of these four papers on the Table 2.3, it is clear that each project offers distinct characteristics and methods for implementing smart shopping trolleys. Project 2.10.1 aims for UHF RFID-based smart trolley with self-checkout system with real-time inventory tracking. Project 2.10.2 aimed to develop a technologically advanced, low-cost system that includes data analysis, interior navigation, and anti-theft security functions. Project 2.10.3 emphasised the use of RFID technology for product scanning, information display on an LCD, and security using IR sensors. Project 2.10.4 advances automation by adding RFID readers, barcode scanners, load cells, and image processing for fraud detection.

Overall, these projects demonstrate the increased interest in enhancing the shopping experience with RFID technology and other smart features. They intend to increase efficiency, decrease time spent at the billing counter, and bring more convenience to customers.

2.12 Summary

In conclusion, the second chapter includes a literature analysis on technology integration in the retail business and introduces the notion of a smart shopping trolley. It addresses the role of technology in modern shopping experiences, the shift from physical to digital purchasing, and the implications of IoT. The chapter focuses on the elements involved in developing a smart shopping trolley, such as RFID, microcontrollers, and website development. It also looks at inventory management systems and the advantages of RFID technology for item detection.

Furthermore, it delves into the operations of RFID readers and tags, the role of microcontrollers as programmable digital processors, and the importance of websites and databases in web development. Few comparisons on research studies on smart shopping

trolleys has been made to highlight the use of technology to improve the shopping experience.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The present chapter provides a comprehensive overview of the project flow. This chapter elucidates the methods employed in the execution of the project throughout its development. The aim of this chapter is to furnish comprehensive information and validation regarding the execution of the smart shopping trolley.

The process of designing and developing the project involves the use of both hardware and web components. The techniques will be proficiently implemented, leading to a fitting mechanism and constituent for the smart shopping trolley designed for daily life, aims to optimise the shopping experience, enhance inventory management, and facilitate operational efficiency for both patrons and personnel. Customers will scan the QR code located on their shopping cart to access a specialised website, dedicated for this project. The online platform will comprise two discrete user interfaces, one for the clientele to view their items upon scanning with RFID, and the other for the employees to monitor inventory. Figure 3.1 below shows the flowchart of the system operation.

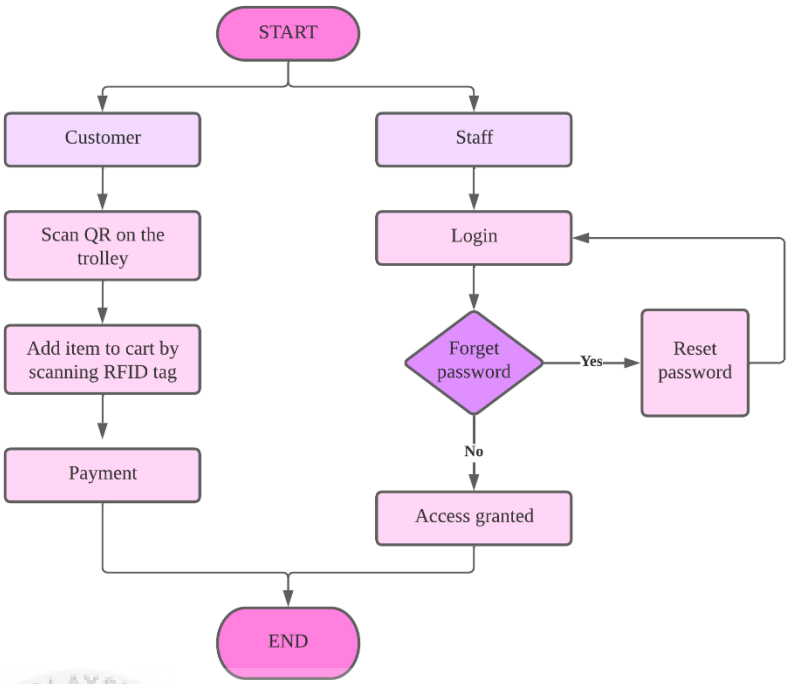

Figure 3.1 Flowchart of the System Operation

3.2 Project Milestone

Prior to commencing the research methodology, the project milestones are delineated. The act of recognising and tracking significant achievements indicates the progress of the project plan. Milestones serve as a means of approximating the duration of a project by delineating the deadlines for each milestone and generating a comprehensive project plan that includes a flowchart. Figure 3.2 below shows the flowchart for the methodology of this project on the surface.

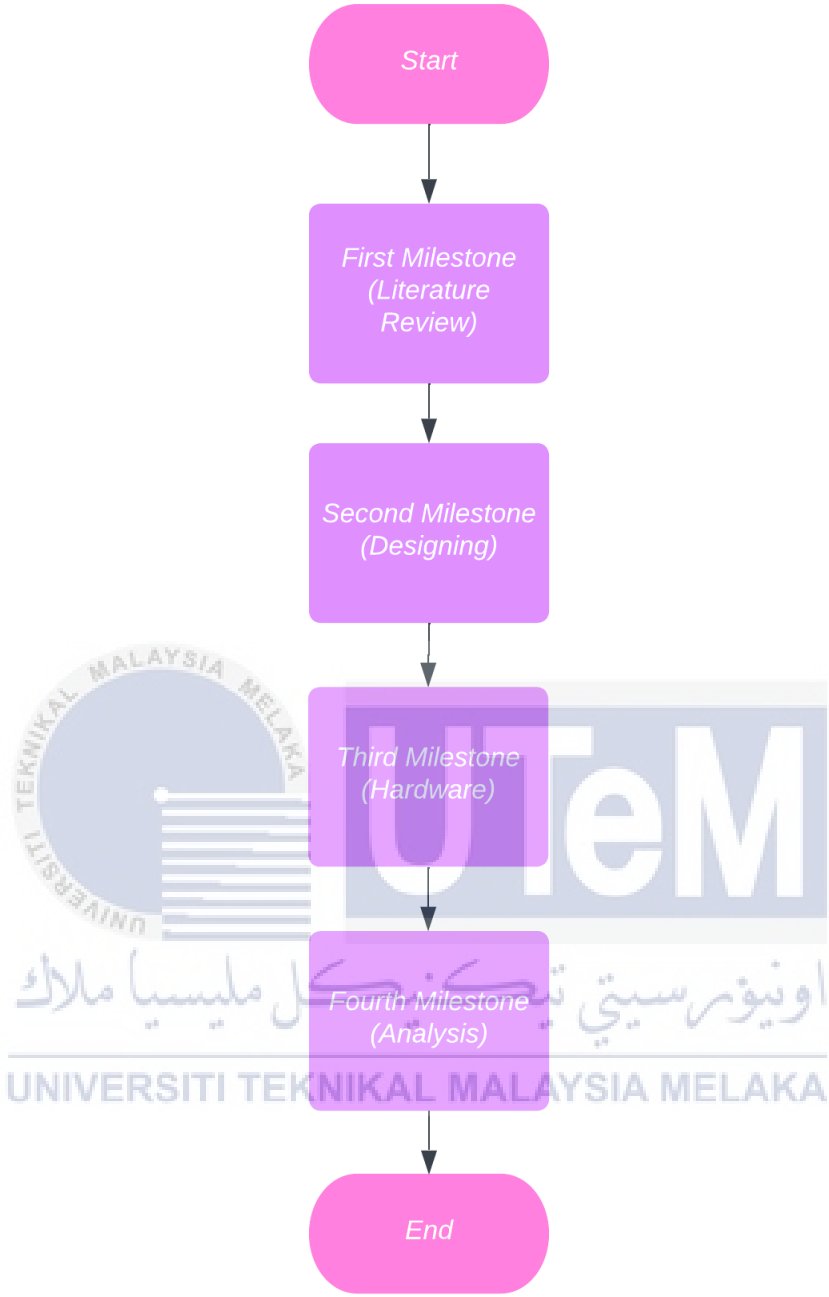

Figure 3.2 Flowchart of Methodology

3.3 First Milestone

The project's aims were initially discussed with the supervisor. The literature review shall be concluded upon finalising all the objectives of the project. The purpose of a literature review is to furnish a comprehensive summary of prior scholarly or institutional

investigations. Prior research has furnished insights and knowledge about the constituents utilised, approaches to resolving issues, and the analytical methodology. The supervisor subsequently sanctioned the scopes that were intended to accomplish the objectives. The flow chart of the literature review is depicted in Figure 3.3.

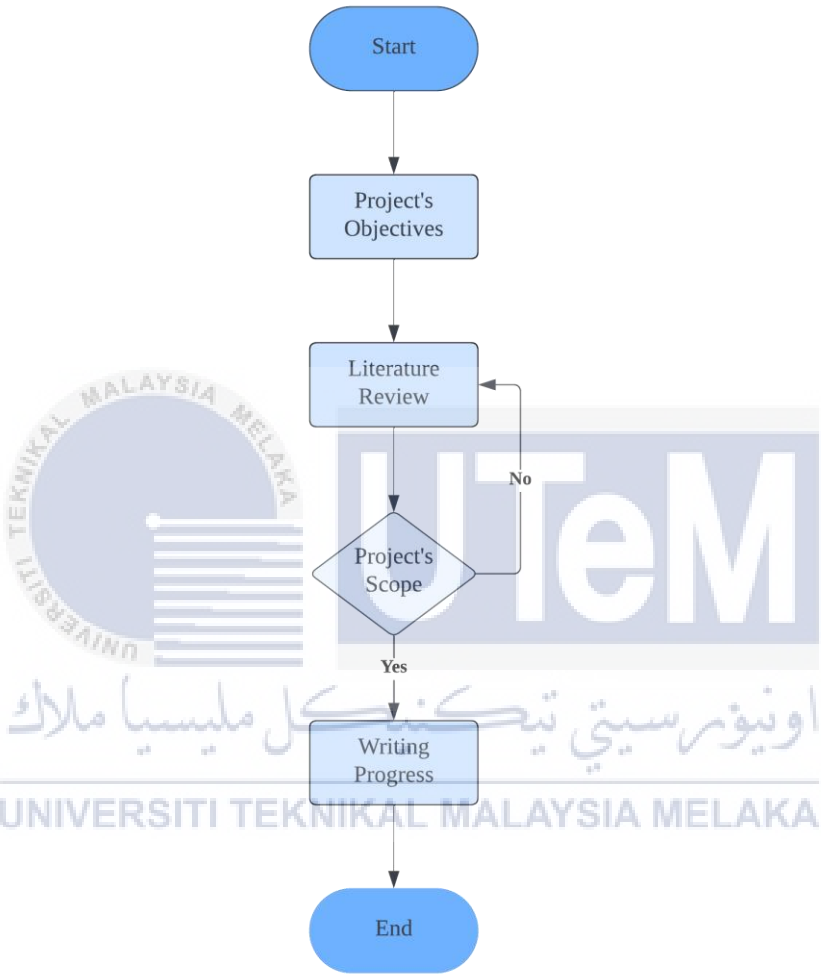

Figure 3.3 Flowchart of the First Milestone

3.4 Second Milestone

The methods and steps for developing the smart trolley system and IoT applications were thoroughly detailed in this section. As per mentioned in the introduction to methodology earlier, this project is consisting of both hardware and IoT development. In order to ensure the expected outcome of our objectives, several crucial steps need to be done,

such as data collecting, implementation, testing, and troubleshooting. The data and output will be analysed by using these steps in Figure 3.4.

