Arab Academy for Science, Technology and Maritime Transport

College of Engineering and Technology

Industrial and Management Engineering

B. Sc. Final Year Project

Implementing Smart Inventory System

Presented By:

Akram Gamal *Jana Mohamed*

Maram Kamal *Mohamed Anis*

Omar Shehab

Supervised By:

Prof. Khaled S. El-Kilany

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Student Name: Akram Gamal
Registration Number: 20200357

Signed: ________________________

Date: DD – MMM – YYYY

Student Name: Jana Mohamed
Registration Number: 20100356

Signed: ________________________

Date: DD – MMM – YYYY

Student Name: Maram Kamal
Registration Number: 20101050

Signed: ________________________

Date: DD – MMM – YYYY

Student Name: Mohamed Anis
Registration Number: 20100210

Signed: ________________________

Date: DD – MMM – YYYY

Student Name: Omar Shehab
Registration Number: 18103117

Signed: ________________________

Date: DD – MMM – YYYY

STUDENTS CONTRIBUTION

Although your project will have a single title with all student names meaning that it is a group project; however, <u>each student must have at least one individual part, including his own aims and objectives, tests, analysis and results verification</u>. Each student should also exactly define his own work in the other shared parts. This individual work will be considered in final evaluation and presentation of each student.

Implementing Smart Inventory System

By:

Akram Gamal
Jana Mohamed
Maram Kamal
Mohamed Anis
Omar Shehab

Chapter	Title	Contributors
1	Introduction	Akram Gamal Mohamed Anis
2	Literature review	Akram Gamal Mohamed Anis Jana Mohamed Maram Kamal Omar Shehab
3	Case study	Akram Gamal Mohamed Anis Jana Mohamed Maram Kamal Omar Shehab
4	Methodology	Jana Mohamed Maram Kamal Omar Shehab
5	Company X system	Jana Mohamed Maram Kamal Mohamed Anis
6	Multi-criteria decision making	Akram Gamal Jana Mohamed
7	Prototype	Akram Gamal Jana Mohamed Maram Kamal Mohamed Anis
8	Simulation	Akram Gamal Jana Mohamed Maram Kamal Mohamed Anis
9	Conclusion and future recommendations	Akram Gamal Jana Mohamed Maram Kamal Mohamed Anis

		Omar Shehab

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ABSTRACT

In today's fast-paced industrial environment, efficient inventory management is essential for maintaining a smooth production flow. At our partner facility, the existing process relied on manual pallet tracking, visual searches, and verbal communication between workers and forklift operators. This led to delays, worker overload, and inefficient use of resources.

To address these challenges, we implemented an RFID-based solution that enables real-time tracking of pallet locations. This system replaces manual searching and coordination, allowing forklift operators to retrieve pallets directly from the production plan.

We approached the problem by developing a simulation model that reflects both the current and proposed systems. The simulation helped us analyze operational performance, while Multi-Criteria Decision-Making Analysis (MCDM) guided the selection of the most suitable RFID components from both technical and economic perspectives.

The results showed a clear reduction in operator utilization and a noticeable improvement in overall cycle time. These changes significantly enhanced the efficiency of inventory handling.

This project demonstrates how integrating RFID technology into raw material inventory can reduce manual workload, eliminate delays, and support a shift toward Industry 4.0 standards by enabling traceability, real-time visibility, and data-driven decision-making.

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LIST OF ACRONYMS/ABBREVIATIONS

RFID	Radio Frequency Identification
MCDMA	Multi-Criteria Decision-Making Analysis
AHP	Analytic Hierarchy Process
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
SKU’S	stock-keeping units

Chapter One

1 INTRODUCTION

In a manufacturing system, the first step towards a productive and profitable system is a cost effective, smart and reliable inventory system. Recent events in the world have shown us that inventory management systems are indispensable. The world market forced all organisations to compete not only in price or quality but also in technology, innovation, reliability and information technology.

The word inventory is an umbrella that encompasses a lot of processes under it like identifying raw materials, establishing a demand forecast that is as accurate as possible using historic sales data and finally choosing a supplier to order from.

Identifying raw materials starts by deciding what our product will be and whether we will be making or buying most of the materials and if we are buying them, are we prioritizing affordability or quality.

The next step is establishing a forecast plan to help us decide on quantities that we will need that is done by either using historical data or a market study based on competitors.

After setting up a reliable forecast the next step is deciding which supplier are we going to buy from by comparing prices, quality and sampling their materials.

Throughout the whole process of ordering, receiving and manufacturing of products. Tracking this process is the most Vital part. This lend a hand to us keep track of inventory levels of raw materials, finished products, back orders and expected deliveries.

1.1 PROBLEM FORMULATION

Traditional inventory tracking methods, often reliant on manual processes, are prone to human error, time-consuming. To address these limitations, the advent of advanced technologies, such as Radio Frequency Identification (RFID), has paved the way for innovative solutions. The first thing that comes to mind in traditional inventory management methods is Lack of Real-Time Inventory Visibility which lead to inefficient tracking of raw materials as traditional methods often rely on manual counts and barcode scanning, which are time consuming and lead to errors. Also, this problem led to Increasing risk of stock outs and overstock situations that happen mainly because Inefficient inventory management which lead to not fully utilizing capacity of inventory, which negatively impact operations and profitability.

1.2 AIM AND OBJECTIVES

1.2.1 Aim

To establish a tracking system that automatically updates the material levels and location on our SAP to help speed up the process of locating pallets in the warehouse and notifies the inventory manager when stock levels are close to the ROP so the material planner can start ordering the next order.

By implementing RFID technology in the warehouse, our aim is to automate the process of tracking inventory levels by having the RFID scanners automatically update stock levels and the location inside the inventory.

1.2.2 Objectives

Our main objective of this project is establishing a smart system that uses RFID technology to speed up the tracking of stock levels, type and location of raw materials in real-time. Also, persuade an increase in the utilization of current capacity for raw materials by optimise the order quantities.

1.2.3 SMART Objectives

Figure 0-1-1: Smart Objectives

(S-specific): To theoretically implement an RFID-based system to automate the tracking and real-time monitoring of materials in inventory.

Focus on optimizing the order quantities to ensure the right number of A-class materials are being ordered based on real-time stock levels to avoid overstocking.

(M-measurable): track how much time is saved on manual inventory tasks such as physically searching for the pallets on shelves due to continuous relocation on shelves by real-time tracked data of the material.

(A-attainable): RFID tags are attached to the materials and read by RFID scanners to be automatically tracked in all movements through the warehouse, moreover, tracking the stock levels of the inventory.

(R-relevant): The data collected by the RFIDs will help adjust the order quantities and time of orders.

(T-time bound): To be achieved in a time frame of 2 semesters in a sufficient quality befitting the project standards.

Chapter Two

2 LITERATURE REVIEW

2.1 RESEARCH QUESTIONS

RQ1: How does RFID impact inventory count in inventory management?

RQ2: What are the most common used methods for selection of RFID components and are there challenges in applying them?

RQ3: What are the methods used to effectively identify and manage A-class inventory?

RQ4: How can RFID technology be effectively used in inventory?

RQ5: What types of RFID readers and antennas will be deployed to capture data across the warehouse or retail environment?

Research questions were used to help with taking decisions in implementing the RFID system.

2.2 REVIEW METHODOLOGY

After identification of the research questions, research was conducted through the Egyptian Knowledge Bank official website. Different databases were utilized like: Elsevier, Wiley, IET, Taylor & Francis, Emerald Publishing and EBSCOhost. The keywords used for this research included: "Digitalization", "Optimum order quantity" or "Economic analysis" and "Inventory management", and, "Decision making analysis". Other specific keywords were also used as: "RFID", and "Discrete Event Simulation". Papers were filtered according to a certain criterion.

2.3 INCLUSION AND EXCLUSION CRITERIA

The following two tables describe the inclusion and exclusion criteria followed while conducting this review survey. Some key points had to be highlighted to be include in the research process, while others had to be excluded as they may not comply with this project's scope.

Inclusion	*Reasons for inclusion*
English papers	English papers were chosen for easier understanding.
Papers after	
Titles, abstract and keywords	Based on these three criteria's selected papers were included that cover the scope of this research.
Journal Articles	Journal articles are written about very specific topics. Before any paper is published it is assessed and approved from different institutions, which makes them more credible.

Table 1: Inclusion and Exclusion

Exclusion	*Reasons for Exclusion*
Papers before 2019	Previously published research papers were prior to 2019 were excluded to limit the research to recent trends.
Articles by non-certified publishers	Not scientifically proven

Table 1-1: Inclusion and Exclusion

The following diagram shows a detailed filtration of the reviewed papers. The initial search was conducted using general keywords, followed by a filter for publication year. Subsequently, the papers were further narrowed down according to the inclusion and exclusion criteria. The final results include a total of 40 papers reviewed in this project.

04 RESULT FROM FILTRATION	IET	WIELY	IOP	ELSEVIER	IEEE
Initial search	N=11,188	N=12377	N=500	N=1082	N=15000
After 2019	N=5028	N=4700	N=412	N=522	N=5600
Journals	N=1050	N=1081	N=106	N=367	N=3000
Industrial sector	N=494	N=664	N=74	N=126	N=68
Keywords	N=26	N=34	N=20	N=28	N=45
Abstract	N=4	N=10	N=6	N=10	N=10

Figure 2-1: Result of filtration

2.4 LITERATURE SEARCH

This figure shows the distribution of publication years for the papers reviewed in our research.

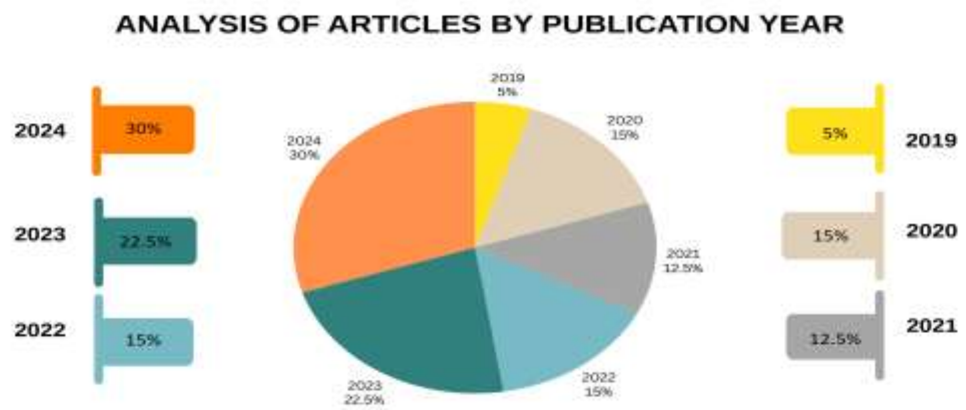

Figure 2-2: Analysis of articles by year

This figure illustrates the distribution of topics across the selected papers. It highlights the relative focus of each topic within the body of research, providing a clear breakdown of how literature is categorized and its relevance to our study.

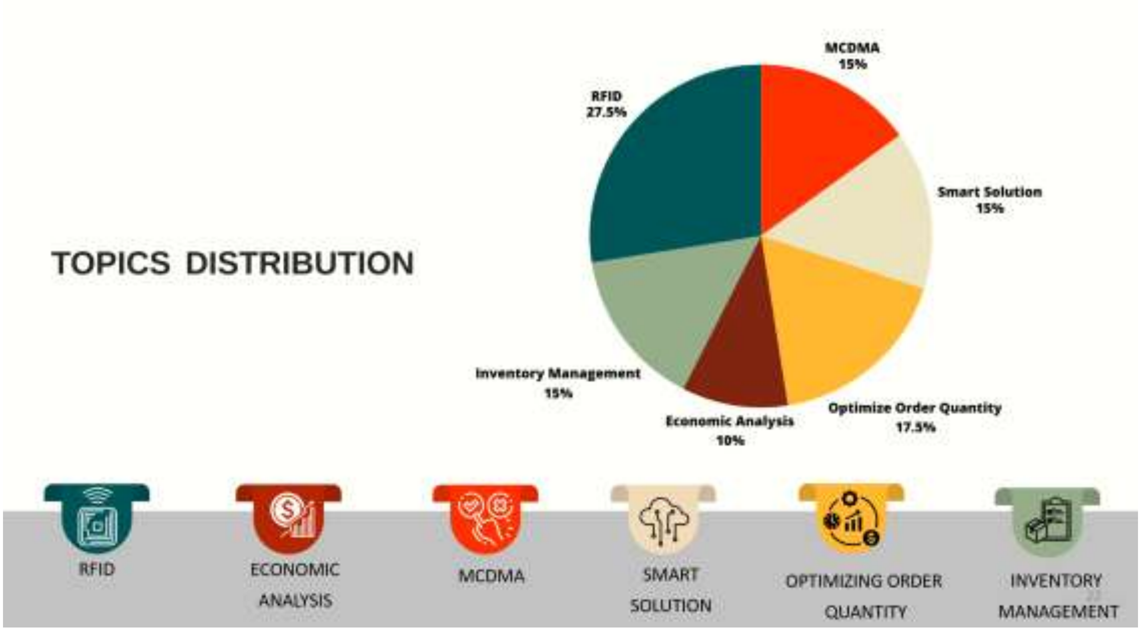

Figure 2-3: Topic distribution

2.5 LITERATURE REVIEW OUTCOME

Our analysis of the literature revealed that the passive approach is more commonly used in RFID-related research, accounting for 63.6% of the papers reviewed, while the active approach was used in 36.4% of the papers.

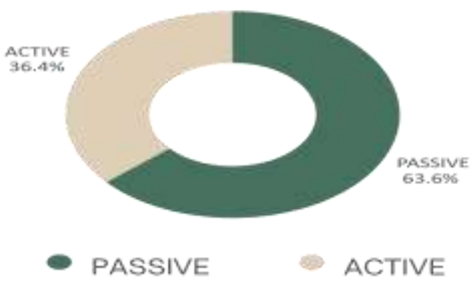

Figure 2-4: Active vs passive`

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Our analysis of the literature on MCDMA revealed that the AHP method was more commonly used, appearing in 80% of the papers reviewed, compared to the TOPSIS method, which was used in 20% of the papers.

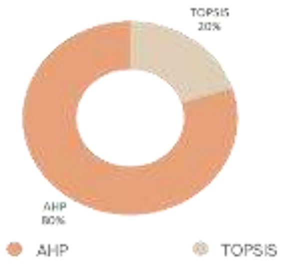


Figure 2-5: AHP VS TOPSIS

2.6 ANSWERS FOR RESEARCH QUESTIONS

RQ1: How does RFID impact inventory count in inventory management?

The real-time tracking of inventory is made a lot easier with RFID technology, which now commonly updates stocks and items as they move through the supply chain. This automated system does away with the errors that are so often associated with counting things by hand. Everything works a lot better and runs a lot smoother when there aren't any humans involved in saying where things are and if things are where they ought to be. With an omniscient view into what's happening inventory-wise at any given time, decisions can be made that will improve an inventory's appearance as well as its performance. More stuff can be seen more often, and the stuff that can't be seen can be assumed to be somewhere else in the performance area.

RQ2: What are the most common used methods for selection of RFID components and are there challenges in applying them?

The methods that are most widely used for selecting components of an RFID system are the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). They are not order-following algorithms; rather, they act like scaffolding to help users visualize how to select components that will converge to a good outcome. Selective components of an RFID system serve many varied and often conflicting purposes, so the selecting of them is a task replete with criteria of different types, clear and unclear, important and less so, and even some that are redundant and some that are not. To help a manager do this selection task, we share a clear, simple, and consistent framework, followed by a multitude of different types of criteria.

RQ3: What are the methods used to effectively identify and manage A-class inventory?