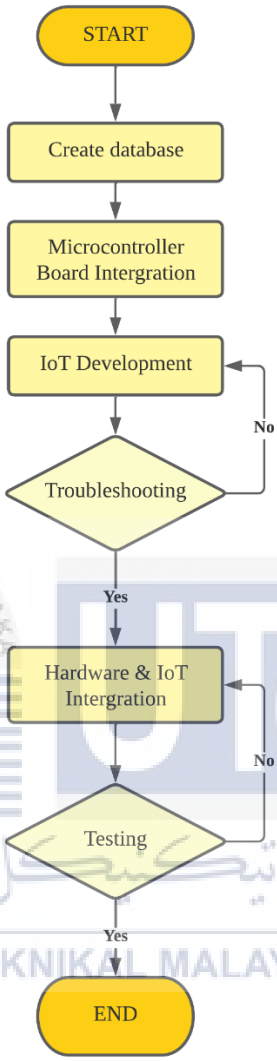

Figure 3.4 Flowchart of Second Milestone

3.4.1 Project Development

This section describes the software that will be used to develop the project to develop the program in connection with the hardware throughout this project. The crucial part of this

section is the microcontroller coding and overall simulation to picture the entire product detection system.

3.4.1.1 Fritzing

Fritzing is an open-source software application that is used to create and document electronic circuits. It has an easy-to-use interface for developing circuit diagrams, bespoke Printed Circuit Board (PCB) layouts, and virtual prototypes of electronic projects. Figure 3.5 below shows Fritzing's workbench.

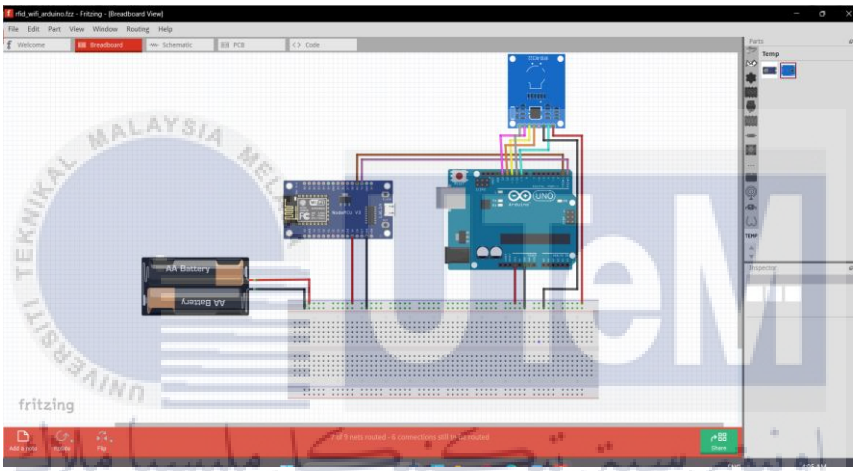

Figure 3.5 Fritzing workbench

Fritzing has a large selection of components, including microcontrollers, sensors, actuators, and other electronic components that may be dragged and dropped into the circuit canvas. Users can also construct specific components and import or export circuit designs in a variety of formats using the software. Fritzing is popular among hobbyists, students, and makers because it makes visualising and sharing electronic ideas easier, making it easier to construct and discuss electronics projects.

3.4.1.2 Arduino IDE

Arduino IDE (Integrated Development Environment) is a programming software for Arduino boards, and some more compatible boards such as ESP 8266. It lets developers write, build, and upload code to Arduino microcontrollers with an easy-to-use interface.

Developers write codes, a simplified form of C++. Code controls how the board interacts with sensors, actuators, and other components. Code verification follows writing. "Verify" or "Compile" in Arduino IDE examines code syntax and structure for problems. Before uploading the code to the board, this method identifies errors, and developers must fix the errors first before uploading it to the board.

Uploading the code to the board follows verification. A computer-to-board USB cord does this. After selecting the board and port, developers click "Upload" in Arduino IDE. It compiles a binary file and sends it to the board's microcontroller. To run the uploaded code, the board is reset during upload. The board executes the instructions and performs the code's program. Serial connectivity between the board and the PC lets developers see its output. Figure 3.6 below shows Arduino IDE's interface.

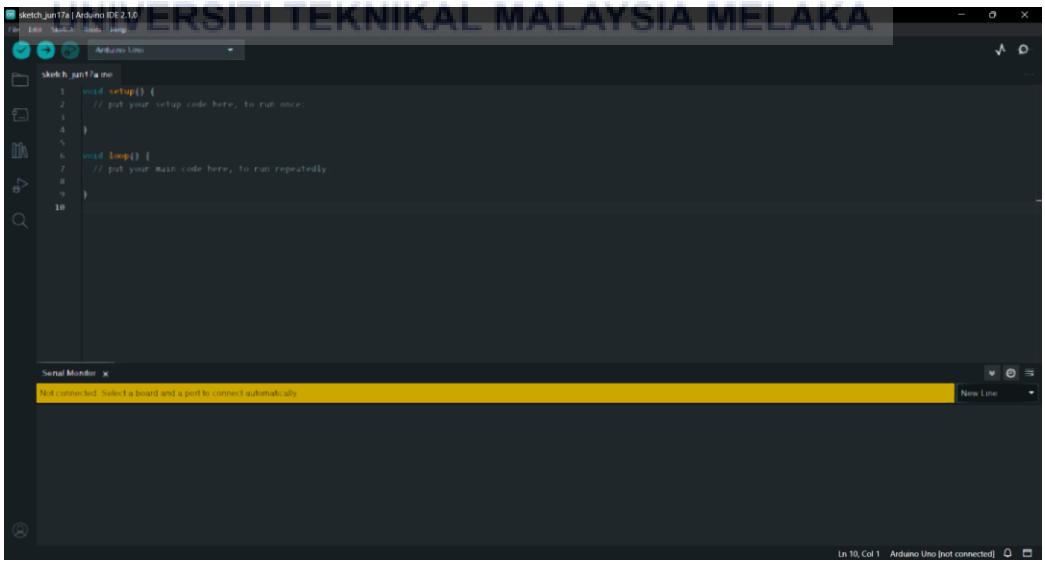

Figure 3.6 Arduino IDE's interface

The Arduino IDE includes more than the essential steps above. These include libraries with pre-written code for typical operations, a serial monitors for debugging and data visualization, and a large developer community sharing projects and resources. Arduino IDE's straightforward interface and code authoring, verification, and uploading facilities streamline IoT project development. It lets novices and expert developers use Arduino microcontrollers to construct various inventive projects.

3.4.2 Web Development

In this chapter, we will dig into the world of web development, that will cover the framework and languages that will be used. Web development covers diverse skills and approaches, from creating visually appealing user interfaces to integrating dynamic functionality.

3.4.2.1 Front-end development

a) React

React is a JavaScript library used to create user interfaces. It enables developers to design reusable user interface (UI) components and refresh the user interface effectively as the underlying data changes. React employs a component-based approach, in which each user interface component is divided into discrete, self-contained units. These elements can be used to build sophisticated user interfaces.

One of React's primary advantages is its ability to create interactive and dynamic web apps. It features a robust ecosystem that includes a plethora of third-party libraries and tools that enhance its capabilities and make development more efficient. React is extensively utilized in web development and has a large developer community, making it a popular choice for designing user interfaces.

a) **HTML**

The standard markup language for constructing the structure and content of web pages is HTML, which stands for Hypertext Markup Language. It includes tags and elements describing various web pages components such as headers, paragraphs, pictures, links, forms, tables, and more. HTML organizes stuff and displays it so web browsers can understand and render it using a hierarchical structure. Web developers may use HTML to arrange the content of web pages, define their semantics, and lay the groundwork for a website's visual design and interaction.

b) **JavaScript**

JavaScript is a popular web development programming language. It offers dynamic functionality and interactive components on web pages. JavaScript is a client-side programming language that can alter web page components, manage user interactions, and do computations. It is adaptable and extensively supported, making it an essential tool for developing dynamic and interactive online experiences.

3.4.2.2 Back-end development

a) Node.js

Node.js is a server-side JavaScript runtime environment that is open source and allows developers to create scalable and high-performance apps. It employs an event-driven, non-blocking I/O approach, making it efficient and well-suited for applications requiring real-time communication or managing many concurrent connections**.**

One of Node.js' key features is its ability to handle asynchronous activities effectively. It manages asynchronous activities, like reading from a file or performing network queries, using callbacks, or async/await syntax, without stopping the

execution of other actions. Because of its non-blocking nature, Node.js is very scalable and capable of handling many concurrent requests**.**

b) SQL

SQL is a database management and manipulation programming language. It allows users to create, retrieve, edit, and remove data from databases in a standardized manner. SQL is extensively used in data administration and plays an important role in effectively storing, retrieving, and managing structured data.

3.4.3 Visual Studio Code

Visual Studio Code (VS Code) is a front-end and back-end programming code editor. It is not restricted to a single development but includes features and tools useful for various projects and programming languages.

For front-end development, VS Code includes syntax highlighting for HTML, CSS, and JavaScript, auto-completion, and debugging. It also supports popular front-end frameworks like React with extensions to enhance development.

VS Code supports many programming languages typically used in server-side development, including Python, Java, C#, PHP, Ruby, and others. It has functionality for editing code, debugging, and interfacing with back-end development tools and frameworks.

3.5 Third Milestone

This subtopic covers the hardware components and controller that will be used in this smart shopping trolley project. The wiring diagram of the prototype will also be shown in this section.

3.5.1 RFID MFRC522

The MFRC522 RFID is a common RFID reader module that runs at 13.56MHz. It enables radio wave contactless communication using RFID tags or cards. The MFRC522 module is often used in RFID-enabled projects such as access control systems, attendance systems, inventory management, etc. It accepts RFID tag protocols such as MIFARE Classic, MIFARE Ultralight, and NTAG. The SPI (Serial Peripheral Interface) communication protocol allows the module to interface with a microcontroller like ESP8266. Users may read and write data to compatible RFID tags or cards by including the MFRC522 RFID module in a project, allowing applications such as identification, authentication, and tracking. Figure 3.7 shows MFRC522 RFID reader.

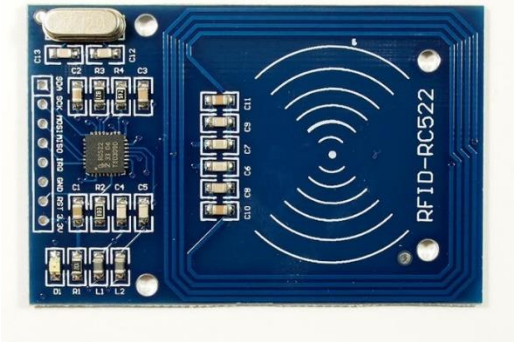

Figure 3.7 MFRC522 RFID

3.5.2 NodeMCU ESP8266

The ESP8266 NodeMCU is an ESP32 microcontroller-based development board. The ESP8266 is a powerful, flexible microcontroller with built-in Wi-Fi and Bluetooth, making it ideal for Internet of Things (IoT) projects. The NodeMCU board is a simple platform for prototyping and creating Internet of Things applications. It has GPIO pins, ADC, SPI, I2C, UART, and other interfaces connecting sensors, actuators, and devices. The Arduino IDE or other compatible programming environments may be used to program the board, making it accessible to many developers. The ESP8266 NodeMCU module's Wi-Fi connectivity allows it to connect to the internet, exchange data with cloud services, and enable remote control and monitoring of IoT devices. Figure 3.8 below shows microcontroller board NodeMCU ESP8266.