Identifying and managing A-class inventory effectively involves using ABC analysis, which divides inventory into three classes—A, B, and C—based on their relative value and importance. A-class items are the most valuable; they are the ones that require the most attention and monitoring, in part because their inventory control is so crucial to avoiding stockouts. ABC analysis is not a directing method; it does not tell managers how to manage. But it does classify items so that managers know which items are important enough to use heavier management methods. Using ABC analysis effectively will yield more or less effective inventory management.

RQ4: How can RFID technology be effectively used in inventory?

RFID technology transforms inventory management through real-time monitoring, improved accuracy, and greater efficiency. By implementing RFID tags to inventory products, companies can track stock quantities and placements without needing manual scans, minimizing human error and conserving time. Moreover, RFID improves warehouse automation, aids in loss prevention via theft detection, and enhances customer experiences by guaranteeing stock availability. For effective RFID implementation, companies need to evaluate their inventory requirements, select appropriate tags and readers, test the technology, blend it with current systems, and educate employees to enhance its effectiveness.

RQ5: What types of RFID readers and antennas will be deployed to capture data across the inventory?

RFID readers and antennas deployed across the inventory include fixed and handheld readers. In contrast to fixed readers, which may be installed at discrete points like entrances or exits, the data is captured automatically while inventories are in transit through them. But handheld readers offer the flexibility to manually scan items in various locations. Antennas play an important role in ensuring accurate data capture. Linear antennas are good to read tags in a single direction or over longer ranges, while a circular antenna will work well where the orientation of the tag may vary to provide adequate readability over the inventory.

Chapter Three

3 CASE STUDY

3.1 STRUCURAL DATA

3.1.1 Factory data

The facility, constructed in 2013, spans a total site area of 35,135 square meters, with a building area of 15,000 square meters. It is designed to handle a maximum production capacity of 98 tons per day. The plant is equipped with multiple production and packaging capabilities, including two dedicated process lines, three packaging lines, and two integrated lines, allowing for efficient and versatile production operations. This combination of advanced infrastructure and high throughput capacity supports the plant's ability to meet large-scale manufacturing demands. The plant has three main output products, Slab Gum (single-line product), Gum pallets and Hard-Boiled Candy. Slab Gum has only one line of production which is called the Single line production, this line produces different flavours and shapes under the same product name. The second production which is the Gum Pallets has three lines of production, 2's Line, FW Line, 10's Line. Every line of these has its own products to produce. Third and last line, Hard-Boiled candy line, this line produces Boiled candy with different flavours. The plant has three packaging lines and 2 integrated lines to help produce the right product with the right quality. Plant X Products Factory x produces 4 products (Chocolate, Gum, Biscuit, and Candy)

Figure 3-1 Factory data

Figure 3-2 Factory data

Figure 3-3 Factory data

Figure 3-4 Factory data

3.1.2 Plant Inventories

The plant has five working inventories with different purposes for each, Raw materials inventory, Pack material and finished goods inventory, Spare parts inventory, Semi-finished Slab Gum inventory and Semi-finished Candy inventory. Raw materials inventory is the first step of the product to be produced, every single ingredient is stored there after receiving it from the supplier.

Semi-finished Slab Gum inventory is the waiting area of the product before being ready to be packed. It is an area that the product is stored there waiting to enter the rest of the process to be completed. Semi-Finished candy inventory has the same purpose of the semi-finished Slab Gum inventory, the candys are stored there under a specific temperature waiting to go in through the rest of the process. Pack material and finished good inventory is the last step of the product before being sent to the customers, it is where the final product is packed and stored until delivery time.

3.1.3 Excluding Departments

The two options for the project in this company was, Production lines or Inventories. Working on the production line was excluded as there was already teams working on process optimization for the lines. The four other inventories were excluded for several reasons. Semi-finished Slab Gum and semi-finished candy inventories were excluded as these two inventories are in the middle between the production lines and some conditions must be present there as specific temperature for storing the “unfinished good” stored there. Spare parts inventory is only used in maintenance times and repairing in case of a machine being down. Pack material and finished good inventory was also excluded as the main goal of the project was optimizing order quantities So, Raw materials inventory was the best option to work on for the project.

3.1.4 Raw Material Inventory

The raw material inventory management system operates within an 8,250 square meter, operates with 102 racks, accommodating a total of 82 stock-keeping units (SKUs). Two forklifts are available for material handling, operated by a team of three employees. The facility runs two shifts, each lasting 8 hours.

- Inventory: 82 SKUs stored across 102 racks
- Equipment: 2 forklifts
- Personnel: 3 forklift operators
- Shift Operations: 2 shifts, 8 hours each

3.2 OPERATIONAL DATA

3.2.1 Raw materials inventory operation

Our case study is focused on the raw materials inventory as it has the longest operation cycles other than the other inventories. After ordering a new planned order from the supplier for the required materials, the materials are scheduled to arrive on a specific date based on both the plant management and the supplier agreement. The materials in the inventory are moved in every morning based on how much is needed to go to the production line, and how much space is needed for the arriving materials. Some materials are just moved inside the inventory if it’s not needed in production. These materials are moved based on its date as the company is managing the inventory based on FIFO (First in First out Theory). When the delivery shipment arrives at the plant, the truck is inspected at the plant gate first then heads to the inventory. The order then is received at the door gate of the inventory and inspected. Then pallets are prepared so the materials can be put on. Here comes the weighing part, every pallet is the weighed to make sure the shipment is right and to make sure that its weight is safe for the racks. Pallets then are stored on the empty shelves that was emptied in the morning but not before getting labelled by QC (Quality Control) team, these labels mark the pallets if it is already inspected by the QC or still under inspection.

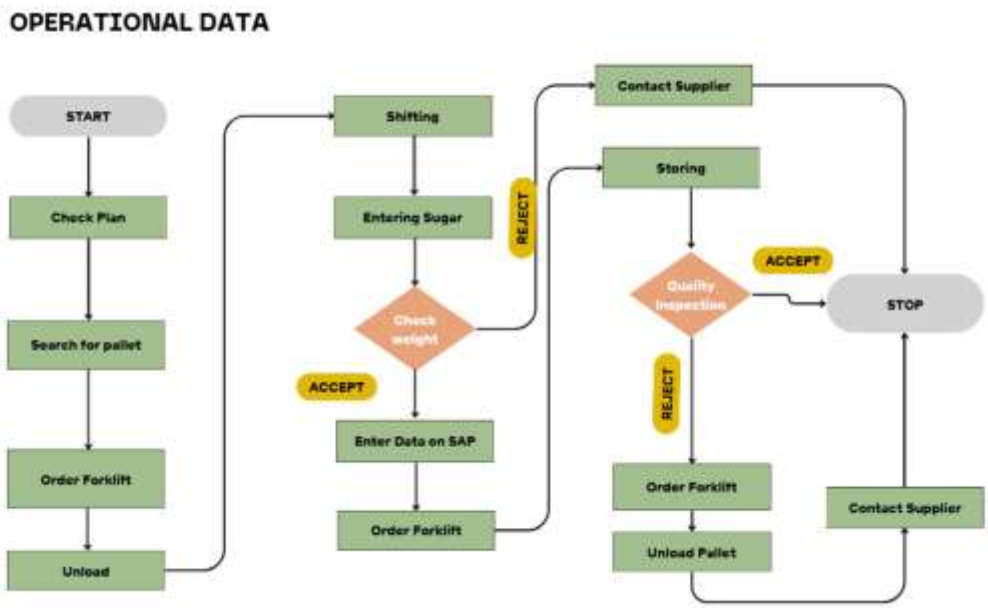


Figure 3-5 Operational data

Raw Material Inventory layout

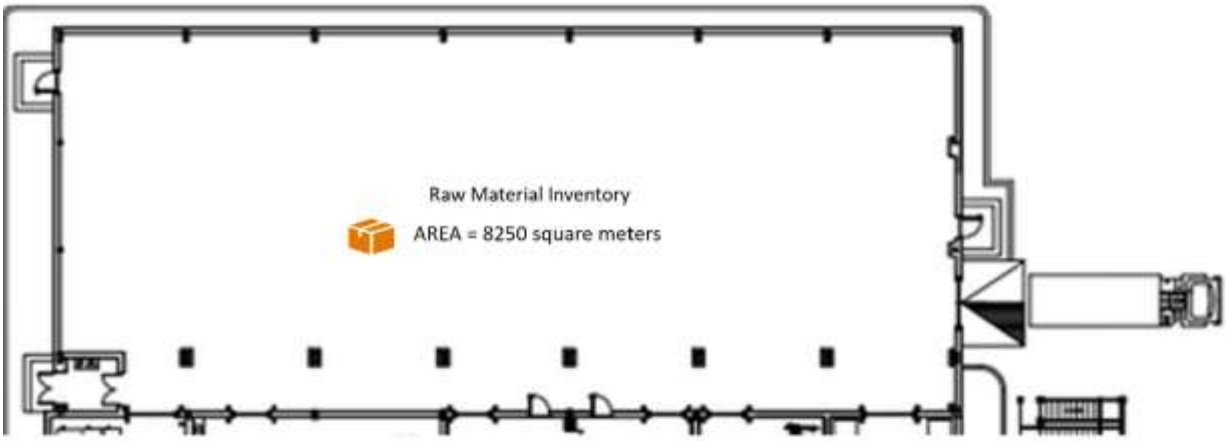


Figure 3-6: Inventory Layout 1

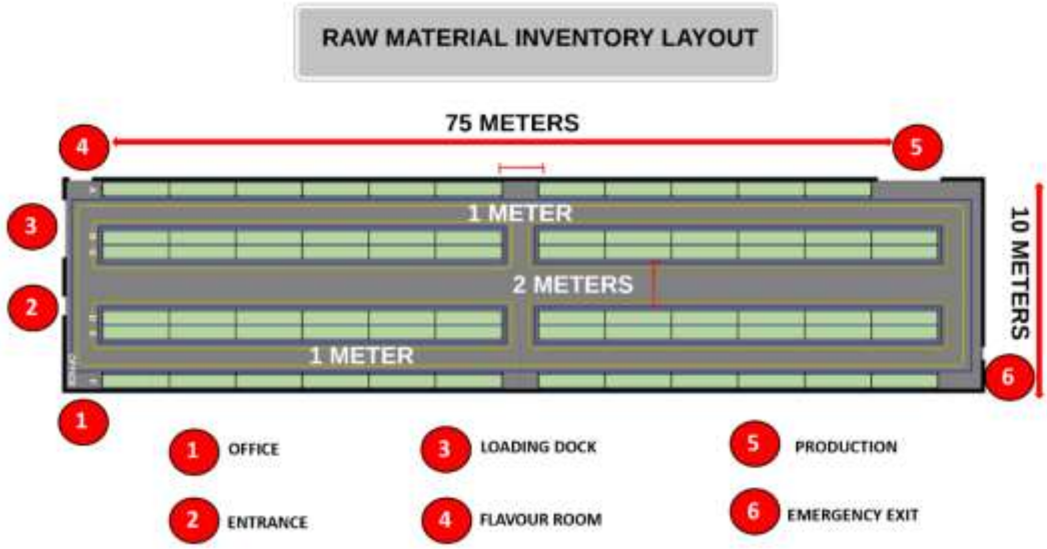


Figure 3-7: Inventory Layout 2

3.3 NUMERICAL DATA

3.3.1 Analysing data and findings

The data of materials was analysed using Microsoft Excel. This was used to help identify the materials stored in the inventory with all parameters, Order Quantities, Lead time and Minimum order quantities of every material.

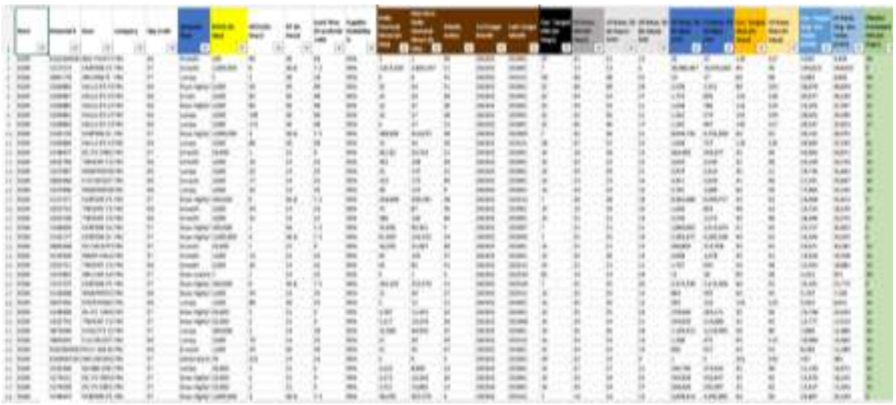


Figure 3-8:Raw materials data

3.3.2 Material classification

The project aim was optimizing the A-class material in the inventory. This is where the ABC-Analysis was used to determine the A-class material. Sugar was the most used material in production So, the project focus will be on the sugar quantities and tracking in the inventory.

ABC analysis is a technique used to prioritize inventory items based on their annual consumption value. The process begins with collecting data on the demand and cost of all raw material items in inventory. Subsequently, the annual consumption value for each item is calculated. Next, all items are ranked from highest to lowest based on their annual consumption percentage. Following this, the cumulative percentage of total consumption is determined for each item. Finally, the items are classified into categories A, B, and C, where category A typically represents 80% of the total consumption, category B represents 15%, and category C represents 5%. This classification helps identify high-value, or A-class, items that require closer monitoring and control.