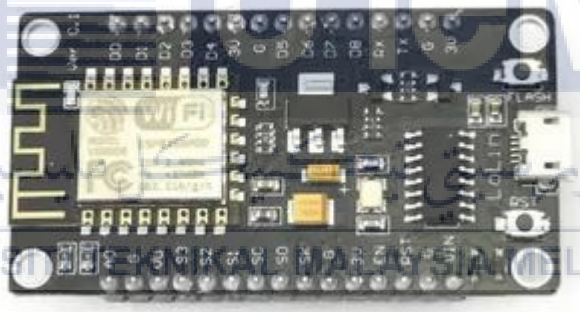

Figure 3.8 NodeMCU ESP8266

3.5.3 9V Power Supply

9V supply will be used to supply all three components, RFID MFRC522 and NodeMCU ESP8266, as two of the latter components are compatible with 9V power supply.

3.5.4 Wiring Circuit

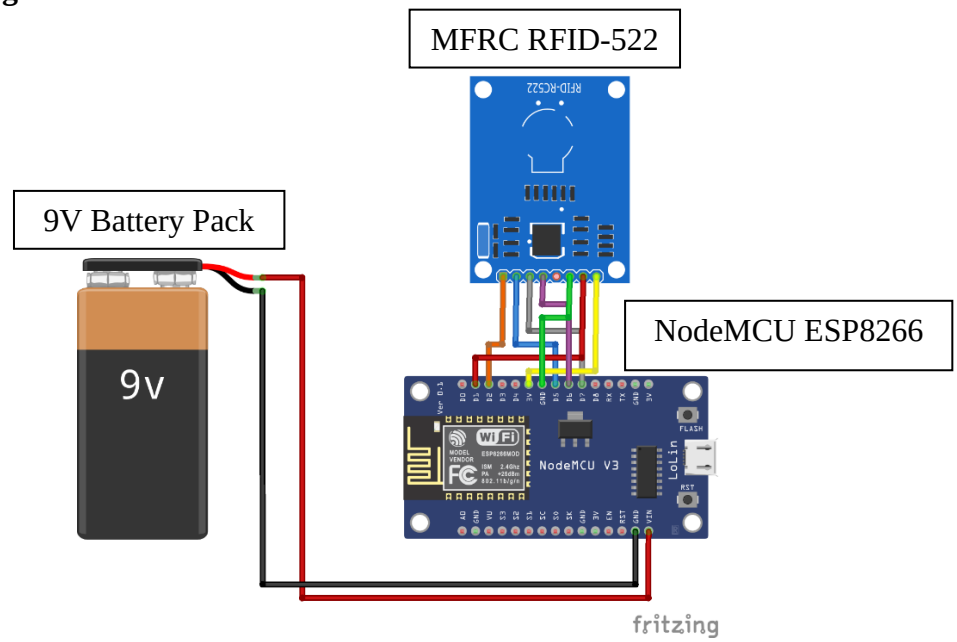

Figure 3.9 Wiring connection of the prototype.

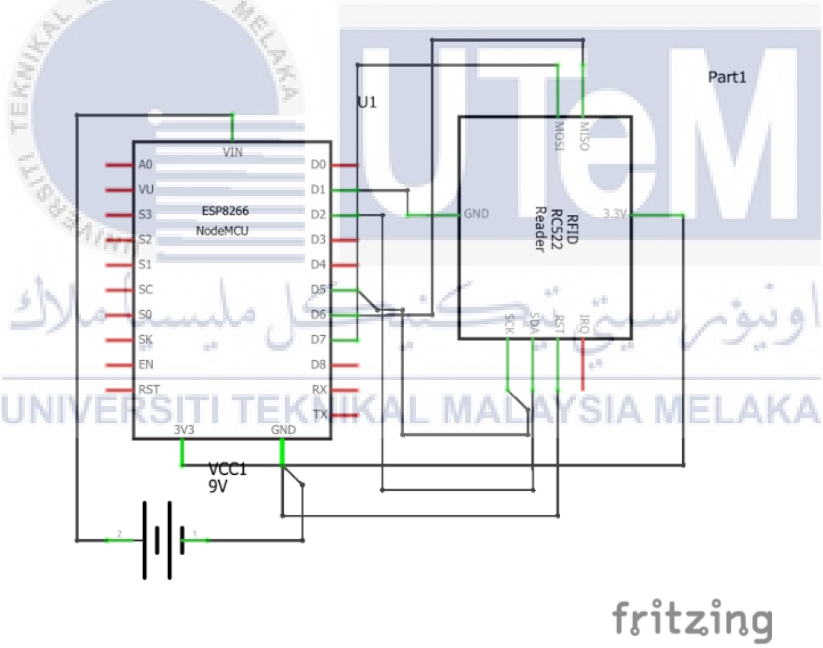

Figure 3.10 Schematic diagram of the prototype

Figures 3.9 and 3.10 above represent the wiring connection that has been connected between NodeMCU ESP8266 and MRFC RFID-522. A 9V battery pack is used to supply the whole circuit,

3.6 Fourth Milestone

The fourth milestone is created by referring to the third objective, which is to analyse the system's performance through data collection utilizing various approaches. The data will next be analysed to see whether the system can detect the objects in real time. If the system's performance is bad, it will be improved by returning to earlier milestones. A test-retest reliability method is used to collect data to measure the consistency of the results. Figure 3.9 below shows the flowchart of the fourth milestone.

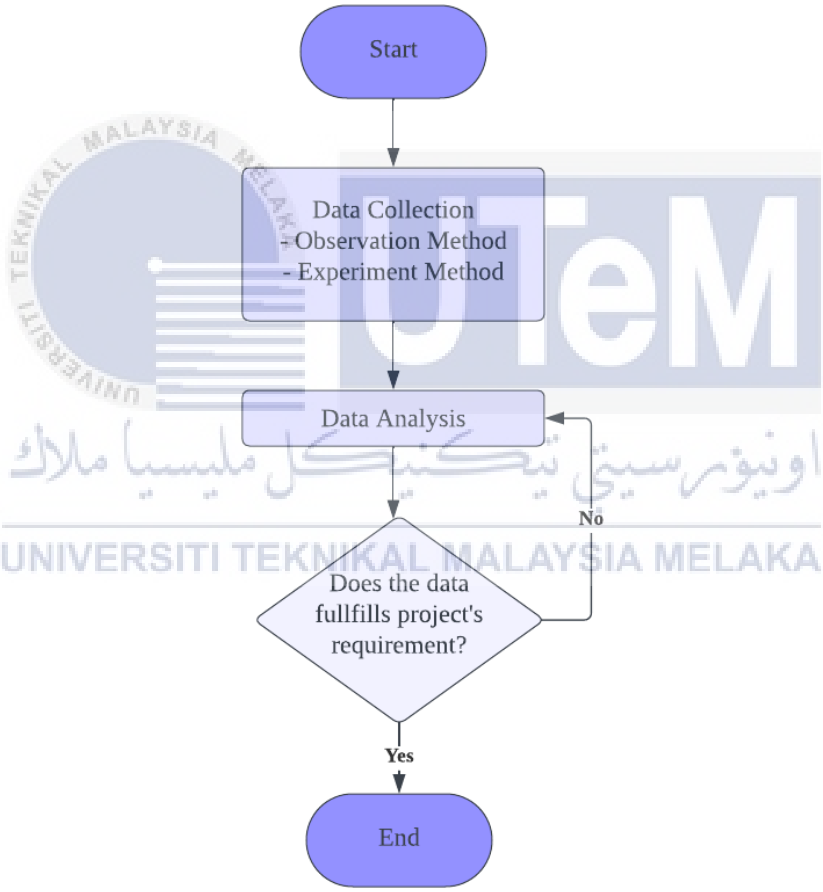

Figure 3.11 Flowchart of fourth milestone

3.7 Summary

This chapter presents a methodology for developing a smart shopping trolley. The main objective of this methodology is to achieve a more straightforward and effective process in making this project. This process flow divides into four branches, making the process more smooth and more systematic. Component research has been made in this chapter as a basis for building the project. Lastly, data analysis will be made to test the capabilities of the project.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This section provides the findings, analysis, and discussion of all data acquired from the system to assess its performance and adjust it to attain the best possible results for this smart trolley project.

4.2 Hardware Results

Several procedures were taken to complete this project, and one of it is hardware implementation. This project requires minimal hardware: NodeMCU ESP 8266 & RFID NFRC522 Mifare. This circuit will be supplied by 9V battery pack, and a switch will be attached to the body to easily turn on/off the circuit. Each of the connections must be secured to achieve the objective and purpose of this project. Figure 4.1, 4.2, and 4.3 shows the hardware of the prototype.

Figure 4.1 Top view of the prototype

Figure 4.2 Close-up view of the prototype

Figure 4.3 Front view of the prototype

4.3 Website Design Results

To achieve one of the objectives of this project, a website made from scratch has been designed to achieve this project's target, which implements the functionality of both sides of ends – customer and staff. The website is made mainly by using PHP, HTML, and

CSS languages, while using MySQL as Figure 4.4 below as a database to contain all the data from RFID and login information. Several QoL functions have been implemented for the

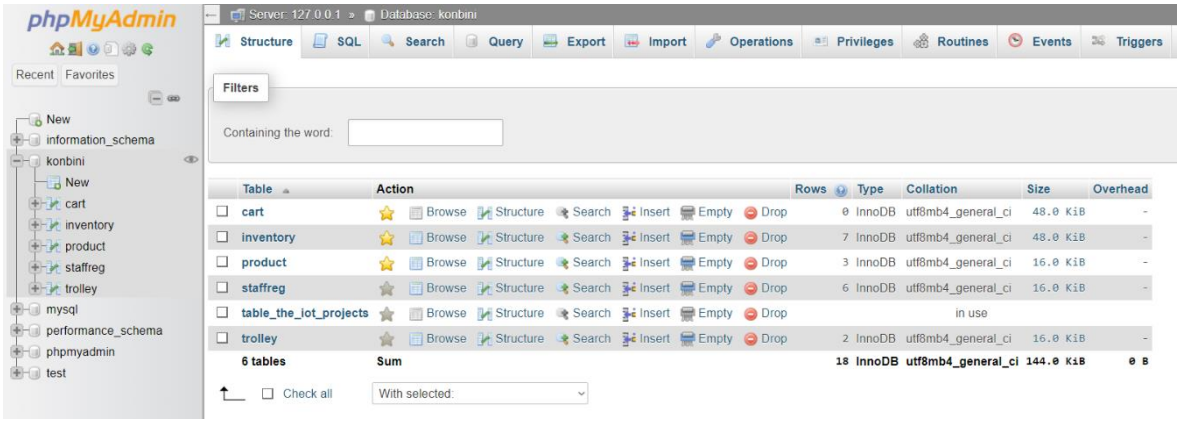

Figure 4.4 Database in MySQL

platform to be used at ease.

4.3.1 Customer's Interface

A website for the shopping trolley has been designed by integrating RFID functionalities with the website's database by using MySQL. Customer will be able to use integrated QR scanner in the login page to receive access to the trolley's webpage. Customer will be registered as a "trolley" according to which trolley they scanned the QR code from. Figure 4.5, 4.6, 4.7 & 4.8 shows the functionalities of the website on consumer's end by using mobile phone. By using this website, users can add items by scanning them on the RFID reader, and it will be automatically registered on the site. Users will have to manually delete the item from the site if they have a change of mind. The site will automatically calculate the items in the cart in real-time. After pressing "Checkout" button, the items from the inventory system will be deducted.

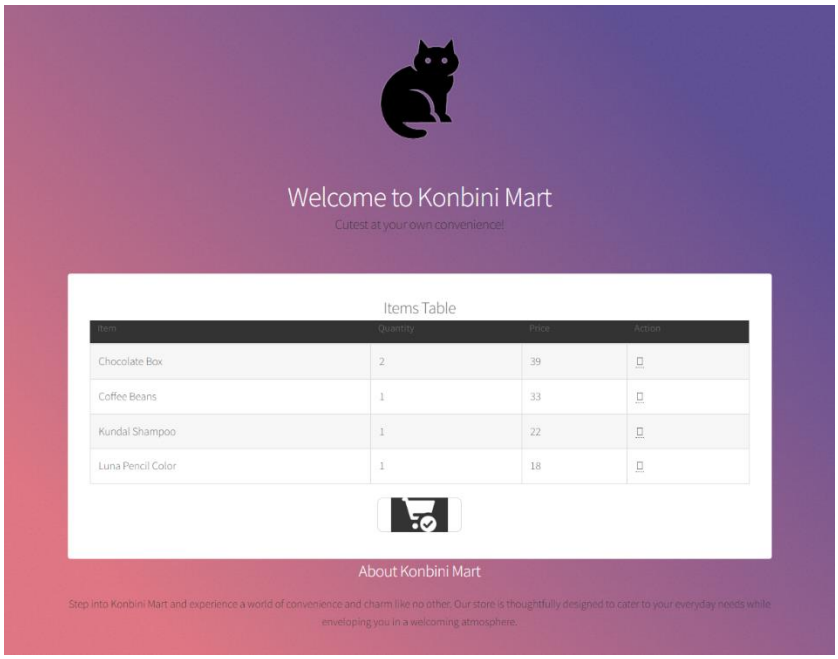

Figure 4.5 Shopping cart

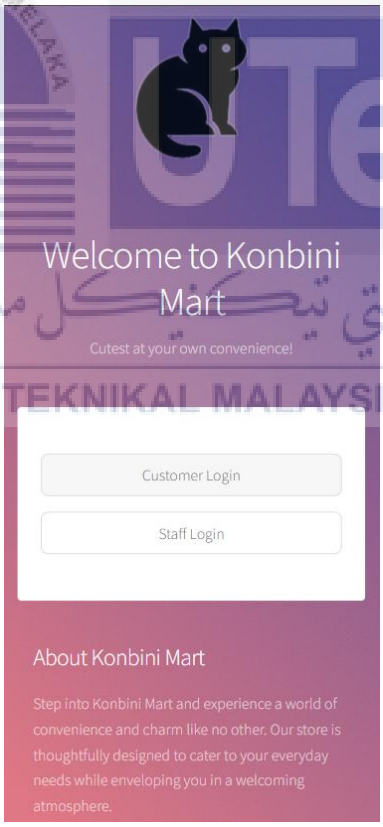

Figure 4.6 Login Page – Home

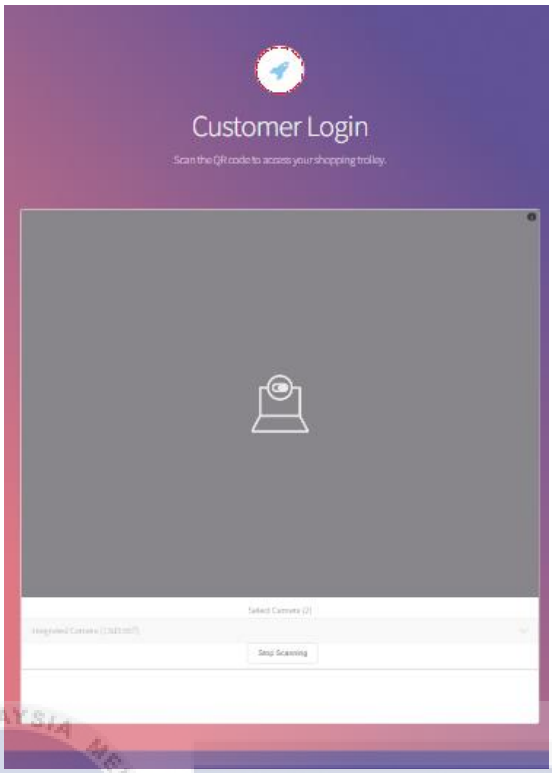

Figure 4.7 Customer login page - QR Scanner

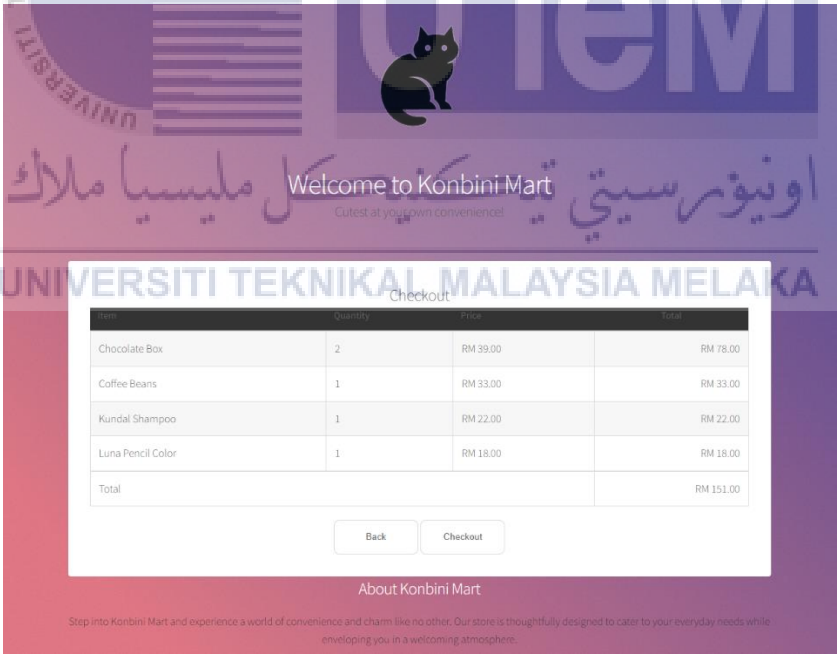

Figure 4.8 Checkout page

4.3.2 Staff's interface

An interface for the inventory management system linked directly to the shopping trolley has been designed by integrating RFID functionalities with the website's database by using MySQL. By using this website, staffs will be able utilise "Create, Read, Update, and Delete" (CRUD) features to:

i. Register as new user

ii. Login as a staff member

iii. Register new item in the inventory by using RFID

iv. Update new stocks on existing item

v. View list of staffs

vi. View list of items in shopping cart

Figures 4.9, 4.10, 4.11, 4.12, 4.13 & 4.14 below show the interface of the inventory system.