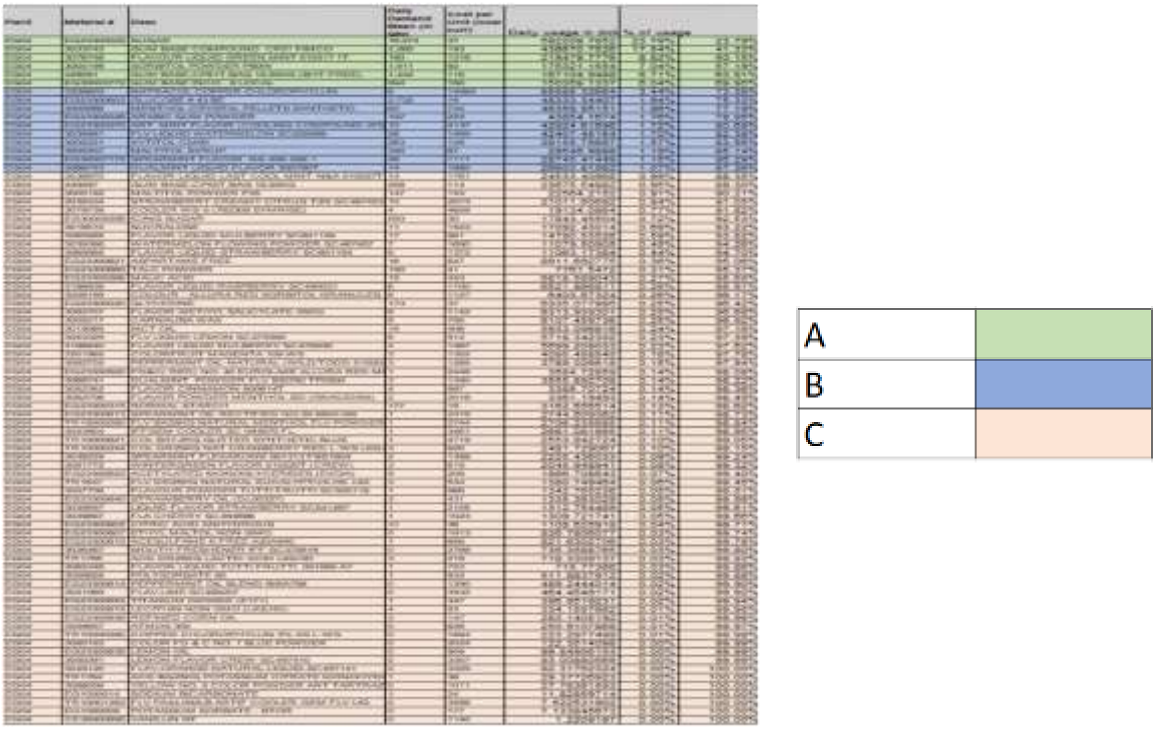


Figure 3-9: ABC data

Chapter Four

4 METHODOLGY

4.1 PROJECT METHODOLOGY

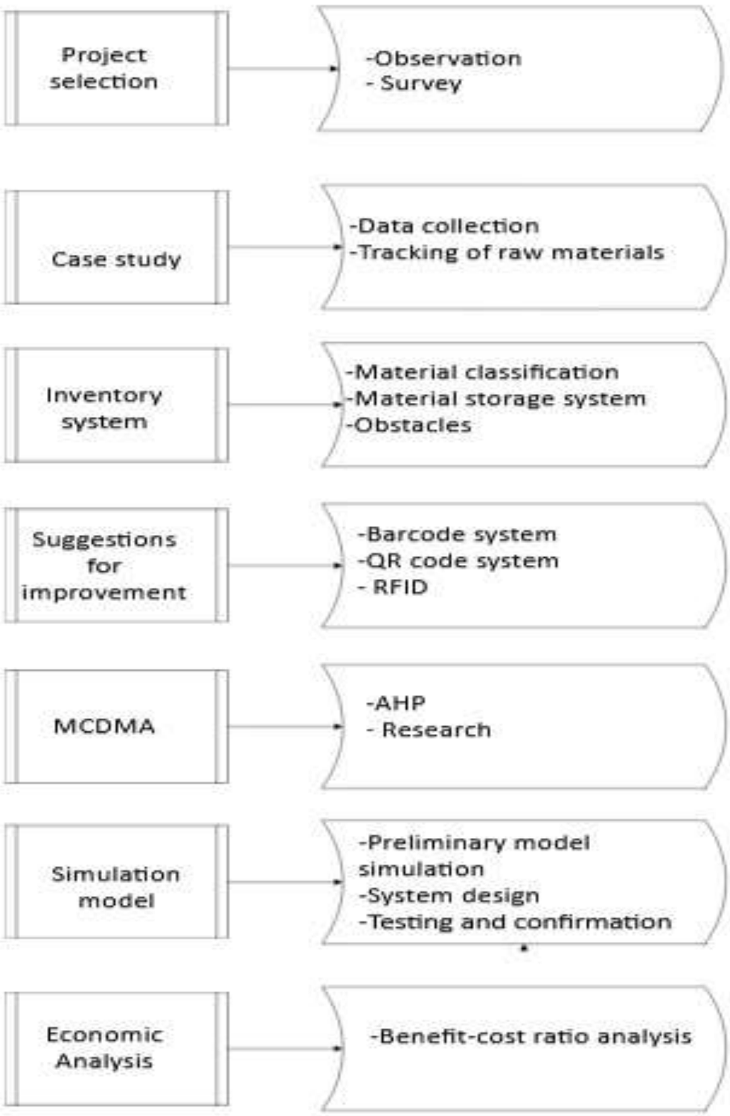


Figure 4-1: Methodology

4.1.1 Company selection

The first step we took in our project was comparing all the options we have in terms of different industries and companies that we could work with. We reached out to multiple companies and then decided to partner with Factory X because we felt that we could help them advance their current inventory system, which is a very important factor in the production planning process.

4.1.2 Case study

We started our work by collecting data about the factory including structural data, inventory data and available projects. We also gathered all available data about their inventory system including the types of raw materials that they use, their ordering system of the materials and quantities which helped us construct and ABC analysis of the most important materials. After that, we performed a root cause analysis using the five why questions and affinity diagram that helped us identify the main problems that they face everyday which led us to decide to help them create an RFID based system that helps them track and locate items in the inventory and can also provide real-time updates on inventory quantities.

Company X was selected as the case study project as explained in chapter three: case study development. The following chapter will further present data collected from Hospital X and identify the proposed system; IoT Monitoring System. The proposed model for selecting the system components is one of the MCDM tools known as AHP, Analytic Hierarchy Process.

4.2 BRIEF SYSTEM METHODOLOGY

The tracking of inventory A-class materials is one of the most important steps to start optimizing quantities of materials in an inventory. Keeping track of these materials quantities, movements inside the inventory and usage rate is not easy as it sounds. So here comes the role of RFID systems and information technology. RFID will be used to track the material’s movement, quantities and holding time (time stored in inventory). RFID systems contain chips, readers and an information technology system. The chips are put into the materials pallets so the reader can detect it wherever and whenever it gets moved in the inventory. This data has to be stored on a database system which is the information technology system so we can keep the history of every material. This process will be tested by a simulation model using Extend Sim software.

4.3 PROJECT IMPACT

Our project’s impact is going to be focused on improving the storage system of inventory items in the facility through optimizing order quantities and the time of orders while also helping the workers locate the pallets quickly to reduce time waste. We will achieve that by changing the current ordering system of A-class raw materials if possible then implementing an RFID system that helps track and auto-update the current inventory levels of materials while also having a locating system inside the storage area. Additional benefits of the system are reducing human error of misplaced palettes and increasing the utilization of already in use racks.

4.4 PROJECT CHALLENGES

The challenges that we faced were trying to monitor the inventory levels that they already have and trying to decide on which type of RFID system would be the most perfect fit for this project. Another obstacle was the fact that they currently don’t have a system for storing the raw materials in specified locations.

4.5 TOOLS

Tool	*Related files*	*Description*
Resource optimization	ABC Analysis	To determine the most used materials in inventory
Rating Methods	MCDMA-AHP	Decision-making rating method that compares alternatives and determines a ranking for each alternative

Discrete Event Simulation	1.ExtendSim 2.Statfit	A simulation program for modelling discrete event, continuous, agent-based, discrete rate, and mixed-mode processes.

Table 2: Tools

4.6 MULTI-CRITERIA DECISION-MAKING ANALYSIS (MCDMA)

We use Multi-Criteria Decision-Making Analysis (MCDMA) to systematically compare at least two alternatives across several conflicting criteria. This approach uses structured methods to combine quantitative and qualitative factors for better, more balanced decisions. Criteria are aggregated using predefined weights by several MCDMA methods, including the quite useful Weighted Sum Model (WSM) as well as the equally important Weighted Product Model (WPM). AHP uses pairwise comparisons to rank alternatives. PROMETHEE along with preference functions also ranks alternatives. The selection of the option closest to the ideal solution is the focus of TOPSIS. ELECTRE eliminates weak alternatives through outranking relationships, whereas Goal Programming minimizes deviations from predefined goals. Data Envelopment Analysis (DEA) compares many inputs along with outputs to assess the efficiency of many decision-making units. These methods help organizations and people identify optimal solutions or zero in on alternatives to handle complicated decision scenarios effectively.

4.7 FUTURE WORK AFTER LITERATURE REVIEW

The project’s future work is to implement IoT monitoring system suitable for inventory tracking.Multi-Criteria Decision-Making Analysis: Analytical Hierarchy Process, AHP model will be used to choose the components of the system. Implementation of the system prototypes to show the system functionality before developing a real model. Simulation model will be used to test the received data from the system. After testing the system for assurance, it will be proposed to the company X and reviewed.

Chapter Five

5 COMPANY X SYSTEM

5.1 INTRODUCTION

This chapter will discuss the IoT system that will be used and identifying the system components and requirements.

5.1.1 IOT MONITORING SYSTEM

An IoT Inventory Monitoring System, integrating RFID Tracking and Inventory Management Systems, revolutionizes warehouse operations by providing real-time visibility into inventory levels, location, and movement. By attaching RFID tags to products, the system enables precise tracking throughout the supply chain. Real-time data collected from RFID readers is transmitted to a central inventory management system, where it is analysed to identify bottlenecks, optimize storage, and improve order fulfilment. This data-driven approach empowers businesses to make informed decisions, reduce labour costs, and minimize stockouts. Additionally, the system can integrate with other IoT technologies, such as sensors and cameras, to monitor environmental conditions and detect anomalies. By leveraging the power of IoT and RFID, businesses can achieve significant improvements in inventory management, leading to increased efficiency, and reduced costs.

5.1.2 RFID (RADIO FREQUENCY IDENTIFICATION) SYSTEM

Radio Frequency Identification (RFID) technology is a wireless communication technology that allows the identification and tracking of objects using radio waves, a cornerstone of modern inventory management, traces its origins to World War II radar systems. In the 1970s, RFID tags were utilized to monitor railway carriages, and by the 1980s, they found applications in toll collection and access control. Today, RFID has evolved into a sophisticated technology, powering diverse industries from supply chain management to retail. Here is a brief literature review of some of the key findings and applications of RFID technology:

1. **Supply Chain Management:**

RFID technology has been widely used in supply chain management to improve inventory management, reduce costs, and increase efficiency. RFID tags can be attached to products, pallets, and containers, allowing them to be tracked and traced throughout the supply chain. This helps to improve visibility and control over the supply chain, leading to better decision making and improved customer satisfaction.

2. **Retail:** RFID technology has been used in the retail industry to improve inventory accuracy, reduce stockouts, and improve customer experience. RFID tags can be attached to products, allowing retailers to track inventory levels in real-time and ensure that they always have the right products in stock. This helps to improve customer satisfaction and increase sales.

3. **Transportation:** RFID technology has been used in transportation to improve logistics, reduce costs, and increase efficiency. RFID tags can be attached to vehicles, containers, and packages, allowing them to be tracked and traced throughout the transportation network. This helps to improve visibility and control over the transportation network, leading to better decision-making and improved customer satisfaction.

Overall, RFID technology has been widely adopted in various industries and has been shown to improve efficiency, reduce costs, and enhance customer satisfaction. As the technology continues to evolve, it is expected to play an increasingly significant role in the digital transformation of numerous sectors.

One notable application of RFID technology is in inventory management. By attaching RFID tags to row materials, businesses can efficiently track their quantity, location, and movement within inventory and supply chains. This leads to improved inventory accuracy, reduced stockouts, and optimized order fulfilment. Additionally, RFID can be used to streamline inventory operations.

5.1.3 RFID READERS

RFID System consists of three main components a reader, antenna, and a tag. In the proposed system, the main function of the RFID system is to track row material flow to identify bottlenecks. One of the main components in the RFID system is the Reader. RFID reader is a device that uses radio frequency signals to communicate with RFID tags. RFID readers have six main components. Radio Frequency Module, Antenna, Control Unit, Power Supply, Housing and Communication Interface. The Radio Frequency Module generates the electromagnetic field that powers the RFID tag and receive the data transmitted. The antenna is used to transmit the signals and receive it from the tag. The control unit manages the communication between the radio frequency module and the device that it is connected to the RFID reader. The power supply provides the power needed to operate the RFID reader. The housing is the outer packaging of the reader that protects it from shocks and external factors. Finally, the communication interface allows the reader to have communication with computer or other devices. There are several types of RFID readers, but the two main types are the active and passive readers. The active RFID reader is compatible with active RFID Tag it has an internal battery that gives a power source to the reader. They have a higher reading range than passive readers. Passive readers have no internal power source and rely on the power from the tag to communicate with. They emit a short-range radio signal. RFID readers can work with both servers and control units depending on the application and the system implementation.

5.1.4 RFID TAGS

Active tags:

Active RFID tags are equipped with an internal power source and transmitter which allows them to provide a constant stream of signal transmission. They provide a longer read distance than their counterparts.

They are commonly used in inventory tracking inside of clothing retail stores to ensure continuous tracking of items.

There are three types of active RFID tags:

1-low frequency RFID: The band ranges from 125KHz to 134 KHz. This provides a very short read range of approximately 10cm and a slow reading speed.

2-High-frequency RFID: The HF band operates between 3MHz and 30MHz. these systems offer a range of 10cm to 1m. They are commonly used in ticketing, payment and data transfer.

3-Ultra high frequency RFID: The UHF frequency band spans from 300MHz to 3GHz. They can achieve a read ranges of up to 12m and offer faster Data transfer rates than the other two types. The most common use of UHF is tracking vehicle movements and controlling access to parking lots and garages, identifying the vehicles automatically.

Passive tags:

Passive RFID tags are the most used types of RFID tags due to their affordability and efficiency in tracking inventory.

Unlike the active tags, they are not equipped with an internal power source, so they need to receive a signal from the reader to provide feedback transmission to relay the information stored on them or provide an update on the current location of the tag.

There are three main types of passive RFID tags:

1- Low frequency: they operate in the range of 30KHz and 300KHz. These tags have a short-read range of only a few inches making them usable in access control applications.

2- High frequency: they operate in the range of 3MHz and 30MHz. They provide a read range of 30cm and are commonly used in contactless payment.

3- Ultra-high frequency: they operate in the range of 300MHz and 3GHz. They provide a more extended read range of 60cm to 1m, and they are commonly used in supply chain management and inventory tracking.

RFID Tags in Raw Material Inventory

RFID technology offers several benefits for managing raw material inventory, including:

1. **Inventory tracking:** RFID tags **enable** real-time monitoring of raw material quantities, improving inventory accuracy and reducing stock discrepancies.
2. **Automated Receiving:** Incoming raw materials can be automatically scanned and recorded into inventory systems without manual data entry, reducing errors and labour costs.
3. **Quality Control and Traceability:**

   RFID allows for tracking of material origin, batch numbers, and handling history, supporting quality assurance and regulatory compliance.
4. **Security and Loss Prevention:**

   Tagged materials can be monitored to prevent unauthorized access, movement, or theft, ensuring better control of valuable raw resources.
5. **Privacy and Security Concerns in Raw Material Inventory:**

   Although RFID technology significantly enhances the efficiency and accuracy of raw material inventory management, it also introduces several privacy and security risks that need careful consideration.

RFID networks are part of larger IT ecosystems and may be exposed to cyber threats like system hacking, unauthorized access, or malware attacks, potentially disrupting operations or compromising inventory data.

To mitigate these risks, companies should implement comprehensive security protocols, including data encryption, restricted access, and routine security assessments. Following best practices in cybersecurity and maintaining compliance with applicable data protection regulations is crucial for secure RFID deployment in raw material inventory systems.

5.1.5 ANTENNA

In an RFID system, the antenna is crucial for wireless communication between the reader and the tags. Its primary function is to transmit radio frequency (rf) signals generated by the reader, creating an electromagnetic field that energizes passive tags within its range. This field allows the tags to harvest power and transmit their stored data back to the reader. The antenna also acts as a receiver, capturing the backscattered signals from the tags and relaying this information to the reader for processing.

5.2 MIDDLEWARE PROCCESSING

The process of scanning RFID tags can sometimes have errors such as duplication which if not managed properly leads to inefficiencies in the inventory levels which can be a costly mistake.

To avoid these mistakes, we can use Middleware processing. It is a software that receives the data from the tags and ensures that the data received is accurate doesn’t contain any duplicate data.

Chapter Six

6 MULTI CRITERIA DECISION-MAKING MODEL

6.1 INTRODUCTION

Analytic Hierarchy Process (AHP) is a framework which we present as a method for decision making in complex issues. AHP models put forth a structure for which to solve large scale problems. With AHP model's decision makers are also able to look at and rank which among many options performs the best in terms of a set of criteria which they identify and put in order by importance. Also used in a variety of sectors like engineering and finance in which large decisions are made of many variables. In using AHP model's decision makers can systemically evaluate each option out which they can then determine the best action that which in turn fulfills their goals. What AHP does is that it puts into play more informed, data-based decision which considers a very wide range of variables and in end produces better results.

6.2 BENEFITS OF AHP

There are several benefits of AHP models as:

- It eliminates biased options (personal biased) by assessing alternatives based on the same criteria which ensures balanced outcomes.

- Most importantly, sensitivity testing. AHP allows user to model the "What-if" scenarios by re-adjusting the weights.

- AHP assigns priority scores for each alternative which helps in allocating resources based on importance.

6.3 MCDMA FRAMEWORK

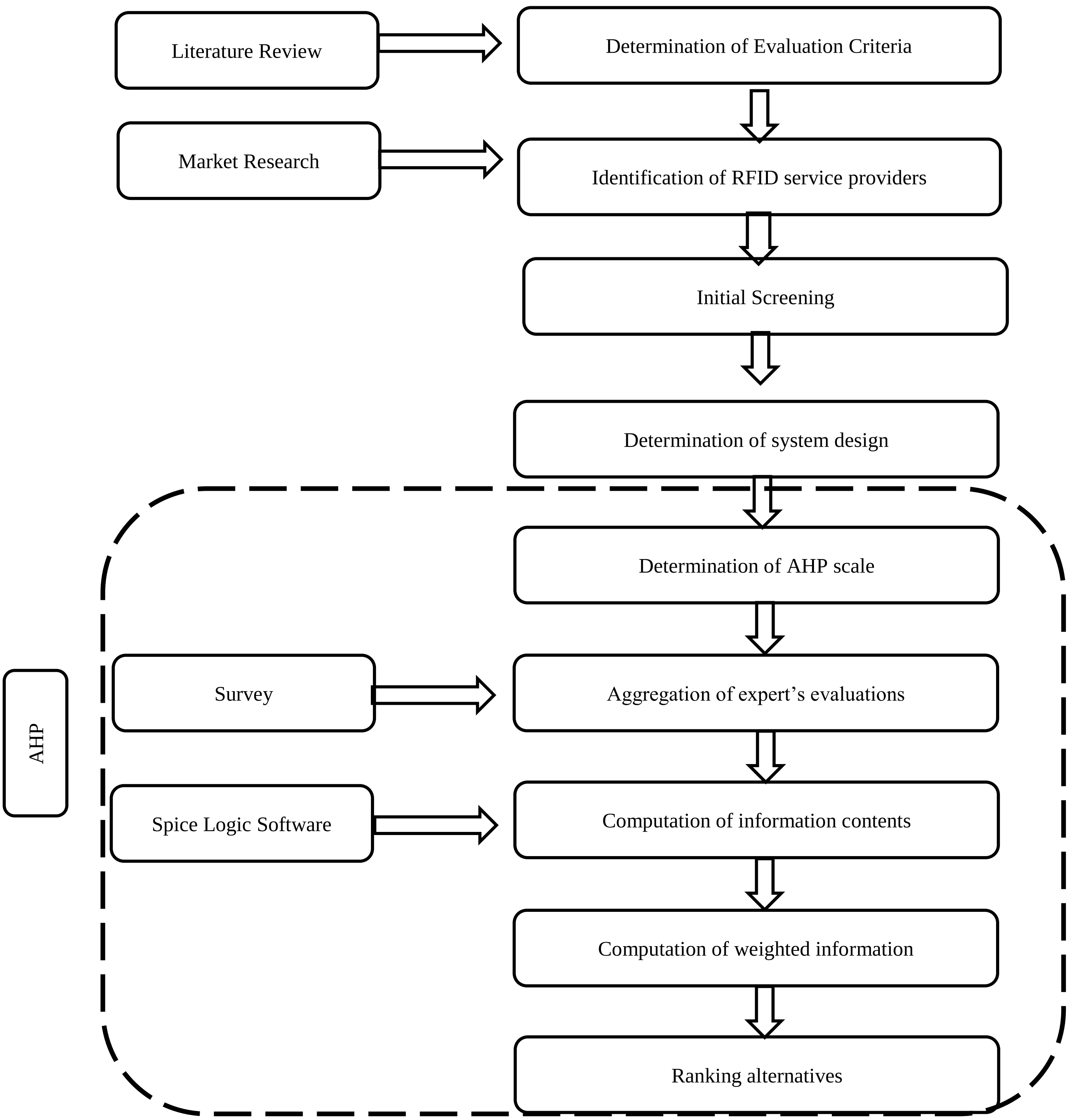


Figure 6-0-1MCDMA

Evaluation criteria are identified as the key functional requirements that characterize each proposed RFID system. These criteria serve as the foundation for comparing and analysing the alternative systems. To establish a well-rounded set of evaluation metrics, a thorough literature review was carried out, drawing from academic sources and industry case studies. In addition, insights from professionals with hands-on experience in RFID implementation were incorporated to ensure practical relevance. The resulting criteria, presented in the following table.

Criteria	**Description**
Price	Price refers to the cost of implementing the RFID-system, including cost of readers, tags, cables, Backend/middleware software
Data Capacity	This criterion addresses how much data an RFID tag can store.
Range	The maximum distance that the RFID tag can send and receive signals with the reader. It varies from which type of RFID is being used, Active or passive.
Transmission Speed	It indicates how fast is the data being exchanged between the tag and the reader.
Ease of integration	It measures how easy the RFID system can be implemented into the existing systems and components.
Infrastructure	The necessary hardware and network components required to implement the system.

Supplier	System providers are also to be evaluated criteria as lead times, Location, spare parts availability

Table 3 MCDMA Criteria

6.4 IDENTIFICATION OF RFID SERVICE PROVIDER

After evaluating different criteria needed for component selection, thorough market research was conducted to determine the available vendors. Different vendors are presented in the following table.

Vendors	Compatible with SAP	Location	Lead time	References
Future Electronics Egypt	Yes	Egypt	1-2 weeks	https://store.fut-electronics.com/collections/rfid
Micro ohm electronics	Yes	Egypt	1-2 weeks	Micro Ohm Electronics
RFID label	Yes	China	2 weeks	https://www.rfidlabel.com/product/desktop-hf-iso-15693-rfid-reader-az-rl173/
The RFID store	Yes	Spain	-	https://therfidstore.eu/e/

Gao RFID	Yes	USA-CANADA	-	https://centrak.com/
Centrak	No	Belgium	4-5 weeks	https://centrak.com/
Rhydo labs	No	India	1-2 weeks	https://www.impinj.com/products/readers?
Amazon	No	China	2-3 weeks	Yanzeo UHF RFID Reader on Amazon
Shenzhen Yuannuode Communication	YES	China	1 month	1.6 Meter 7dBi Long Range UHF RFID Antenna on Alibaba
Guangzhou Tenhanyun Technology	Yes	China	15 days	30dBm UHF RFID Reader with RS232/RS485/RJ45 Interface on Alibaba

Table 4 Suppliers

6.5 INITIAL SCREENING

Prior to the AHP model formulation, results obtained needed to be filtered according to appropriate criteria to facilitate the process of selection. The following figure shows the initial screening process of evaluation criteria and vendors.

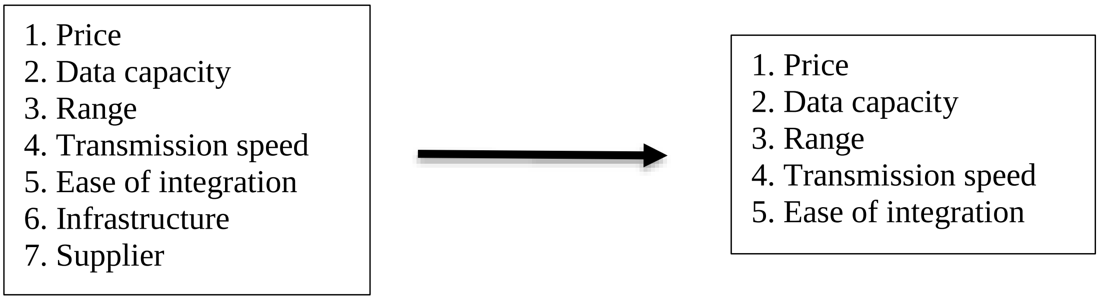


Figure 6-0-1 Intial screening

Criteria such as infrastructure and supplier were eliminated. System compatibility with SAP is an essential functional requirement and is used to filter vendors and system providers. All selected vendors need to provide a system compatible with the desired inventory information system as it is necessary to be able to integrate the RFID system to the SAP system. High frequency systems have long transmission distance and speed, and vice versa. The frequency criteria alone is not a comparative measure to assess different alternative vendors.

6.6 EVALUATION CRITERIA INITIAL SCREENING

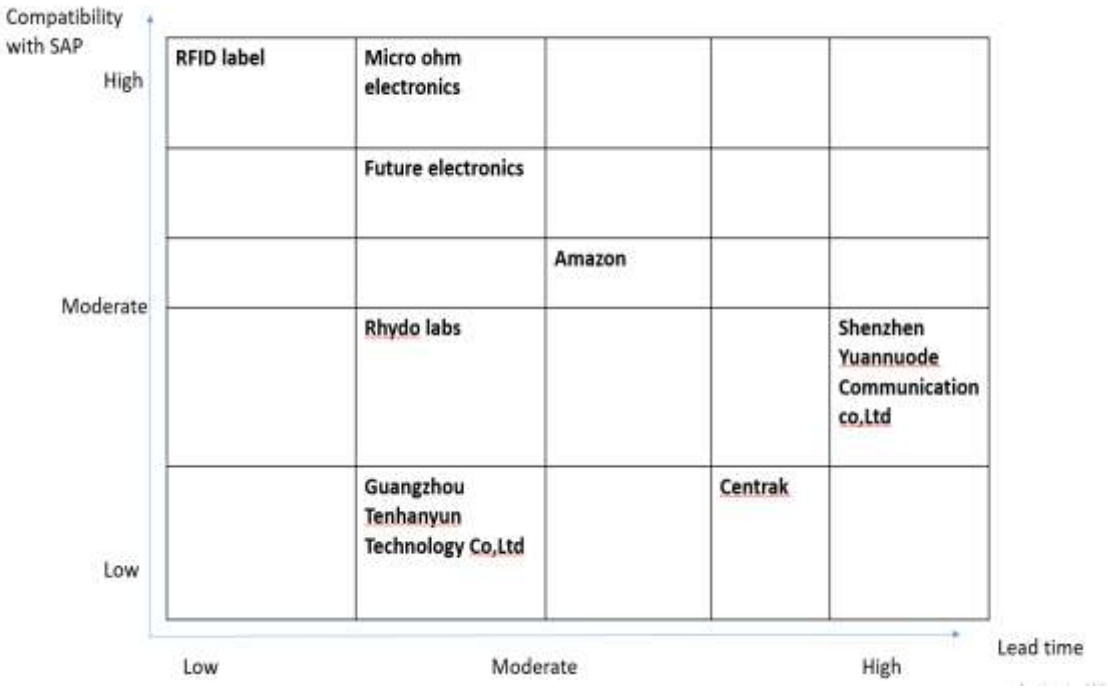


Figure 6-0-2

Figure 6-3 presents the vendors' initial screening results. Low lead times were preferred over high ones, as faster service enhances both the effectiveness and reliability of the implementation process. Additionally, system compatibility with SAP and the availability of integration-related data were key filtering factors in the selection process. The vendor evaluation matrix illustrates the positioning of several RFID components suppliers based on these two primary criteria: lead time and SAP system compatibility. Vendors located in the upper-left quadrant of the matrix, such as RFID Label and Micro Ohm Electronics, offer both high compatibility with SAP and short lead times, making them strong candidates for seamless ERP integration and efficient rollout. Future Electronics and Amazon are positioned in the moderate range for both criteria, indicating acceptable options that may still require additional considerations for scheduling or integration. In contrast, vendors like Shenzhen Yuannuo Communication Co., Ltd. and Centrak are associated with longer delivery times, which could lead to potential delays in implementation. Guangzhou Tenhanyun Technology Co., Ltd., with both low SAP compatibility and high lead time, ranks as the least suitable among the options considered. Based on this screening, RFID Label stands out as the most appropriate vendor, offering the best balance between technical integration capabilities and procurement efficiency.

6.7 INTERVIEW DESIGN

This section outlines the development of an interview-based checklist created to collect essential data for implementing an RFID system in raw material inventory management. Rather than distributing a standard questionnaire, interviews were conducted with key personnel to gain a deeper understanding of the current inventory tracking processes, operational challenges, and the organization's readiness for adopting RFID technology. The interviews focused on several critical areas, including awareness of RFID systems, existing technical and environmental conditions, staff involvement, infrastructure compatibility, and concerns related to cost, maintenance, and training. By using a guided, face-to-face discussion format with stakeholders at Factory X, the collected insights were more detailed, specific, and reflective of real operational needs. This approach ensured that the proposed RFID solution would be both technically feasible and practically aligned with day-to-day inventory operations, supporting improvements in accuracy, efficiency, and search time reduction. The result of these interviews is summarized in the following checklist:

1. **What method is currently used for tracking raw materials?**

   ☐ Manual (Paper-based) ☐ Barcode System ☐ ERP System ☐ Other

2. **What are the key challenges faced in the current inventory process?**

   ☐ Difficulty locating raw materials ☐ Inaccurate inventory records ☐ Loss or misplacement of items ☐ Lack of real-time visibility

3. **Are you familiar with RFID technology and its applications?**

   ☐ Yes ☐ Somewhat ☐ No

4. **How effective could RFID be in addressing current inventory issues? (1 = Not effective, 5 = Very effective)**

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

5. **Have you ever used or participated in an RFID-enabled system before?**

☐ Yes ☐ No

6. **Are materials stored in conditions that could interfere with RFID signals (e.g., metal containers, liquid substances)?**

☐ Yes ☐ No

7. **How important is real-time location tracking of pallets?**

☐ Not important ☐ Slightly important ☐ Moderately important ☐ Very important ☐ Critical

8. **What factors would influence the adoption of RFID technology?**

☐ Cost ☐ System compatibility ☐ Staff training ☐ Maintenance requirements

9. **What concerns do you have regarding the use of RFID in inventory?**

☐ Privacy/security ☐ Interference with other systems ☐ Training and adoption by staff ☐ Maintenance and reliability ☐ Initial investment cost

10. **Does your facility have a reliable internet or network connection to support RFID readers?**

☐ Yes ☐ No ☐ Partially

6.8AHP SOFTWARE

6.8.1 SPICE LOGIC ANALYTIC HIERARCHY PROCESS

The Analytic Hierarchy Process (AHP) method was applied using the Spice Logic software to support the selection of the most suitable RFID tag. The goal was clearly defined, relevant criteria were identified—such as read range, durability, material compatibility, and cost—and suitable tag alternatives were listed to form the evaluation structure.

6.8.2 MODEL DEVELOPMENT

Pairwise comparisons were conducted between the criteria to assign appropriate weights reflecting their importance. Each RFID tag alternative was then evaluated against all criteria to determine overall performance and compatibility. In the evaluation process, a pairwise comparison method was used to systematically determine the relative importance of each criterion. This allowed for a detailed, two-at-a-time assessment that clarified preferences and ensured accuracy. The process was repeated across all criteria to derive consistent and objective weightings for the decision-making model.

6.8.3 ANALYSIS AND RESULTS:

Five criteria were chosen to evaluate the RFID tags: Cost, Range, Data Capacity, Ease of Integration, and Speed. These criteria were selected based on practical considerations in RFID system design and deployment. Using pairwise comparisons, we evaluated the relative importance of each criterion.