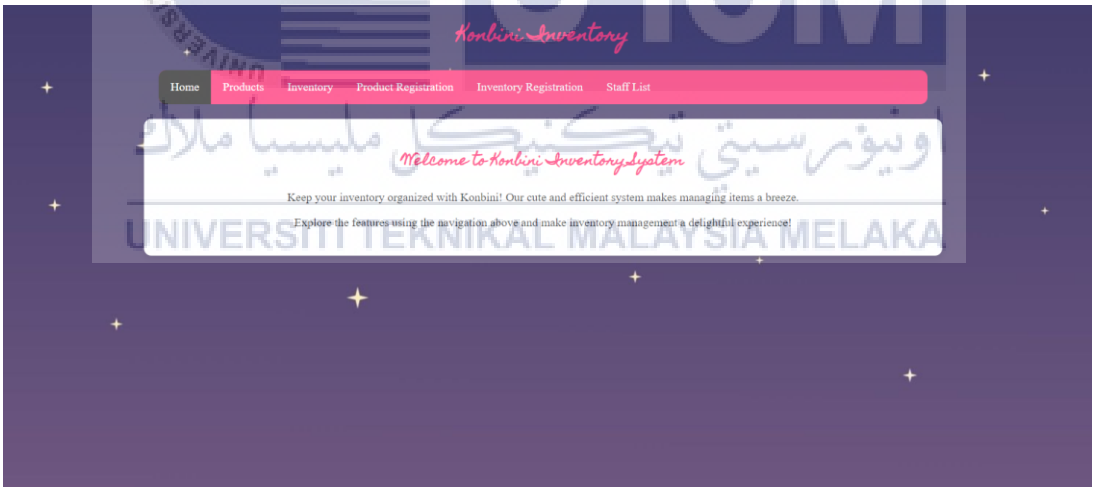

Figure 4.9 Home page - Inventory System

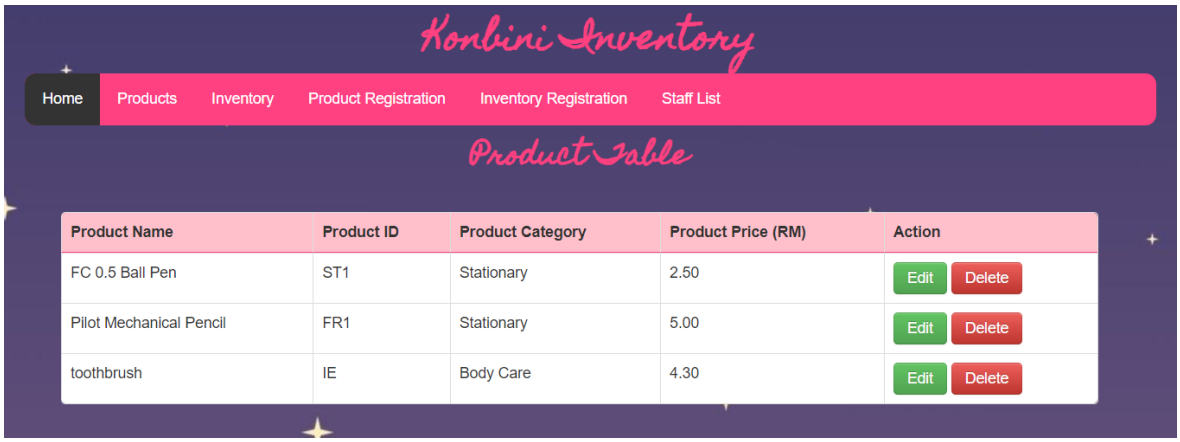

Figure 4.10 Product table

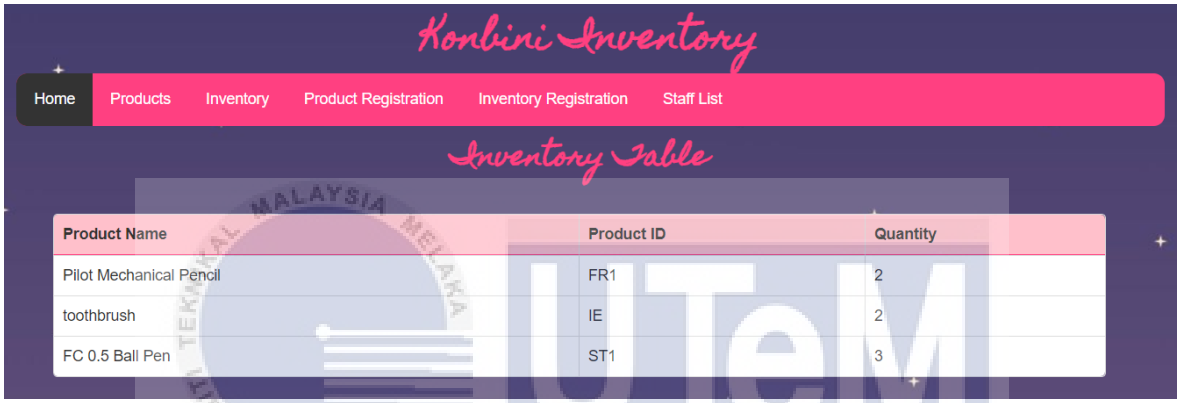

Figure 4.11 Inventory Table

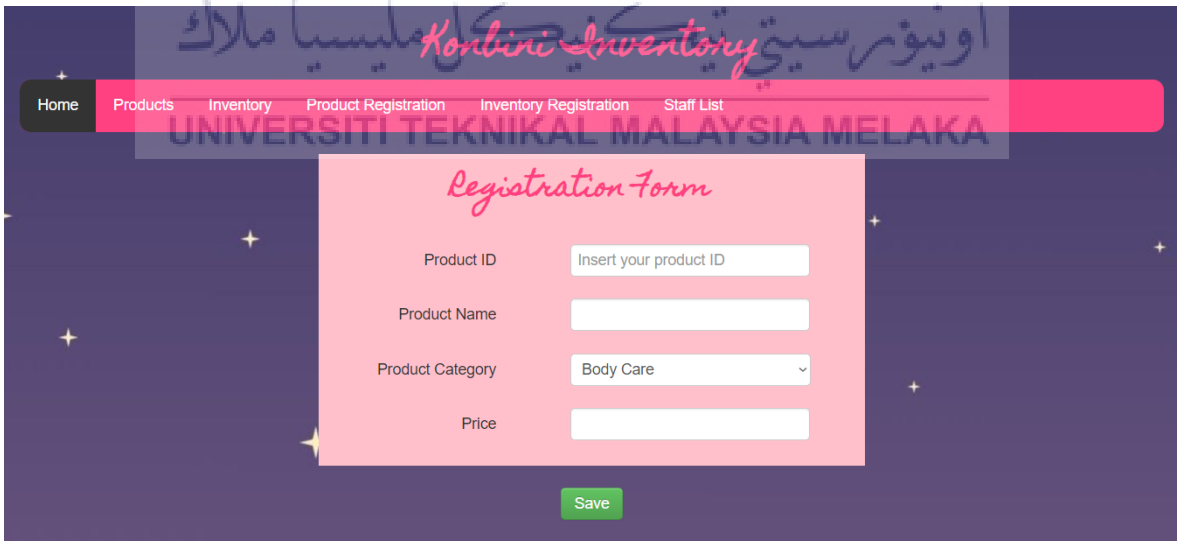

Figure 4.12 Product Registration

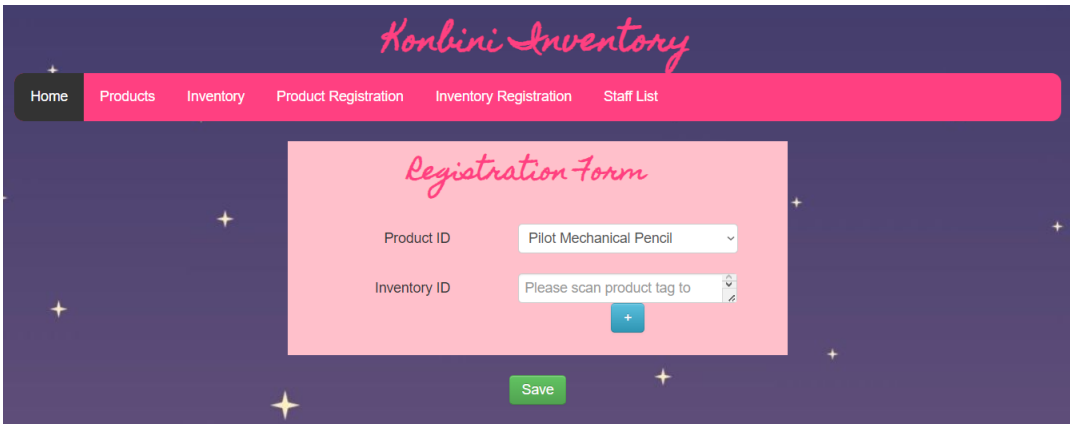

Figure 4.13 Inventory registration form

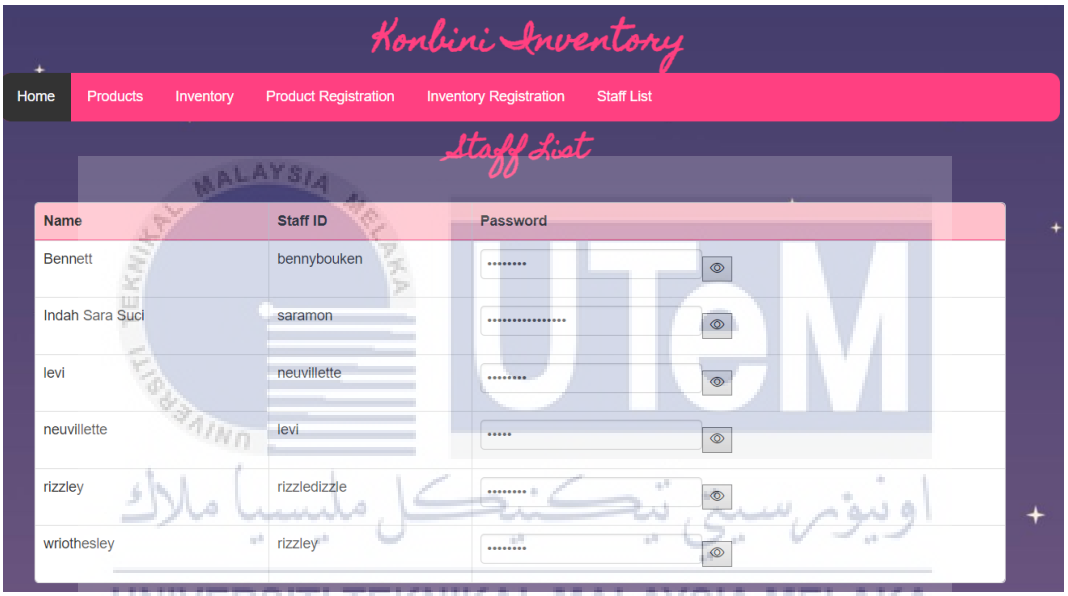

Figure 4.14 Staff list

4.4 Experiment

The main focus of the research is on assessing how well RFID works in terms of scanning time. Previous research indicates that RFID is expected to provide quicker scanning times than barcodes. Therefore, this experiment was made to prove the hypothesis from the previous research, in line with the third objective above, which is to analyse the effectiveness of the RFID technology in improving the retail industry.

4.4.1 Experiment method

Data were collected by using a test-retest reliability test to collect data to measure the consistency of the results, if a small number of differences between the two sets of results is measured, the higher the test-retest reliability. The test was held in a local convenience store, Store X located in Senawang, Negeri Sembilan by conducting an observation of scanning time differences between RFID and barcodes. A group of volunteers of 10 people were assigned to conduct the experiment, by performing the daily operation in Store X. The volunteers conducted the scanning operation by using both technologies and their scanning cycle will be observed, and video recorded to reduce errors in reading the time. Measurements were taken in shifts, which are morning and evening shift within a span of 5 days, hence 2 sessions per day. This consideration was taken to avoid disrupting Store X's normal operation. This experiment used 30 varied items that has been tagged with barcode, and 30 RFID tags.

4.5 Results and analysis

4.5.1 Experiment results

Table 4.1 below shows the result of the experiment, with 10 volunteers using both method of scanning items, RFID and barcode for 30 items.

Table 4.1 Experiment results

Volunteer	Session		Total RFID reading time (s)	Average RFID reading (s)	Total Barcode reading time (s)	Average barcode reading (s)
	Morning	Evening				
1	/		90.5	3.02	134.9	4.49
2		/	98.2	3.27	120.5	4.02
3	/		113.7	3.79	154.4	5.15
4		/	99.5	3.32	132.1	4.40

5	/		92.1	3.07	148.0	4.93
6		/	101.0	3.37	132.3	4.41
7	/		99.8	3.33	120.8	4.03
8		/	95.3	3.18	101.4	3.38
9	/		111.9	3.73	150.2	5.00
10		/	97.4	3.24	109.6	3.65
TOTAL			**99.94**	**3.33**	**130.42**	**4.35**

When evaluating the 10 samples of each method, it is clear from the findings above that RFID scanning is far faster than barcode scanning. Consistent trends can be seen in the data gathered from the volunteers' RFID and barcode scanning times for 30 items each.

First, it's clear that RFID scanning works consistently better than barcode scanning when comparing the volunteers' average scanning times. For all volunteers, the 10 samples average of the total barcode scanning time is ≈ 130.42 seconds with the minimum time of 101.4 seconds and maximum time of 150.2 seconds. Whereas the 10 samples average total RFID scanning time is ≈ 99.94 seconds with a minimum time of 90.5 seconds and maximum time of 111.9 seconds. The total RFID scanning time for all participants is significantly less than the total barcode scanning time, suggesting that RFID technology facilitates a quicker and more effective approach. Figure 4.11 shows the graph of total reading time, with 10 samples over time.

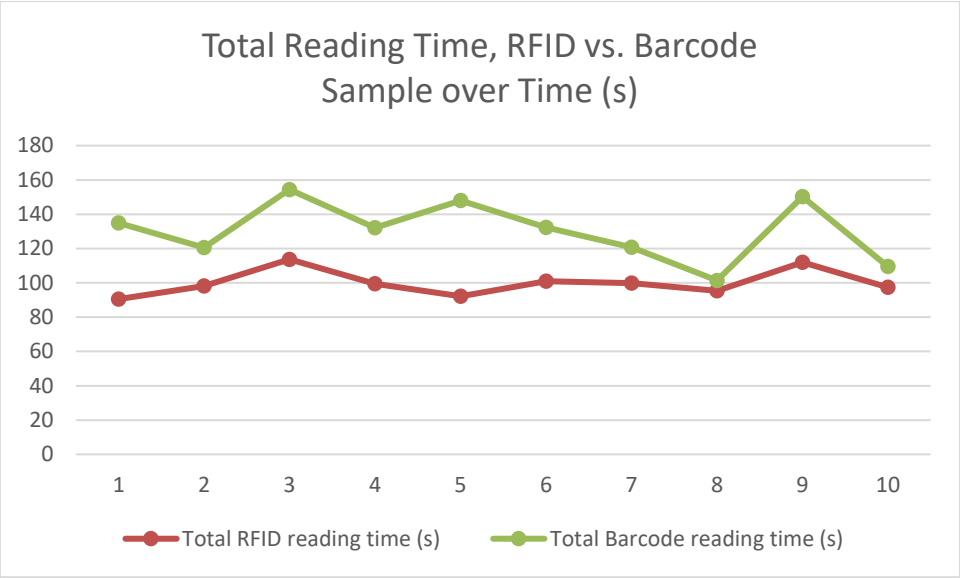

Figure 4.15 Total reading time graph

Furthermore, across all 10 volunteers, the average scanning times for RFID are consistently shorter than those for barcode scanning. Observation from 10 volunteers with 30 items each show that the average time taken per item by using RFID is ≈ 3.33 seconds per item with the minimum average 3.02s and the maximum 3.09s, meanwhile the average time taken by using barcode is ≈ 4.35 seconds per item with the minimum average 3.38s, and the maximum of 5.15s. This means that while using RFID technology instead of barcode scanning, volunteers spent on average, less time per item. Figure 4.12 shows the graph of average reading time, with 10 samples over time.

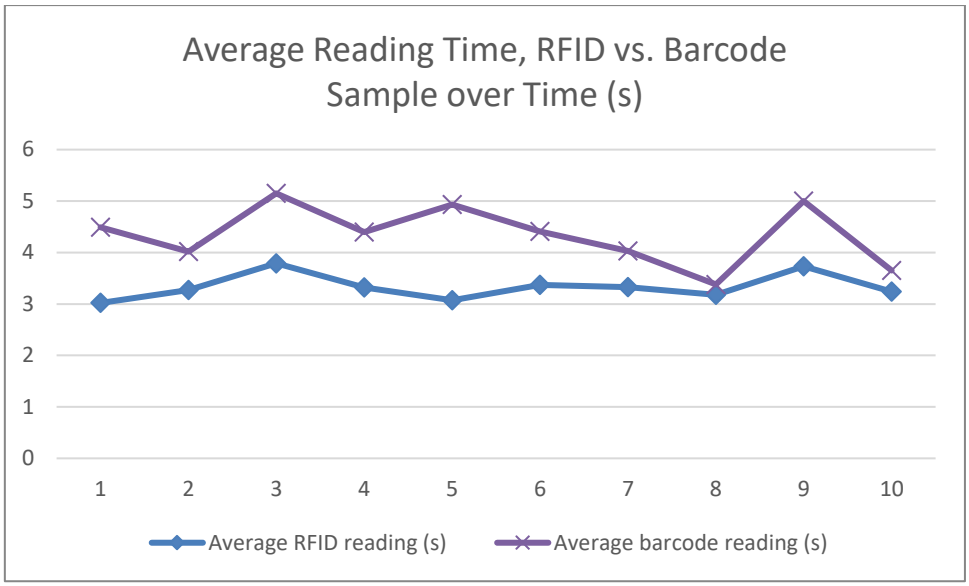

Figure 4.16 Average reading time graph

4.5.2 Percentage of reduction in total reading time analysis

By using data that have been tabulated in Table 4.1, we were able to calculate percentage of reduction in total reading time by using RFID over barcode, using this formula:

$$\left(\frac{Total\ Barcode\ Reading\ Time - Total\ RFID\ Reading\ Time}{Total\ Barcode\ Reading\ Time}\right) x\ 100$$

Table below shows the result of the calculated percentage by using the formula above:

Table 4.2 Percentage of reduction of total reading time

Volunteer	Total RFID Reading Time (s)	Total Barcode Reading Time (s)	Percentage of Reduction
1	90.5	134.9	32.89%
2	98.2	120.5	18.54%
3	113.7	154.4	26.38%
4	99.5	132.1	24.58%
5	92.1	148.0	37.84%
6	101.0	132.3	23.63%
7	99.8	120.8	17.34%
8	95.3	101.4	6.02%
9	111.9	150.2	25.51%
10	97.4	109.6	12.12%
Average percentage over 10 samples			**≈ 21.48%**

The reduction in percentage shows that, overall, volunteers' reading times for RFID scanning were, on average, ≈ 21.48% lesser than the readings for barcode scanning. In the spread of 10 volunteers, a range of reduction from 6.02% up to 37.84% of total reading time has been observed. This supports the theory that, in this situation, RFID is faster than conventional barcode scanning and by using RFID reading method, an average of 21.48% of total reading time can be reduced by using RFID.

4.5.3 Percentage of reduction in average reading time analysis

Data that have been tabulated in Table 4 were calculated to find the percentage of reduction in average reading time by using RFID over barcode, using this formula:

$$\left(\frac{Average\ Barcode\ Reading\ Time - Average\ RFID\ Reading\ Time}{Average\ Barcode\ Reading\ Time}\right) x\ 100$$

Table 4.3 below shows the result of the calculated percentage by using the formula above:

Table 4.3 Percentage of reduction of average reading time

Volunteer	Average RFID Reading Time (s)	Average Barcode Reading Time (s)	Percentage of Reduction
1	3.02	4.49	32.96%
2	3.27	4.02	18.66%
3	3.79	5.15	26.21%
4	3.32	4.40	24.55%
5	3.07	4.93	37.89%
6	3.37	4.41	23.86%
7	3.33	4.03	17.36%
8	3.18	3.38	5.92%
9	3.73	5.00	25.40%
10	3.24	3.65	11.23%
Average percentage over 10 samples			**21.80%**

When compared to barcode scanning, RFID technology shows an average reduction in reading time per item of about 21.80%. This predictable decrease implies that RFID is constantly faster when it comes to reading times on average, shows in result ranging from

5.92% up to 37.89% in average reduction time from barcode reading time. This further supports the experiment's hypothesis and proves the efficiency of RFID application in the commercial daily operation.

4.5.4 Justification of the differences in analysis

4.5.4.1 Percentage of increase in reading time

Understanding the differences or distribution of RFID & barcode scanning times between various volunteers can be gained by measuring the percentage increase in average RFID reading time relative to the minimum average time. This calculation was done by using the equation below that it supports in comprehending how the average RFID reading time of each volunteer differs from the dataset's minimum average time.

$$\left(\frac{Average\ RFID\ Reading\ Time - Minimum\ Average\ RFID\ Reading\ Time}{Minimum\ Average\ RFID\ Reading\ Time}\right) x\ 100$$

Table 4.4 Percentage increase in average RFID reading

Volunteer	Average RFID Reading Time (s)	Percentage increase
1	3.02	0%
2	3.27	8.28%
3	3.79	25.50%
4	3.32	9.93%
5	3.07	1.66%
6	3.37	11.59%
7	3.33	5.30%
8	3.18	23.51%
9	3.73	7.28%
10	3.24	6.95%
Average Percentage Increase		**10.76%**

Based on Table 4.4 above, calculating the percentage increase in average RFID reading time compared to the minimum average time adds a dimension of analysis that helps

interpret the distribution and consistency of RFID scanning times among the volunteers in the dataset. A small percentage (<10.76%) rise indicates greater consistency in the RFID scanning times, whereas a larger percentage (≥10.76%) increase implies greater variability, and were read noticeably longer than those of the others. This could draw attention to any anomalies or situations where RFID scanning is not as efficient. Furthermore, it offers indirect details regarding the RFID system's resiliency and dependability. A small percentage increase indicates that the RFID technology is giving users more consistent outcomes.

Understanding the similarities and differences or variability of the two technologies can be achieved by comparing the percentage increase in RFID reading times with a calculation similar to that used for barcode scanning, as shown in the equation below:

$$\left(\frac{Average\ Barcode\ Reading\ Time - Minimum\ Average\ Barcode\ Reading\ Time}{Minimum\ Average\ Barcode\ Reading\ Time}\right) x\ 100$$

Table 4.5 Percentage increase in average barcode reading

Volunteer	Average Barcode Reading Time (s)	Percentage increase
1	4.49	41.20%
2	4.02	26.42%
3	5.15	61.64%
4	4.40	38.36%
5	4.93	54.72%
6	4.41	38.68%
7	4.03	26.73%
8	3.38	6.29%
9	5.00	57.23%
10	3.65	14.77%
Average Percentage Increase		**36.63%**

Based on the Table 4.5 above, calculating the percentage increase in average barcode reading time compared to the minimum average time adds a dimension of analysis that helps interpret the distribution and consistency of barcode scanning times among the

volunteers. It helps in figuring out how much volunteers' barcode reading times vary from one another. Greater variety in reading durations is shown by a higher percentage increase (≥36.63%) indicating that some volunteers have much higher average reading times than others and this further suggested that their barcode reading times are noticeably longer than those of the rest. In addition, it offers additional details regarding the stability and dependability of the barcode scanning technology. A small percentage increase indicates that more users are receiving results from the barcode scanning system that are consistent.

4.5.4.2 Post-experiment survey

This survey has been done by using Google Form to further understand the factors of variability in this experiment, such as human error and technical difficulties. This survey also ensures the external factors of variability in this experiment are valid and accounted. Full version of this survey is attached in the Appendices section below.

i. Experience and familiarity

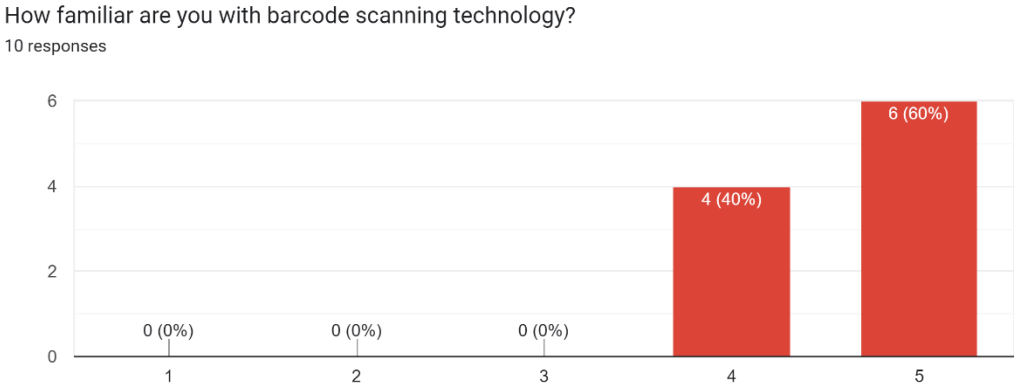

Figure 4.17 Familiarity with barcode technology

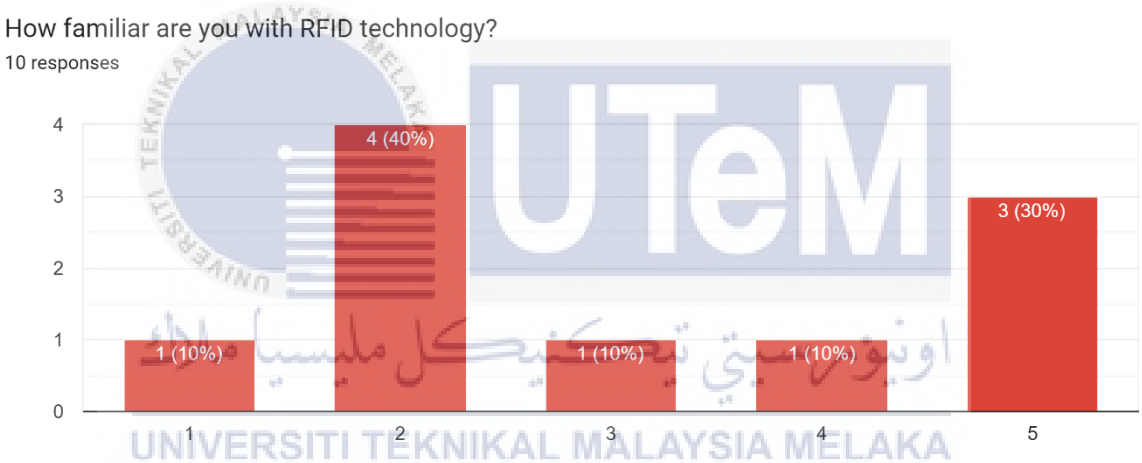

Figure 4.18 Familiarity with RFID technology

Figure 4.13 and 4.14 above shows that most volunteers show great familiarity with barcode technology comparing to RFID. 5 volunteers responded otherwise, implies that they had little to no familiarity with RFID before the experiment.