The resulting priority weights were:

- Cost: 0.388
- Speed: 0.261
- Range: 0.192
- Ease of Integration: 0.104
- Data Capacity: 0.054

This distribution indicates that Cost is the most significant consideration, with nearly 39% of the total weight. Speed and Range follow, suggesting that performance in real-time and communication distance are also important. Ease of Integration and Data Capacity received lower weights, suggesting they are less critical for the application under study.

The Consistency Ratio of the pairwise comparisons was calculated to be 0.092, which is under the acceptable threshold of 0.10. This confirms that the judgment matrix was logically consistent and reliable.

Priority Trade-offs

	Cost	Range	Data Capacity	Ease of integration	Speed	Priorities
Cost	1	2	4	4	3	0.388
Range	0.5	1	4	3	0.5	0.192
Data Capacity	0.25	0.25	1	0.25	0.2	0.054
Ease of integration	0.25	0.333	4	1	0.25	0.104
Speed	0.333	2	5	4	1	0.261

* Consistency Ratio calculated as 0.092

Table 5 AHP trade-offs

After determining the weight of each criterion, a pairwise comparison was also performed for the

Active and Passive RFID tags against each criterion.

Under the Cost criterion, Passive RFID tags were strongly preferred, with a priority of 0.833, compared to 0.167 for Active tags. This aligns with the common understanding that Passive tags are significantly cheaper to produce and deploy.

Regarding Range, Passive tags again scored higher (0.667) than Active tags (0.333). While Active tags generally offer longer range, in this context, Passive tags were sufficient and more efficient per unit cost and application scope.

For Data Capacity, Passive tags held a priority of 0.800 versus 0.200 for Active. Though Active tags often have more storage, this suggests that the required application did not demand high data capacity, and Passive tags were seen as more adequate.

Ease of Integration favoured Passive tags substantially (0.875 versus 0.125), indicating they are generally easier to implement within existing systems due to simpler power and communication requirements.

The only criterion where Active tags dominated was Speed, achieving a priority score of 0.857 compared to 0.143 for Passive tags. This result highlights that Active tags transmit data faster and more consistently due to their powered nature.

	Active	*Passive*	*Priorities*
Cost(0.388)			
Active	1	0.2	0.167
Passive	5	1	0.833
Speed(0.261)			
Active	1	6	0.857
Passive	0.167	1	0.143
Range(0.192)			
Active	1	0.5	0.33
Passive	2	1	0.667
Ease Of Integration(0.104)			
Active	1	0.143	0.125
Passive	7	1	0.875
Data Capcity(0.054)			
Active	1	0.25	0.2
Passive	4	1	0.8

Table 6 Active VS Passive AHP

To determine the most suitable RFID tag, a multi-criteria utility model was used to combine the performance of each option across all five evaluation criteria. Each criterion was assigned a weight based on its relative importance, and the performance scores of the

Active and Passive RFID tags under each criterion were incorporated into a single aggregated score using the following utility function:

Utility Score = 0.39 × (Cost) + 0.19 × (Range) + 0.05 × (Data Capacity) + 0.10 × (Ease of Integration) + 0.26 × (Speed)

By applying this function to the priority values obtained from the pairwise comparisons, the final utility scores were calculated as follows:

- Passive RFID Tag:0.623
- Active RFID Tag: 0.377

These results clearly indicate that the Passive RFID tag offers a better overall balance across the evaluation criteria. It significantly outperforms the Active tag in terms of cost-effectiveness, ease of integration, and acceptable performance in range and data capacity. While the Active tag does have an edge in speed, this advantage is not sufficient to compensate for its weaknesses in other critical areas.

Thus, the analysis supports the selection of the Passive RFID tag as the most appropriate solution. The use of the AHP-based utility model ensures that the decision is both systematic and aligned with the practical priorities of the intended application.

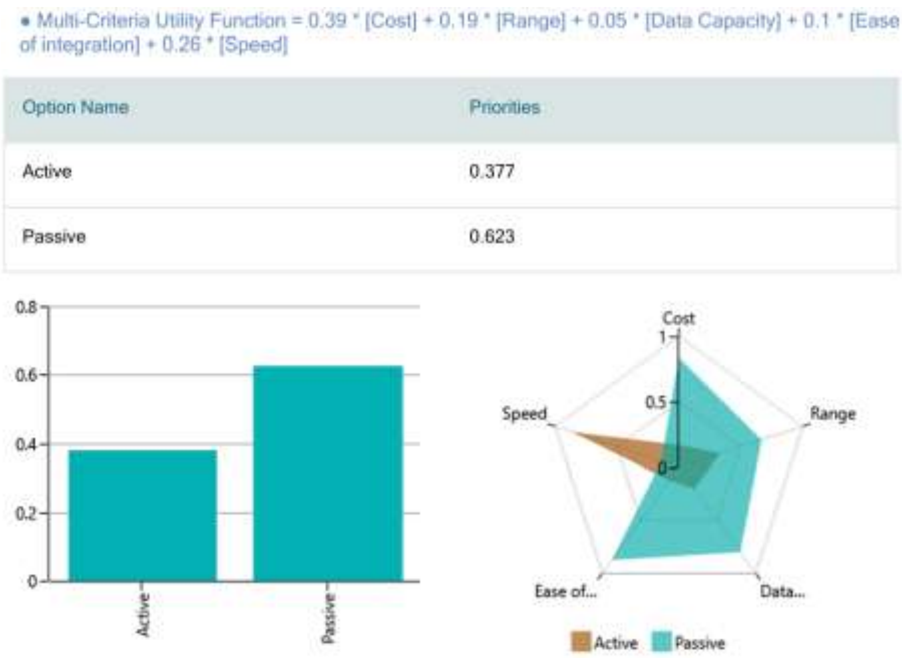


Figure 6-0-3

Stacked bar chart effectively illustrates how each criterion (Cost, Range, Data Capacity, Ease of Integration, and Speed) contributes to the total weighted score of both the 'Active' and 'Passive' alternatives. The height of each coloured segment within the bars directly reflects the weighted score derived from the pairwise comparisons for that specific attribute.

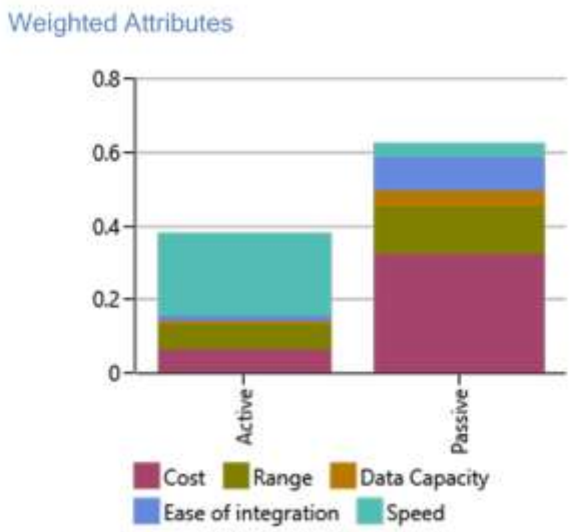


Figure 6-0-4 Attributes

6.8.4 Sensitivity Analysis

To evaluate the robustness of the decision-making results, a one-way sensitivity analysis was conducted. This type of analysis involves varying the weight of one criterion at a time while keeping the weights of all other criteria constant or adjusting them proportionally to maintain the total weight . The purpose is to assess how sensitive the final rankings of the alternatives are to changes in individual criterion weights. In this analysis, each criterion's weight was incrementally varied across a defined range (e.g., from 0.1 to 0.9), and the MCDM method was reapplied. The Cost criterion, which had the highest original weight, was selected first for the sensitivity analysis. Its weight was systematically varied while the remaining criteria were adjusted proportionally. The goal was to observe how changes in the importance of cost would impact the final ranking of the alternatives

1. The influence of the cost criterion on the selection of Active vs. Passive tags. Since cost held the highest weight (0.388), even slight changes could affect the final outcome.
2. The trade-off between Cost and Speed—the two most weighted criteria. Adjusting the importance between them would reveal how sensitive the outcome is to the decision-maker’s priorities.

Before applying the one-way sensitivity analysis, the decision model evaluated the alternatives based on the original criterion weights. The Cost criterion held the highest importance, as reflected in the evaluation interface. In this initial state, the system showed a clear preference for the Passive alternative over the Active one, with a current Active/Passive ratio of 1:5. The decision change sensitivity was indicated as 36.25%, meaning that a moderate shift in the weight of the cost criterion could significantly influence the overall decision. These baseline results provided a reference point for assessing how adjustments to the cost weight would affect the final ranking of alternatives.

Figure 6-0-5 Sensitivity analysis

6.8.5 Scenario 1

After adjusting the weight of the Cost criterion in the one-way sensitivity analysis, the importance of cost was set to a level where both Active and Passive alternatives were evaluated as equally important. This adjustment led to a significant shift in the decision outcome, with the Active/Passive ratio changing from 1:5 to 1:1, indicating that both options became equally preferred under the new weighting. The decision change sensitivity increased to 78.75%, demonstrating that the final decision is highly sensitive to the weight assigned to cost. This result highlights the critical role that cost plays in influencing the overall ranking and confirms the importance of carefully assigning weights to this criterion during the decision-making process.

The sensitivity analysis results also included a detailed breakdown of the most influential variables affecting the decision outcome. These were displayed in the "Sensitive Variables" panel, where each variable was associated with a green percentage. These percentages represent the degree of impact that each criterion or pairwise comparison has on the final ranking of the alternatives. A higher percentage indicates that a small change in that variable can lead to a significant shift in the decision result. For example, the criterion "Speed" showed an impact of 86%, meaning that altering the comparison of speed between the Active and Passive alternatives

would strongly affect the overall preference. Similarly, "Cost" and "Range" also demonstrated high sensitivity, with impact levels of 79%, signifying their critical role in shaping the outcome. These findings highlight which criteria are most influential in the decision-making process and are therefore essential focal points in the sensitivity analysis. In contrast, variables with lower percentages were considered less impactful, as changes in their values would not substantially alter the decision. This analysis helps validate the robustness of the chosen alternative and guides future adjustments or prioritizations in the evaluation model.

Figure 6-0-6 Scenario 1

6.8.6 Scenario 2

The second adjustment in the sensitivity analysis centres on the "Cost" criterion, where the evaluation between the "Active" and "Passive" options has been updated. In the matrix view, Active is now given a value of 2, indicating weak importance over Passive, which is rated as 1. This adjustment means that, in terms of cost, the Active option is perceived as more favourable, though only slightly. The accompanying bar chart visually reinforces this distinction, showing that Active has a notably higher score for cost compared to Passive. This shift in evaluation reflects a scenario where cost considerations now modestly favour the Active option.

The Sensitivity Analyzer provides a detailed breakdown of how sensitive the decision is to each variable. After the adjustment, "Cost" emerges as the most sensitive variable, with a sensitivity index of 79%. This means the overall decision is highly responsive to changes in the cost evaluation between Active and Passive. The next most sensitive criteria are "Range" (71%) and "Speed" (69%), both of which still play significant roles in influencing the outcome. Other variables, such as the relative weightings between range and speed (34%), ease of integration (31%), and data capacity (26%), show much lower sensitivity indices. This indicates that the decision is less likely to be affected by changes in these factors, and thus, the model is relatively robust to their variation. Small changes in the cost evaluation will not affect your decision. Only a very large change in how you compare costs between Active and Passive (almost 79%) would make you choose Passive instead of Active.

Figure 6-0-7 Scenario 2

6.8.7 Scenario 3

The third adjustment in the sensitivity analysis centres on the "Active/Passive Ratio" criterion, where the evaluation between the Active and Passive options has been updated. In the matrix view for Cost, Active is now given a value of 3, indicating moderate importance over Passive, which is rated as 1. This adjustment means that, in terms of cost-related benefits, the Active option is perceived as more favourable. The accompanying bar chart visually reinforces this distinction, showing that Active has a notably higher score for cost compared to Passive. This shift in evaluation reflects a scenario where cost considerations now clearly favour the "Active" option.

The Sensitivity Analyzer provides a detailed breakdown of how sensitive the decision is to each variable. After this adjustment, "Cost" emerges as the most sensitive variable, with a sensitivity index of 69%. This means the overall decision is significantly responsive to changes in the cost evaluation between "Active" and "Passive." The next most sensitive criteria are "Speed" (48%), "Ease of integration" (15%), and "Data Capacity" (8%), all of which play significantly lesser roles in influencing the outcome compared to cost.

Figure 6-0-8 Scenario 3

6.8.8 Scenario 4

The fourth adjustment shows a strong preference for the Active option, mainly because of how much better it performs on Cost. Cost is now considered extremely important. The current "Active/Passive Ratio" is 9 to 1, meaning Active is far more beneficial. This makes Active very stable as the chosen option; it would take a huge change for Passive to become better. While the decision is 50% sensitive to the ratio, Active is currently so far ahead that it's unlikely to switch. Most other factors don't affect the decision much, with only Cost and Speed still showing some sensitivity.

Figure 6-0-9 Scenario 4

6.8.9 Sensitivity Analysis Conclusion

The sensitivity analysis was conducted to examine how changes in the evaluation of the Cost criterion affect the final decision, as Cost had the highest weight in the original AHP model. Initially, Passive RFID was the preferred alternative. Four scenarios were developed, progressively increasing the cost advantage of the Active RFID option. In Scenario 1, where cost was evaluated equally for both options, the decision shifted to a neutral preference (Active = Passive), demonstrating high sensitivity. In Scenario 2, where Active was slightly favored in cost, Passive was still selected, but the decision remained highly sensitive to further changes. By Scenario 3, with a moderate cost advantage, Active became the preferred option, although the model still showed some sensitivity. Finally, in Scenario 4, where Active was strongly favored (cost ratio 9:1), the decision clearly supported Active, and the model showed increased stability — meaning a large change would be required to reverse the outcome. These results confirm that the final decision is heavily influenced by how cost is evaluated, and careful attention must be paid to cost estimations during the decision-making process.

6.9 SYSTEM DETAILS

This chapter shifts focus to the Real System, moving beyond the conceptual and prototype stages to delve into the proposed full-scale implementation. This section will elaborate on the comprehensive design and operational framework intended for practical application, detailing how the system's structure and component integration are configured to meet the demands of a real-world operational setting. The aim is to provide a clear understanding of the final system's capabilities, its functional specifications, and the anticipated impact on operational efficiency and inventory management.

There are two distinct design proposals for the system. The first design (System 1) aims for comprehensive optimization of the system, focusing on maximizing efficiency and performance across all functionalities. The second design (System 2) serves as an alternative suggestion, offering a similar approach without aiming for the full scope of optimization present in the primary design.