ii. Ease of use

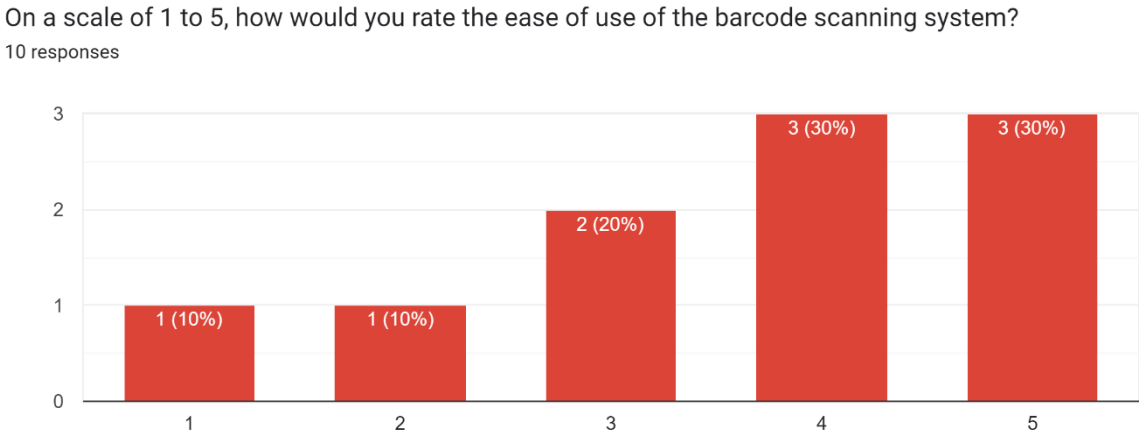

Figure 4.19 User friendly scale on barcode system

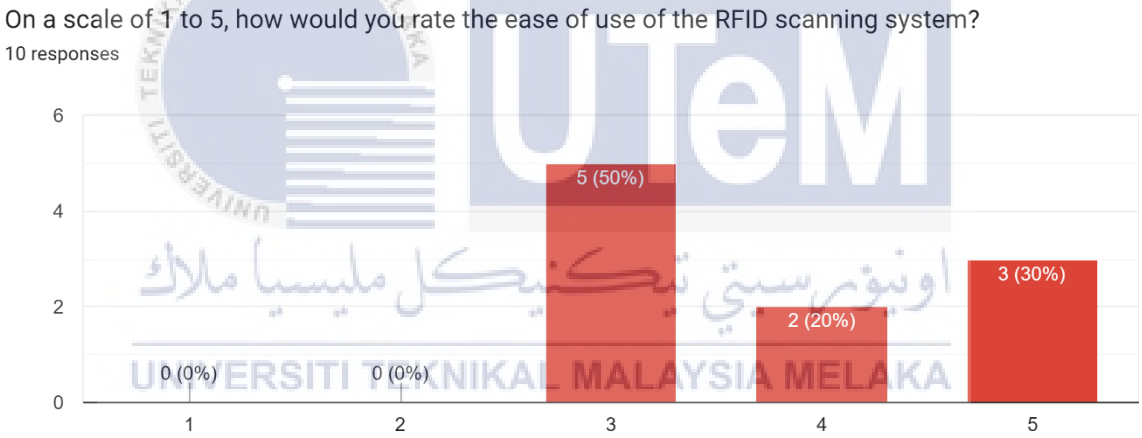

Figure 4.20 User-friendly scale on RFID system

Based on Figure 4.15 and 4.16, 6 volunteers responded that barcode systems were easy to use, meanwhile 2 of them thought that it was hard to use. Meanwhile, the responses with RFID systems were great, 5 volunteers responded that it was easy to use, and 5 more volunteers think it was somewhat easy to use.

iii. Issues faced during scanning

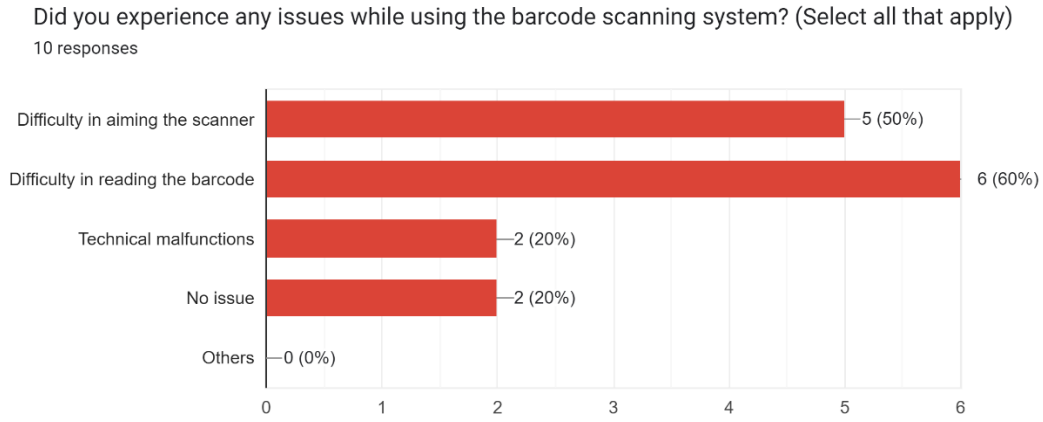

Figure 4.21 Issues faced with barcode

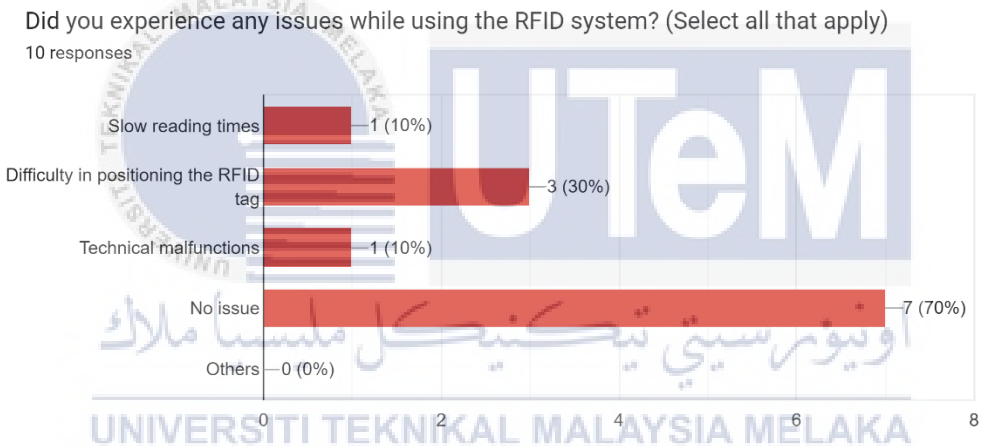

Figure 4.22 Issues faced with RFID

Figure 4.17 and 4.18 shows the issues faced by the 10 volunteers during the experiment, and volunteers were able to pick multiple answers in this question. 6 people had difficulties in reading the barcode, 5 people had difficulties in aiming the scanner, 2 volunteers had technical difficulties, and 2 other people had no issues. In contrast, 7 volunteers had no issues during the experiment with RFID, meanwhile the remaining 3 people had issues in positioning the RFID tags, 1 person had technical issues, and had slow RFID reading times.

iv. Comfortability

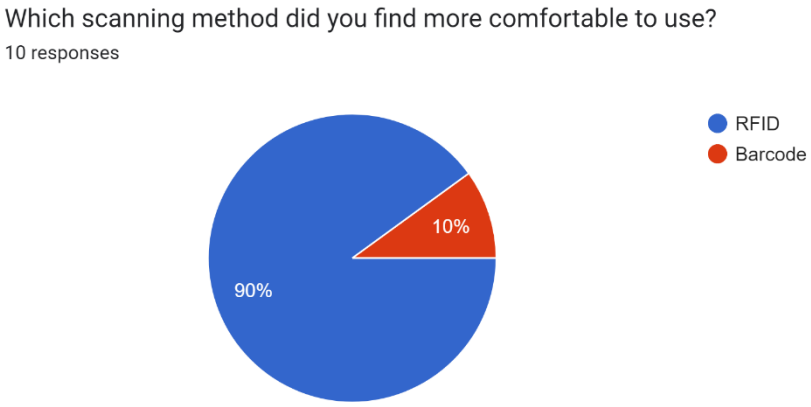

Figure 4.23 Comfortability

According to Figure 4.19 above, 9 out of 10 people found that RFID scanning method was the most comfortable to use after the experiment. 1 person was more comfortable in using barcode scanning method than RFID. Based on the majority response, RFID is the preferred choice in the aspect of comfort.

4.5.5 Final Verdict

The first observation that RFID is faster in this experiment carried out by volunteers is supported by the constant decrease in total and average reading times for RFID compared to barcode scanning. While RFID is typically efficient, there are some variances in performance among volunteers, as evidenced by the average percentage increase, which indicates a considerable level of variability in RFID reading times, mainly caused by difficulty in positioning the RFID tags according to the feedback survey. Next, a wider range of reading durations among the participants utilizing barcode scanning is indicated by the larger average percentage increase in barcode reading times, proven by the post-experiment

survey that most volunteers had difficulty in scanning the barcode and finding the accurate angle to aim on the barcode. In summary, the experiment has proven the hypothesis that RFID technology delivers more reliable and faster performance than barcode technology. This further strengthens the application of RFID technology on a shopping cart in the retail industry, as it is more efficient compared to the conventional method of scanning by using barcode technology over the counter.

4.6 Summary

In this chapter, the hardware implementation section describes how the project's physical components were successfully deployed and integrated. This includes the smart shopping carts' integration of RFID technology, which guarantees smooth communication between the RFID tags and the system. The successful operation of the RFID readers, tags, and related hardware throughout this phase is notable and adds to the project's overall success. This chapter concludes with a thorough summary of the project's concrete results, which include the effective incorporation of RFID technology, an online interface, and perceptive experimental findings. The project's aims are validated by the convergence of these features, which also establishes the project as a promising progress in the field of smart shopping solutions throughout the industry.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The current study delved into creating an intelligent shopping cart utilizing RFID technology to augment inventory monitoring and customer satisfaction in retail settings. The study utilized a thorough approach that encompassed hardware and web development aspects. A hardware implementation has been made to serve as the physical prototype of this project, by using a small-sized trolley, integrated with NodeMCU ESP8266 and LF-type RFID MRFC-522, supplied by a 9V battery pack. Next, a website that caters to both customers and retail staff has been designed to streamline the process of the retail industry. Both interfaces are intra-connected, and stocks deducted from checking out from the cart will be auto deducted in real-time, so that the staff will be aware of the lack of stocks on the aisle. Plus, customers will be able to have a better shopping experience by being able to just checkout their items by using the shopping trolley, instead of queueing in a long line. Lastly, an experiment to prove the effectiveness of the RFID was made, and RFID technology has proven itself to perform swifter operations rather than using the conventional method of scanning by using barcode. By achieving all three objectives, this project has been proved as a big success, and hopefully the utilization of smart shopping trolley by using RFID will be a norm in the retail industry one day.

5.2 Potential for Commercialization

RFID smart shopping carts are designed to provide customers with a seamless and effective shopping experience by streamlining the procedure. Retailers may dramatically cut

wait times and increase customer satisfaction by utilizing RFID technology for automated item recognition and checkout. The enhanced user experience is a major factor in RFID-enabled shopping carts' commercial success.

RFID intelligent shopping carts provide a feasible solution to problems with inventory control. Retailers may avoid stockouts and overstock problems by maintaining precise inventory levels thanks to real-time item tracking. This guarantees that shelves are continuously well-stocked, improving the consumer shopping experience.

The move towards digital receipts, made possible by RFID technology, supports the community's growing concern for environmental sustainability. By reducing paper usage and optimizing inventory management, RFID smart shopping carts contribute to eco-friendly retail practices, resonating with environmentally conscious consumers.

5.3 Future Works

For future improvements, the smart shopping trolley can implement these features:

i) Upgrade the RFID from LF to HF or UHF to enhance the readability and scanning ranges.

ii) Location-based tracker to navigate users to find the products from the retail catalogue by using GPS.

iii) Image processing feature that allows the user to identify the relevant products in the store.

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APPENDICES

Appendix A (Google Form Survey)

RFID and Barcode Scanning Experiment Feedback

Description for the Google Form Survey:

Thank you for participating in our RFID and Barcode Scanning Experiment. Your feedback is invaluable in helping us analyze the performance of these technologies. Please take a few minutes to share your thoughts and experiences. Your input will contribute to the improvement of scanning systems in various applications.

Thank you!

indahsarasuci@gmail.com Switch accounts

Not shared

* Indicates required question

Age *

- 18 - 24
- 25 - 34
- 35 - 44
- 45 - 54
- 65 or older

Gender *

- ◯ Male
- ◯ Female

How familiar are you with RFID technology? *

	1	2	3	4	5	
Very unfamiliar	◯	◯	◯	◯	◯	Very familiar

How familiar are you with barcode scanning technology? *

	1	2	3	4	5	
Very unfamiliar	◯	◯	◯	◯	◯	Very familiar

On a scale of 1 to 5, how would you rate the ease of use of the RFID scanning system? *

	1	2	3	4	5	
Very difficult	◯	◯	◯	◯	◯	Very easy

On a scale of 1 to 5, how would you rate the ease of use of the barcode scanning system? *

	1	2	3	4	5	
Very difficult	○	○	○	○	○	Very easy

Did you experience any issues while using the RFID system? (Select all that apply) *

- [ ] Slow reading times
- [ ] Difficulty in positioning the RFID tag
- [ ] Technical malfunctions
- [ ] No issue
- [ ] Others

Did you experience any issues while using the barcode scanning system? (Select all that apply) *

- [ ] Difficulty in aiming the scanner
- [ ] Difficulty in reading the barcode
- [ ] Technical malfunctions
- [ ] No issue

Did you experience any issues while using the barcode scanning system? (Select all that apply) *

- [ ] Difficulty in aiming the scanner
- [ ] Difficulty in reading the barcode
- [ ] Technical malfunctions
- [ ] No issue
- [ ] Others

Which scanning method did you find more comfortable to use? *

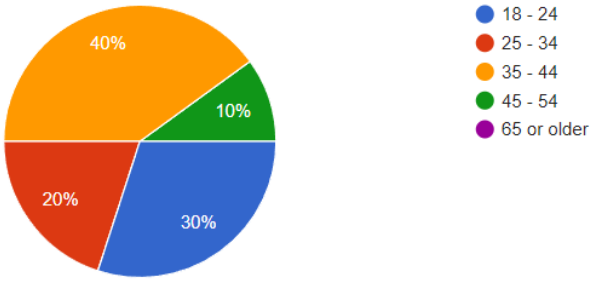
- ( ) RFID
- ( ) Barcode

Submit Clear form

Age

Copy

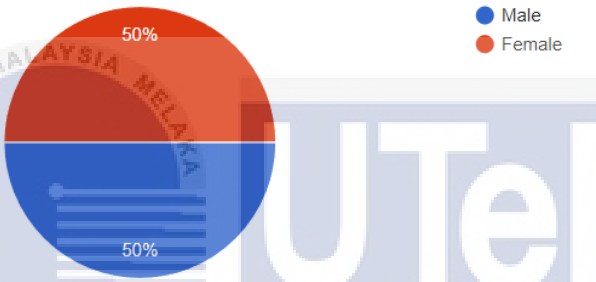
10 responses



Gender

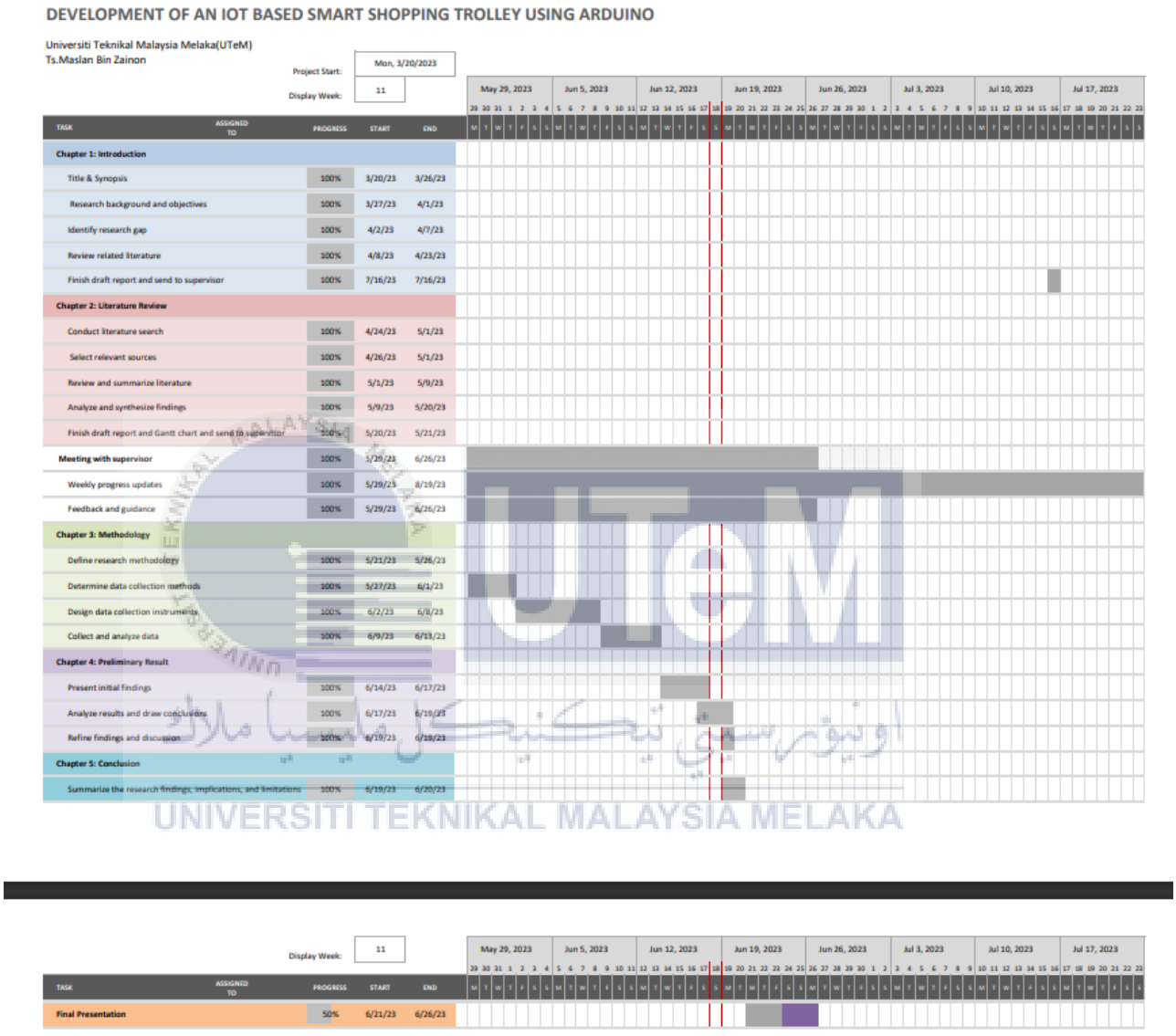
Copy

10 responses



Appendix B (Gantt Chart)

Gantt chart PSM 1



Gantt chart PSM 2

DEVELOPMENT OF AN IOT BASED SMART SHOPPING TROLLEY USING ARDUINO

Universiti Teknikal Malaysia Melaka(UTeM)
Ts.Maslan Bin Zainon

Project Start: Mon, 3/20/2023

TASK	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14
Chapter 1: Introduction														
Study & understand the aim of the project														
Discuss with supervisor														
Identify the problem statement														
Identify project scope														
Finish draft report and send to supervisor														
Chapter 2: Literature Review														
Conduct literature search														
Select relevant sources														
Review and summarize literature														
Finish draft report and send to supervisor														
Chapter 3: Methodology														
Define research methodology with a flowchart														
Identify every milestones														

TASK	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14
Design data collection instruments														
Hardware research														
Chapter 4: Preliminary Result														
Present initial findings														
Analyze results and draw conclusions														
Refine findings and discussion														
Chapter 5: Conclusion														
Summarize the research findings, implications, and limitations														
Final Presentation														

Appendix C - Coding from Arduino IDE

```
#include <ESP8266WebServer.h>
#include <ESP8266HTTPClient.h>
#include <SPI.h>
#include <MFRC522.h>

#define SS_PIN D2
#define RST_PIN D1
MFRC522 mfrc522(SS_PIN, RST_PIN);

#define ON_Board_LED 2
const char* ssid = "nuguya 2.4G";
const char* password = "***********";

ESP8266WebServer server(80);

int readsuccess;
byte readcard[4];
char str[32] = "";
String StrUID;

void setup() {
  Serial.begin(115200);
  SPI.begin();
  mfrc522.PCD_Init();

  delay(500);

  WiFi.begin(ssid, password);
  Serial.println("");

  pinMode(ON_Board_LED, OUTPUT);
  digitalWrite(ON_Board_LED, HIGH);
```

```
  Serial.print("Connecting");
  while (WiFi.status() != WL_CONNECTED) {
    Serial.print(".");
    digitalWrite(ON_Board_LED, LOW);
    delay(250);
    digitalWrite(ON_Board_LED, HIGH);
    delay(250);
  }
  digitalWrite(ON_Board_LED, HIGH); /
  Serial.println("");
  Serial.print("Successfully connected to : ");
  Serial.println(ssid);
  Serial.print("IP address: ");
  Serial.println(WiFi.localIP());

  Serial.println("Please tag a card or keychain to see the UID !");
  Serial.println("");
}
void loop() {
  readsuccess = getid();

  if (readsuccess) {
    digitalWrite(ON_Board_LED, LOW);
    HTTPClient http;

    String UIDresultSend, postData;
    UIDresultSend = StrUID;

    postData = "UIDresult=" + UIDresultSend;

    WiFiClient client;

    http.begin(client, "http://192.168.1.41/konbini/getUID.php");
```

```
    http.addHeader("Content-Type", "application/x-www-form-
urlencoded");

    int httpCode = http.POST(postData);
    String payload = http.getString();

    Serial.println(UIDresultSend);
    Serial.println(httpCode);
    Serial.println(payload);

    http.end();
    delay(1000);
    digitalWrite(ON_Board_LED, HIGH);
  }
}
int getid() {
  if (!mfrc522.PICC_IsNewCardPresent()) {
    return 0;
  }
  if (!mfrc522.PICC_ReadCardSerial()) {
    return 0;
  }


  Serial.print("THE UID OF THE SCANNED CARD IS : ");

  for (int i = 0; i < 4; i++) {
    readcard[i] = mfrc522.uid.uidByte[i];
    array_to_string(readcard, 4, str);
    StrUID = str;
  }
  mfrc522.PICC_HaltA();
  return 1;
}
```

```
void array_to_string(byte array[], unsigned int len, char buffer[]) {
  for (unsigned int i = 0; i < len; i++)
  {
    byte nib1 = (array[i] >> 4) & 0x0F;
    byte nib2 = (array[i] >> 0) & 0x0F;
    buffer[i * 2 + 0] = nib1  < 0xA ? '0' + nib1  : 'A' + nib1  - 0xA;
    buffer[i * 2 + 1] = nib2  < 0xA ? '0' + nib2  : 'A' + nib2  - 0xA;
  }
  buffer[len * 2] = '\0';
}
```