6.9.1 SYSTEM 1

For achieving maximum accuracy in inventory management is to install an RFID reader in each of the 520 storage cells, along with additional readers ranges of 2 m at the entrance and exit of the facility. This setup mirrors the prototype previously tested and offers a comprehensive, real-time tracking system. By allowing instant identification and location of multiple items, it eliminates delays and reduces manual effort. As a result, the system greatly improves worker productivity, minimizes errors, and ensures a highly efficient and accurate storage operation. To implement this solution, the following components are required, along with their corresponding prices:

SYSTEM			
Tools	Q.	Price	Total
ESP32 Development Board (WIFI and Bluetooth) 30-Pin with CP2102	522	EGP 400.00	EGP 208,800.00
18650 Battery Holder 2-Slot	520	EGP 25.00	EGP 13,000.00
18650 Battery Holder 3-Slot	2	EGP 20.00	EGP 40.00
PCB Board Fiberglass FR4 20*20	135	EGP 95.00	EGP 12,825.00
Beston Rechargeable 18650 Li-ion Battery 3000mAh	1564	EGP 175.00	EGP 273,700.00
Plastic Project Box Waterproof F2 158x90x60mm IP65	520	EGP 275.00	EGP 143,000.00
Waterproof Project Box 200mmx120mmx55mm	2	EGP 275.00	EGP 550.00
Pin Headers Female 2.54mm : 40-Pin, Straight	1044	EGP 6.00	EGP 6,264.00
Pin Headers Male 2.54mm : 40-Pin, Straight	522	EGP 6.00	EGP 3,132.00
Mini Rocker Switch ON-OFF 6A/250VAC KCD1-104 4Pin	522	EGP 10.00	EGP 5,220.00
LM2596HVS DC-DC Buck converter 3A Step Down Module	522	EGP 70.00	EGP 36,540.00
Battery Charger 18650 2 Cell MD-202A	177	EGP 50.00	EGP 8,850.00
Red Metal LED 12V	522	EGP 22.00	EGP 11,484.00
USB DC-DC Step Down Converter Module 6-20V to 5V 3A	2	EGP 70.00	EGP 140.00
MAX3232 Module RS232 to TTL Converter Adaptor Board	2	EGP 20.00	EGP 40.00
LM2596HVS DC-DC Buck converter 3A Step Down Module	522	EGP 70.00	EGP 36,540.00
Copper Spacer F/F M3*6mm	5220	EGP 2.75	EGP 14,355.00
LED Strips Connecting Cable 6 Wire 28AWG 1 meter	522	EGP 13.50	EGP 7,047.00
4 Channels IIC I2C Logic Level Converter Bi-Directional Module 3.3V to 5V Shifter	522	EGP 94.00	EGP 49,068.00
UHF RFID Sticker (Long Range) 73.5x21.2mm	1056	EGP 6.00	EGP 6,336.00
Reader (2 meter)	2	EGP 5,450.00	EGP 10,900.00
Reader(30cm)	520	EGP 790.00	EGP 410,800.00
Micro USB Data Cable	1	EGP 35.00	EGP 35.00
		total	EGP 1,258,666.00

Table 7 System 1

6.9.2 SYSTEM 2

The second design proposes a cost-effective alternative by placing a single RFID reader 3 meters in the middle of each rack instead of installing one in every storage cell, along with additional readers range of 2 m at the entrance and exit of the inventory. This significantly reduces the total number of readers required while still aiming to provide efficient inventory tracking. However, this approach may result in reduced accuracy, as overlapping signals could occur when items are read from moving forklifts or from the front side of the rack. Despite this limitation, the issue can potentially be resolved through software algorithms that continuously monitor and filter the data, automatically eliminating duplicate or repeated readings to maintain reliable tracking.

SYSTEM 2			
Tools	Q.	Price	Total
ESP32 Development Board (WIFI and Bluetooth) 30-Pin with CP2102	24	EGP 400.00	EGP 9,600.00
18650 Battery Holder 2-Slot	24	EGP 25.00	EGP 600.00
18650 Battery Holder 3-Slot	0	EGP 20.00	EGP 0.00
PCB Board Fiberglass FR4 20*20	6	EGP 95.00	EGP 570.00
Beston Rechargeable 18650 Li-ion Battery 3000mAh	48	EGP 175.00	EGP 8,400.00
Plastic Project Box Waterproof F2 158x90x60mm IP65	24	EGP 550.00	EGP 13,200.00
Waterproof Project Box 200mmx120mmx55mm	2	EGP 275.00	EGP 550.00
Pin Headers Female 2.54mm : 40-Pin, Straight	48	EGP 6.00	EGP 288.00
Pin Headers Male 2.54mm : 40-Pin, Straight	24	EGP 6.00	EGP 144.00
Mini Rocker Switch ON-OFF 6A/250VAC KCD1-104 4Pin	24	EGP 10.00	EGP 240.00
LM2596HVS DC-DC Buck converter 3A Step Down Module	24	EGP 70.00	EGP 1,680.00
Battery Charger 18650 2 Cell MD-202A	40	EGP 50.00	EGP 2,000.00
Red Metal LED 12V	24	EGP 22.00	EGP 528.00
USB DC-DC Step Down Converter Module 6-20V to 5V 3A	24	EGP 70.00	EGP 1,680.00
MAX3232 Module RS232 to TTL Converter Adaptor Board	24	EGP 20.00	EGP 480.00
LM2596HVS DC-DC Buck converter 3A Step Down Module	24	EGP 70.00	EGP 1,680.00
Copper Spacer F/F M3*6mm	240	EGP 2.75	EGP 660.00
LED Strips Connecting Cable 6 Wire 28AWG 1 meter	24	EGP 13.50	EGP 324.00
4 Channels IIC I2C Logic Level Converter Bi-Directional Module 3.3V to 5V Shifter	24	EGP 94.00	EGP 2,256.00
UHF RFID Sticker (Long Range) 73.5x21.2mm	1056	EGP 6.00	EGP 6,336.00
Reader (2 meter) TCP IP/RS232/485/WG/Relay	24	EGP 4,000.00	EGP 96,000.00
Micro USB Data Cable	1	EGP 35.00	EGP 35.00
		total	EGP 147,251.00

Table 8 System 2

The two proposed RFID system designs differ significantly in their structure, coverage, and implementation cost. System 1 adopts a high-precision approach by placing a reader in each of the 520 storage cells, along with readers at the entrance and exit. This design uses short-range RFID readers to ensure pinpoint accuracy and avoid signal interference, making it highly effective for real-time, detailed inventory tracking. However, this accuracy comes at a high cost, with a total implementation price of 1,125,666 EGP due to the large number of readers required.

In contrast, System 2 reduces the number of readers by installing a single, long-range reader in the center of each rack. This setup significantly lowers hardware costs, with a total estimated cost of 147,251 EGP. While this system is more budget-friendly, it sacrifices some tracking precision, as the broader reading range may cause signal overlap or duplicate scans especially from nearby racks or moving forklifts. These inaccuracies, however, can be mitigated through software that filters and validates data in real time. Overall, System 1 offers maximum accuracy at a higher cost, while System 2 provides a more affordable solution with acceptable trade-offs in precision.

C h a p t e r S e v e n

7 PROTOTYPE

7.1 INTRODUCTION

The prototype was created with the goal of improving raw material inventory management through increased accuracy, decreased manual error, and real-time updates for improved inventory control. Integrated data for simple monitoring and analysis, real-time inventory status updates, and automatic raw material tracking are some of the key features. These features collectively aim to streamline inventory operations, minimize discrepancies, and support timely decision-making in the supply chain.

7.2 PROTOTYPE DEFINITION AND AIM

The prototype is a functional model developed to accurately track the real-time location of raw material pallets within the inventory storage area. Its primary purpose is to identify not only whether a pallet is in stock but also to determine its exact position—specifically, which rack it is stored in. This level of precision addresses a critical challenge in inventory management: the difficulty of locating specific materials quickly and reliably. By introducing an automated approach that minimizes the need for manual searches and lowers the possibility of misplaced or mistaken goods, the prototype seeks to increase the visibility and traceability of raw materials. Utilizing location tracking technology, the system makes sure that every pallet can be quickly identified and located, increasing overall productivity, cutting down on wasted time, and promoting improved warehouse organization and inventory accuracy.

7.3 DATA COLLECTION

To evaluate the effectiveness of the prototype, data collection focused on measuring the time required to complete key inventory processes before and after implementation. Several times trials With collaboration with the Industrial Service Complex at the AASTMT main campus branch, To evaluate the effectiveness of our prototype, we implemented our prototype and tested it to place palettes and record the exact time of placing on the rack using Things Board software shown in figure 7-1 that is connected to the RFID system

Figure 7-1 Prototype

The next step was downloading the data collected from software to an excel file that shows the RFID tag number and time of placement shown in tables below

Timestamp	Rfid 1
2025-06-29 13:13:19	4900EF2DE1
2025-06-29 13:18:13	011535CC1F
2025-06-29 13:18:28	011535CC1F
2025-06-29 13:19:39	011535D040
2025-06-29 13:23:52	4900EF2DF2
2025-06-29 13:26:58	4900EF246D
2025-06-29 13:33:30	4900EF2E1E
2025-06-29 13:40:45	4900EF2E3D
2025-06-29 13:51:24	4900EF2DD4

Timestamp	rfid 2
2025-06-29 13:13:20	4900EF2DE1
2025-06-29 13:20:48	011535D040
2025-06-29 13:23:31	4900EF2DE1
2025-06-29 13:30:24	4900EF2DFE
2025-06-29 13:35:54	4900EF2E39
2025-06-29 13:38:34	4900EF2E11
2025-06-29 13:45:50	4900EF2E30

Figure 7-2 Data

7.4 SYSTEM DESIGN PHOTOS

RFID readers are placed on the roof of the storage cell to easily read the data from the RFID sticker on the palette shown in the figures below

Figure 7-4 System design

Figure 7-3 System design

7.5 PROTOTYPE DETAILS

Prototype is specifically designed to validate the concept of integrating Radio-Frequency Identification (RFID) technology within a storage facility to enhance inventory management and operational efficiency. This design incorporates a dual-range reader system: small-range readers are positioned within two cells of the storage facility. The readers located within the storage cells are intended to update the precise location of each placed pallet within the SAP (ERP system). This integration aims to significantly reduce the time workers and forklift operators spend manually locating pallets required for daily production operations.

The components utilized in this prototype design with their quantities and prices are as follows:

Prototype			
Tools	**Quantity**	**Price**	**Total**
ESP32 Development Board (WIFI and Bluetooth) 30-Pin with CP2102	3	EGP 400.00	EGP 1,200.00
18650 Battery Holder 2-Slot	2	EGP 25.00	EGP 50.00
18650 Battery Holder 3-Slot	1	EGP 20.00	EGP 20.00
PCB Board Fiberglass FR4 20*20	1	EGP 95.00	EGP 95.00
Beston Rechargeable 18650 Li-ion Battery 3000mAh	7	EGP 175.00	EGP 1,225.00
Plastic Project Box Waterproof F2 158x90x60mm IP65	2	EGP 275.00	EGP 550.00
Waterproof Project Box 200mmx120mmx55mm	1	EGP 275.00	EGP 275.00
Pin Headers Female 2.54mm : 40-Pin, Straight	6	EGP 6.00	EGP 36.00
Pin Headers Male 2.54mm : 40-Pin, Straight	3	EGP 6.00	EGP 18.00
Mini Rocker Switch ON-OFF 6A/250VAC KCD1-104 4Pin	3	EGP 10.00	EGP 30.00
LM2596HVS DC-DC Buck converter 3A Step Down Module	3	EGP 70.00	EGP 210.00
Battery Charger 18650 2 Cell MD-202A	2	EGP 50.00	EGP 100.00
Red Metal LED 12V	3	EGP 22.00	EGP 66.00
USB DC-DC Step Down Converter Module 6-20V to 5V 3A	1	EGP 70.00	EGP 70.00
MAX3232 Module RS232 to TTL Converter Adaptor Board	2	EGP 20.00	EGP 40.00
LM2596HVS DC-DC Buck converter 3A Step Down Module	3	EGP 70.00	EGP 210.00
Copper Spacer F/F M3*6mm	30	EGP 2.75	EGP 82.50
LED Strips Connecting Cable 6 Wire 28AWG 1 meter	2	EGP 13.50	EGP 27.00
4 Channels IIC I2C Logic Level Converter Bi-Directional Module 3.3V to 5V Shifter	10	EGP 94.00	EGP 940.00
UHF RFID Sticker (Long Range) 73.5x21.2mm	10	EGP 54.00	EGP 540.00
Micro USB Data Cable	1	EGP 35.00	EGP 35.00
Readers 30-50 cm	2	EGP 790.00	EGP 1,580.00
shipping	1	EGP 2,690.00	EGP 2,690.00
Reader 1-3 m	1	EGP 5,450.00	EGP 5,450.00
shipping	1	EGP 2,250.00	EGP 2,250.00
Tax	1	EGP 4,280.00	EGP 4,280.00
Micro USB Data Cable	1	EGP 35.00	EGP 35.00
tags 125 KH	10	EGP 10.00	EGP 100.00
		total	EGP 22,204.50

Table 9 ProtoType Prices

7.6 CONCLUSION AND RECOMMENDATIONS

After Implementing RFID-System prototype we observed that our process and cycle time were significantly reduced. This proves that factory X will benefit from implementing this system. We noticed that two operations can be removed from the process, “Checking the production plan” and “Searching for pallets”. These operations used to take a large amount of time which resulted in increased cycle time and operator time waste. Therefore, after testing the system the process changed that only one worker which is the forklift worker identify the locations of the required pallets from the system and start to unload these pallets. Unfortunately, the results from the prototype were recorded on only one day due to time limitations to visit the inventory. Recording the results based on more than one day results might help in validating the data more.

After implementing the prototype, several observations and areas for improvement were noticed. The cultural rigidity is one of the most important issues discussed throughout this report and significantly highlighted through this experiment. The workers do not fully comprehend the system and acknowledge its impact quickly. There was also a logistical problem in purchasing the readers from foreign suppliers which led to an increase in shipping and delivery time that forced us to delay the implementation process. This problem can be fixed by ordering the required components from local suppliers.

Chapter Eight

8 SIMULATION

8.1 INTRODUCTION

A discrete event simulation model was built to replicate and analyze the raw material inventory process, specifically focusing on A-class materials. The model was developed to evaluate the effectiveness of using RFID technology in tracking pallet location, quantity, and movement within the warehouse.

8.2 MODEL AIM

The simulation aims to improve inventory accuracy and reduce the time spent searching for raw materials by testing the integration of RFID components. It also helps in determining the optimal RFID setup and evaluating different order quantity strategies for key materials.

8.3 MODEL CONCEPTUALIZATION

The following flowchart shows how raw materials are tracked in the inventory using RFID, from arrival to their release to production and inventory update.

After observing the movement of raw material pallets over several days, it was found that materials are often scanned multiple times, first at the warehouse entry point and later during their production release.

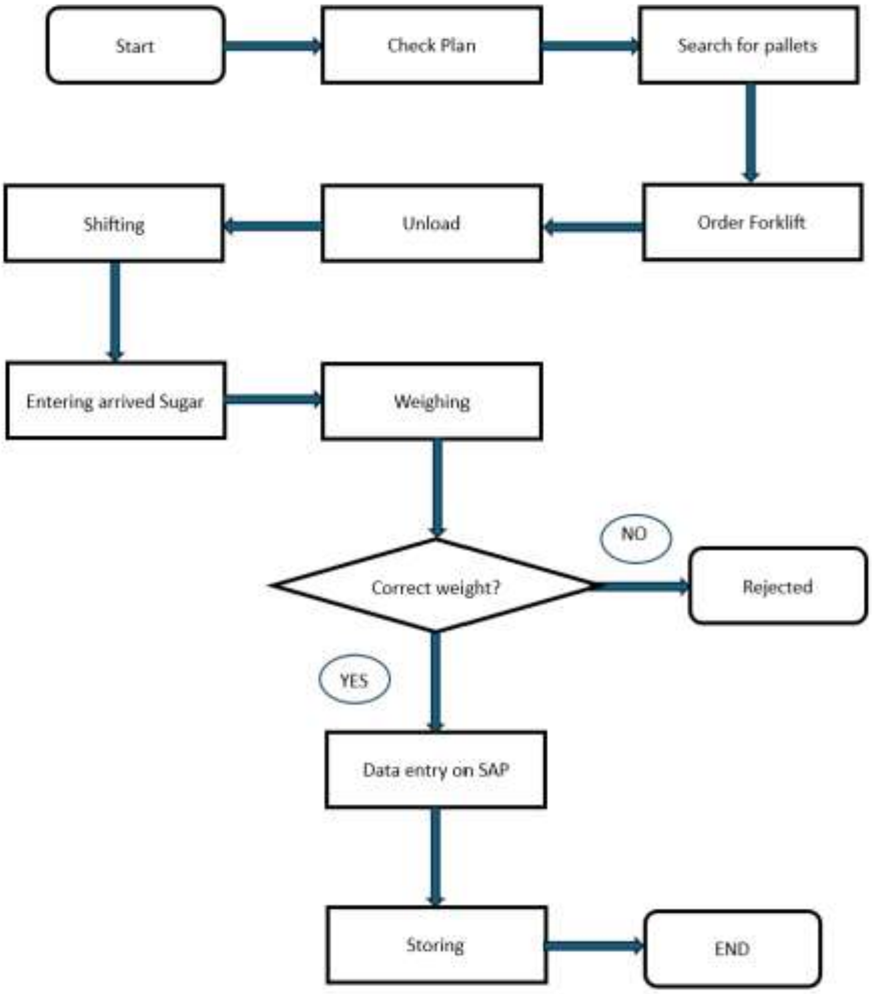


Figure 8-1 Model Conceptualization

8.4 OPERATIONAL DATA

Operational data describes the sequence of steps a raw material pallet goes through in inventory. First, the pallet arrives at the inventory and is scanned by the RFID reader at the entry point. Then, it is moved to the rack, where another RFID reader records its exact storage position. The inventory system is updated with this location data. When the material is needed, it is scanned again and released for production. Finally, the inventory records are updated to reflect the material's movement.

The first step in developing the simulation model was to identify and apply all activities involved in the raw material inventory process, along with their associated resources. This was done to construct a complete representation of a typical order processing problem and ensure the simulation reflects actual operational workflows.

To accurately represent activity durations in the simulation model, time values were defined in ExtendSim using the *UNIF(Real)* function. This function allows for assigning a uniform distribution between a specified minimum and maximum value, reflecting variability in task durations. The time data was collected through direct observation using a stopwatch during actual operations. Each activity was timed multiple times, and the minimum and maximum recorded durations (in minutes) were used as inputs to the simulation model to ensure realistic and representative behaviour. As shown below in figure 8-2

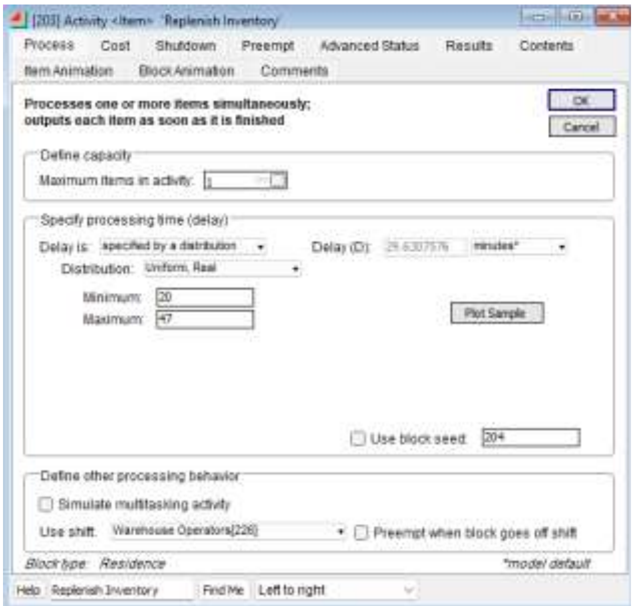
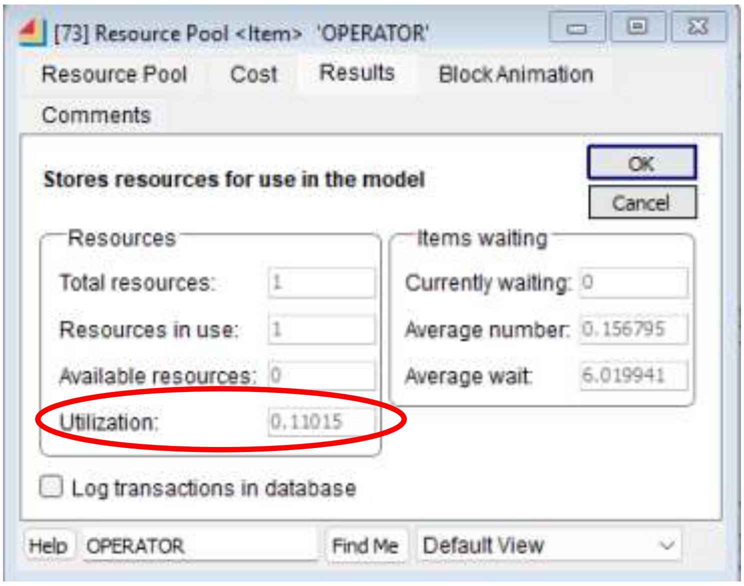


Figure 8-2 ExtendSim simulation

Initially, we focused on the order processing problem by creating a simple simulation model using one of the A-class raw materials, which is sugar. The model assumed an order quantity of 22,000 units and a daily lead time. Based on the simulation results, we observed that the operator utilization rate was relatively low at 11% and the average cycle time was 114.7 seconds



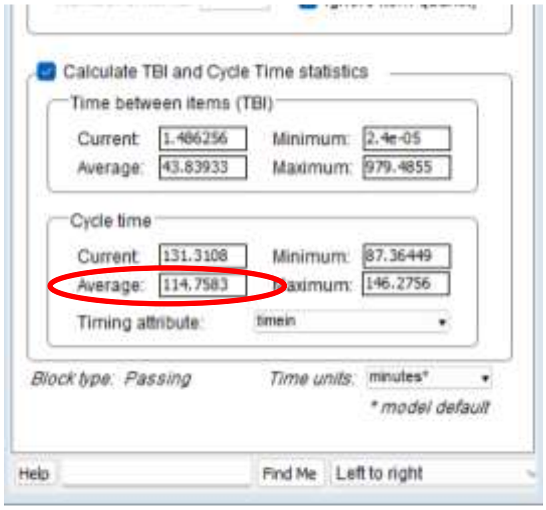
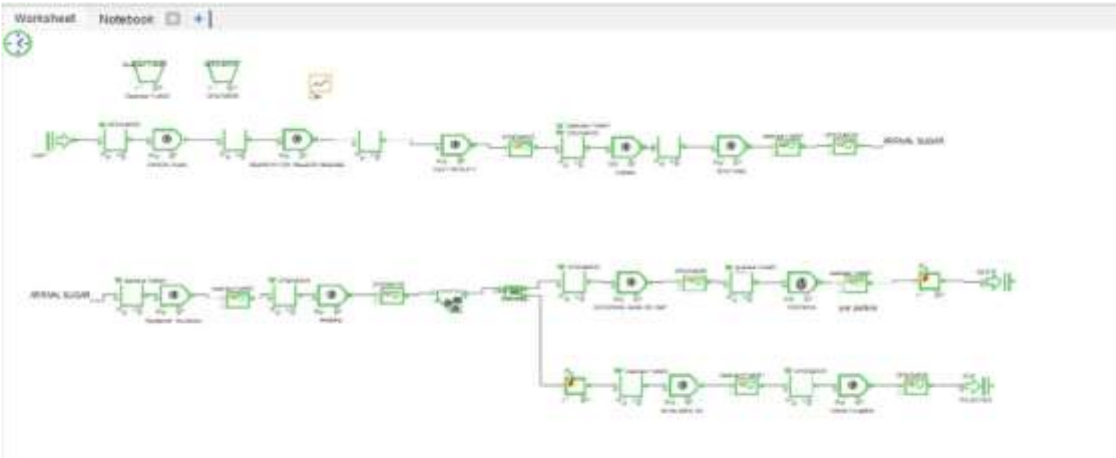


Figure 8-3 ExtendSim Simulation

Figure 8-4 ExtendSim Simulation

Figure 8-5



Simulation Model

In addition, since the operator utilization was found to be low at 11%, we extended the simulation by including another A-class raw material, Sorbitol. Sorbitol has an order quantity of 21,000 units and a lead time of 60 days. This allowed us to analyze the impact of processing multiple raw materials on utilization and average cycle time. As a result, the worker utilization increased to 23% while the average cycle time increased to 1373 minutes.

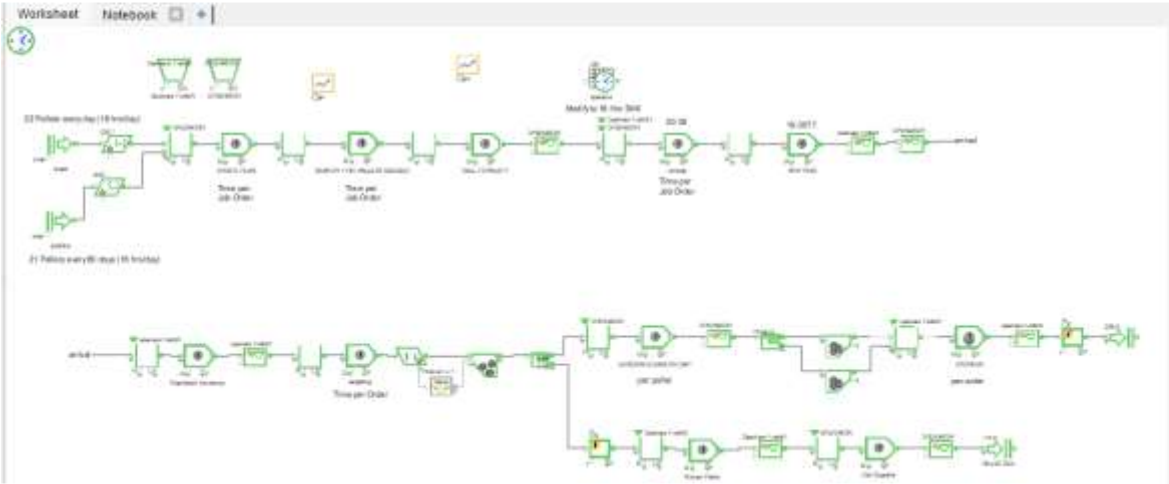
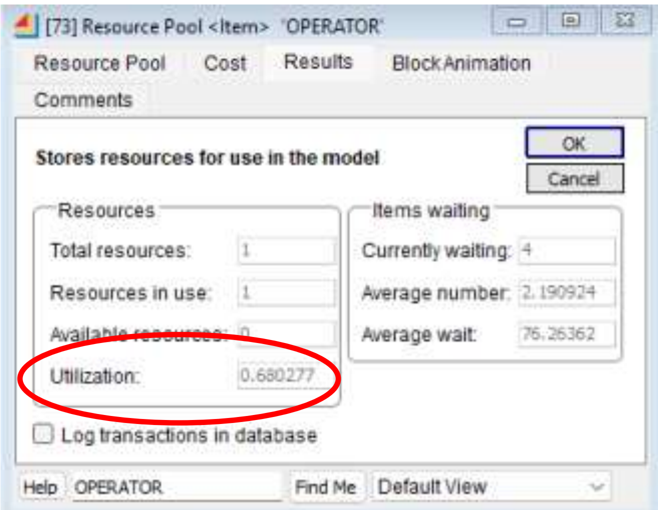


Figure 8-6 Simulation mode

To bring the simulation model closer to real-life conditions, we included all six A-class raw materials: FLAVOUR LIQUID GREEN MINT 510417 1T, GUM BASE COMPOUND CP21 FIMCO, SUGAR, SORBITOL POWDER P60W, GUM BASE INCO - 6 LOCAL, and GUM BASE CP61T, BAG 18.50KG (BHT FREE). Each material was assigned its actual order quantity and lead time. Specifically, FLAVOUR LIQUID GREEN MINT 510417 1T had an order quantity of 15,000 units and a lead time of 90 days; GUM BASE COMPOUND CP21 FIMCO had 6,000 units and a 10-day lead time; SUGAR had 22,000 units with a daily lead time; SORBITOL POWDER P60W had 21,000 units and a 60-day lead time; GUM BASE INCO - 6 LOCAL had 6,000 units and a 10-day lead time; and GUM BASE CP61T, BAG 18.50KG (BHT FREE) had 10,000 units and a 60-day lead time. As a result of all materials in the simulation, the worker utilization increased significantly to 68% and the average cycle time increased to 3217 minutes.



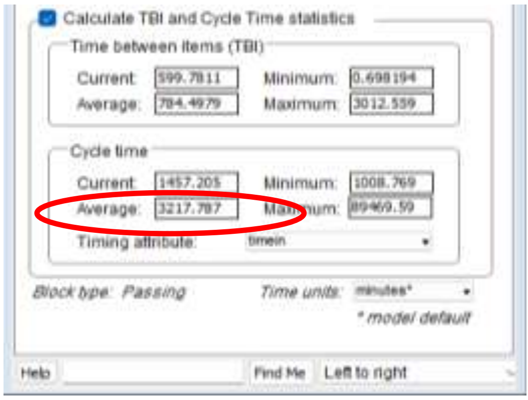


Figure 8-7 ExtendSim Simulation

Figure 8-8 ExtendSim Simulation

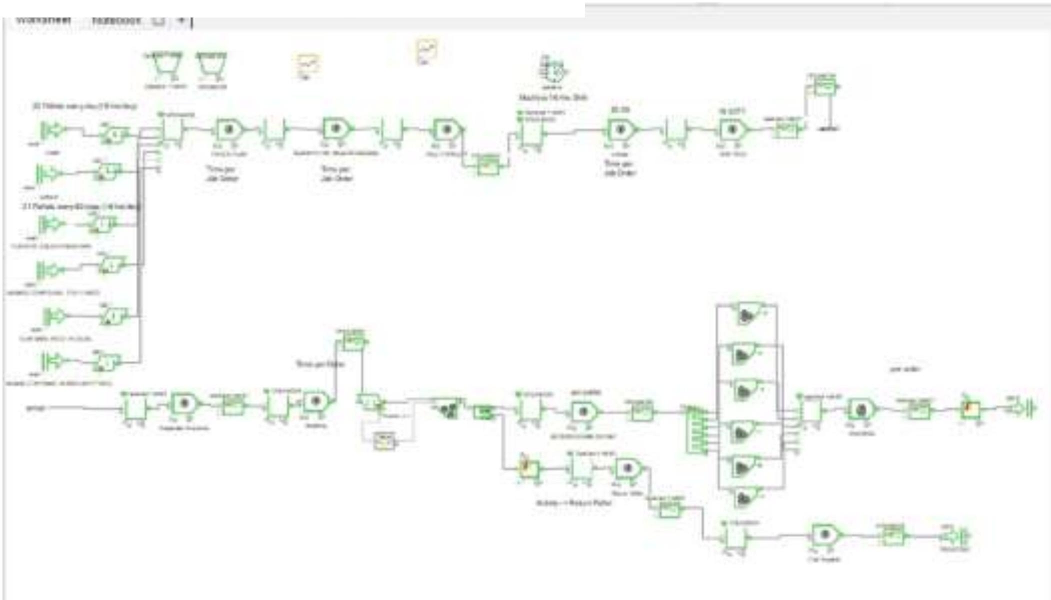


Figure 8-9 Simulation Model

Finally, this model represents the last stage of improvement, where we implemented the RFID system. In this version, the "search for pallets needed" and “check plan “activity block were removed, as the RFID system now provides real-time pallet location data and the operator won’t spend time checking for availability of pallets. As a result of these enhancements, the worker utilization decreased to 15.3 % and the average cycle time was reduced to 1807 minutes. The drop in utilization is due to the elimination of time previously spent searching for pallets, allowing the process to run more efficiently.

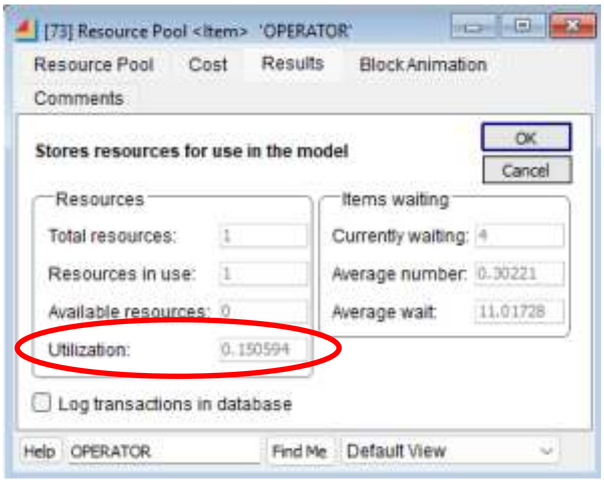


Figure 8-11 ExtendSim Simulation

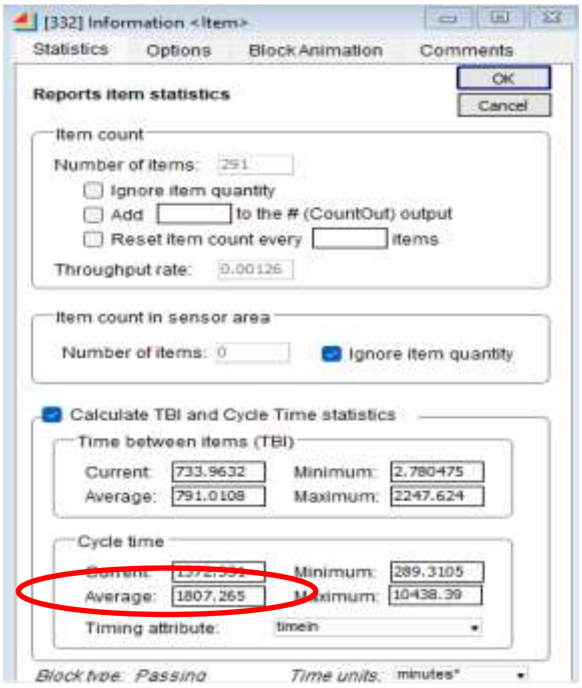


Figure 8-12 ExtendSim Simulation

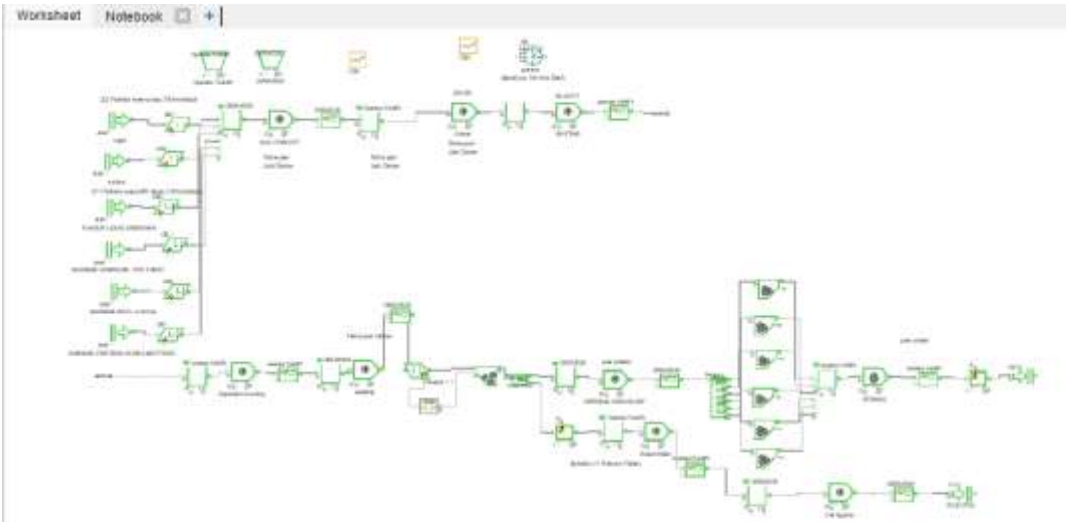


Figure 8-10 Simulation Model

8.5 OBSERVATIONS AND CONCLUSIONS

Simulation is a powerful tool for analysing and evaluating the behaviour of systems. In this project, a discrete event simulation model was developed to represent the raw material inventory process, with the objective of assessing how RFID technology can enhance operational efficiency. The focus was on using RFID to accurately identify the location of pallets in the warehouse, which in turn would reduce wasted time and improve overall performance.

The RFID system enabled real-time tracking of pallet movements and recorded critical data such as arrival times and storage locations. This allowed the simulation model to be built using realistic time distributions and accurately reflect real-world operations. One of the key outcomes of implementing RFID was the elimination of two time-consuming activities: "Searching for pallets" and "Check order." These steps were no longer required, as RFID provided instant visibility into pallet locations and inventory status.

Worker utilization was a key performance measure in the simulation. Worker utilization was highest (68%) in the scenario involving A-class materials without RFID. However, after implementing RFID and removing the manual searching and checking activities, utilization dropped to 15%, and the overall cycle time decreased from 3217 to 1807 minutes. These changes demonstrate the efficiency gained through automation and process streamlining.

In conclusion, the simulation model and RFID prototype confirmed that automating pallet identification in the raw material inventory process can significantly reduce **manual** effort, lower cycle times, and improve resource utilization. The project highlights the practical benefits of RFID in industrial inventory systems, particularly in environments with large product volumes and frequent pallet movements

8.6 ECONOMIC ANALYSIS

The economic analysis presented in this section is based on the results generated from a simulation model focused specifically on A-class raw materials**,** which represent the most critical and high-value items in inventory. The simulation outcomes provided detailed insights into labor utilization, cycle time, and process efficiency before and after implementing the RFID system. Building on these results, we conducted a cost assessment by identifying the required system components and estimating their prices. The breakdown of the components and associated costs used in the investment calculation is shown below.

SYSTEM (A-class material) 80 cells			
Tools	Q.	Price	Total
ESP32 Development Board (WIFI and Bluetooth) 30-Pin with CP2102	82	EGP 400.00	EGP 32,800.00
18650 Battery Holder 2-Slot	80	EGP 25.00	EGP 2,000.00
18650 Battery Holder 3-Slot	2	EGP 20.00	EGP 40.00
PCB Board Fiberglass FR4 20*20	135	EGP 95.00	EGP 12,825.00
Beston Rechargeable 18650 Li-ion Battery 3000mAh	244	EGP 175.00	EGP 42,700.00
Plastic Project Box Waterproof F2 158x90x60mm IP65	2	EGP 550.00	EGP 1,100.00
Waterproof Project Box 200mmx120mmx55mm	80	EGP 275.00	EGP 22,000.00
Pin Headers Female 2.54mm : 40-Pin, Straight	160	EGP 6.00	EGP 960.00
Pin Headers Male 2.54mm : 40-Pin, Straight	82	EGP 6.00	EGP 492.00
Mini Rocker Switch ON-OFF 6A/250VAC KCD1-104 4Pin	82	EGP 10.00	EGP 820.00
LM2596HVS DC-DC Buck converter 3A Step Down Module	82	EGP 70.00	EGP 5,740.00
Battery Charger 18650 2 Cell MD-202A	28	EGP 50.00	EGP 1,400.00
Red Metal LED 12V	82	EGP 22.00	EGP 1,804.00
USB DC-DC Step Down Converter Module 6-20V to 5V 3A	2	EGP 70.00	EGP 140.00
MAX3232 Module RS232 to TTL Converter Adaptor Board	2	EGP 20.00	EGP 40.00
LM2596HVS DC-DC Buck converter 3A Step Down Module	82	EGP 70.00	EGP 5,740.00
Copper Spacer F/F M3*6mm	820	EGP 2.75	EGP 2,255.00
LED Strips Connecting Cable 6 Wire 28AWG 1 meter	82	EGP 13.50	EGP 1,107.00
4 Channels IIC I2C Logic Level Converter Bi-Directional Module 3.3V to 5V Shifter	82	EGP 94.00	EGP 7,708.00
UHF RFID Sticker (Long Range) 73.5x21.2mm	240	EGP 6.00	EGP 1,440.00
Reader (2 meter)	2	EGP 5,450.00	EGP 10,900.00
Reader(30cm)	80	EGP 790.00	EGP 63,200.00
Micro USB Data Cable	1	EGP 35.00	EGP 35.00
		total	EGP 217,246.00

Table 10 System 1 with only A-Class materials

Parameter	Value
Cycle time before	3217 min
Cycle time after	1807 min
Utilization before	68%
Utilization after	15%
Worker salary Annual	EGP 115,000
Number of workers	3
Workdays/year	240 Days
Work Hours/Day	16 hrs./day (2 shifts * 8 hr)
RFID System Cost (Investment)	EGP 1,251,775

Table 11 Results

This analysis focuses on the A-class raw materials and is based on the results generated from the simulation model. Each worker is scheduled to work 8 hours per day, and the system is operated by a total of 3 workers covering two shifts. Over 240 working days per year, this results in a total annual work time of 5,760 hours. This figure represents the total available labor hours specifically dedicated to handling A-class materials, as modeled in the simulation before and after implementing the RFID system.

The implementation of the RFID system led to a significant reduction in operator utilization. Before RFID, the total utilized working hours were approximately 3,916.8 hours annually, based on a 68% utilization rate across 5,760 available worker-hours. After implementing the system, utilization dropped to 15%, resulting in only 864 utilized hours per year. This change reflects an annual time savings of 3,052.8 hours, indicating a substantial improvement in labor efficiency and the elimination of non-value-added tasks such as searching for pallets and manual order checking.

Based on an annual salary of EGP 115,000 and a total of 1,920 working hours per worker, the hourly wage is calculated to be approximately EGP 59.90. With the implementation of the RFID system, the annual time saved across all workers amounts to 3,052.8 hours. Multiplying the saved hours by the hourly wage results in an estimated annual labor cost savings of EGP 182,869 for the 3 workers.

The Return on Investment (ROI) was calculated by dividing the annual labour cost savings (EGP 182,869) by the total RFID system investment (EGP 217,246), resulting in an ROI of 84.2%. This high ROI demonstrates that the system is not only financially viable but also highly profitable, offering substantial cost savings relative to the initial investment.

The payback period is calculated by dividing the total investment cost (EGP 217,246) by the annual labor cost savings (EGP 182,869), resulting in a payback period of approximately 1.19 years. This indicates that the initial cost of implementing the RFID system will be fully recovered through labor savings in just over one year, making it a highly efficient and financially attractive investment.

Chapter Nine

9 9 CONCLUSION AND FUTURE RECOMMENDATIONS

9.1 PROJECT SUMMARY

Industry 4.0 represents the evolution of traditional inventory management with the integration of technologies such as RFID. It aims to improve operational efficiency, reduce human intervention and improve inventory accuracy. This transformation leads to smarter, faster and more relivable inventory environments that are capable to adapt to dynamic business needs.

The RFID-System plays an important role in advancing inventory operations. Instead of manual processing, it enables real-time tracking of pallet locations. This minimizes the searching time, worker utilization and overall cycle time. This system enables forklift workers to work independently on digital production plans received.

The implementation of the RFID system led to significant efficiency improvements. Operator utilization decreased from 68% to 15%, representing a reduction of approximately 78%,. Additionally, the average cycle time dropped from 3,217 minutes to 1,807 minutes, resulting in a reduction of approximately 44%, highlighting the system's effectiveness in streamlining operations and accelerating process flow.

To conclude, using RFID technology in inventory delivers various advantages including process optimization, improved resource-utilization, real-time tracking and reduced cycle-times

9.2 PROJECT IMPACT

Our project's impact is going to be focused on improving the storage system of inventory items in the facility through optimizing order quantities and the time of orders while also helping the workers locate the pallets quickly to reduce time waste. We will achieve that by changing the current ordering system of A-class raw materials if possible then implementing an RFID system that helps track and auto-update the current inventory levels of materials while also having a locating system inside the storage area. Additional

benefits of the system are reducing human error of misplaced palettes and increasing the utilization of already in use racks.

9.3 PROJECT CHALLENGES

Our project faced three major challenges, the first one was trying to decide which RFID system is the most suitable to use whether passive or active. That decision was crucial to the overall cost of our project. The second challenge was a logistical problem in trying to order the suitable parts and having to wait for customs clearance. The final problem was that the factory performs audits every month which sometimes overlapped with our scheduled meetings.

9.4 TECHNICAL BARRIER:

In the Egyptian context, especially in industrial settings, there is often hesitation or reluctance to adopt new technologies. Many workers express concerns that automation and technological advancements may render their roles obsolete, potentially leading to job loss. As a result, they tend to favor traditional methods and resist changes to established workflows, which poses a significant barrier to the successful integration of systems like RFID.

9.5 ETHICS AND SAFETY

One of our primary concerns throughout the development of this project was enhancing the existing safety measures in the factory's storage facility. During our observations, we identified that workers responsible for locating pallets had to physically walk through the facility, using paper references containing the last four digits of the Batch ID. This manual process required significant physical effort and often led to neck and shoulder strain due to repeated head movements and poor ergonomics. By implementing our RFID-based system, this step is eliminated entirely, thereby reducing physical strain and improving overall worker well-being.

From an ethical standpoint, our approach aligns with the professional standards established by ABET and the Institute of Industrial and Systems Engineers (IISE). These standards emphasize integrity, accountability, and public safety, reinforcing the idea that engineering is a service to society. By improving worker safety, reducing physical strain, and ensuring technological safety compliance, our project upholds these ethical principles. We have maintained a commitment to responsible design and implementation, ensuring that our solution not only enhances operational efficiency but also protects the health and well-being of the individuals who interact with it.

9.5.1 Swot Analysis

Strength	Weakness
• The RFID system provides live data updates, allowing for precise tracking of raw materials in terms of quantity, type, and location. • The implementation of RFID technology encourages employees to develop new skills, particularly in data analysis, inventory control, and operating advanced RFID systems.	• Implementing RFID systems requires training employees to use new technology effectively. • RFID systems rely heavily on network infrastructure (such as Wi-Fi, servers, and communication protocols). If the network is unreliable, RFID data can be delayed or lost.
Opportunities	Threats
• RFID technology is continually evolving, with improvements in tag readability, range, and data processing capabilities. As the technology advances, the RFID system can be further optimized for better efficiency, accuracy, and lower costs.	• The RFID system may require technical support for installation, and ongoing maintenance. If the company lacks sufficient access to qualified support, it can experience delays or issues. • Regular maintenance of RFID tags, readers, and infrastructure is essential to ensure the system functions efficiently. Over time, equipment may require repairs or upgrades • As with any technology, RFID systems can become obsolete as newer, more advanced systems are developed. Continuous innovation and market shifts could make your RFID solution less effective

Figure 9-2 Action Plan I

Figure 39-2 ACTION PLAN II

References:

[1] M. Hehua, “Application of Passive Wireless RFID Asset Management in Warehousing of Cross-Border E-Commerce Enterprises,” *J Sens*, vol. 2021, 2021, doi: 10.1155/2021/6438057.

[2] R. Atkins, A. Sener, and J. Russo, “A Simulation for Managing Retail Inventory Flow Using RFID and Bar Code Technology,” *Decision Sciences Journal of Innovative Education*, vol. 19, no. 3, pp. 214–223, Jul. 2021, doi: 10.1111/dsji.12232.

[3] “I Gusti Made Karmawan ABSTRACT Impact of RFID on Retailer’s Inventory.”

[4] M. Alnahhal, B. L. Aylak, M. Al Hazza, and A. Sakhrieh, “Economic Order Quantity: A State-of-the-Art in the Era of Uncertain Supply Chains,” Jul. 01, 2024, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/su16145965.

[5] M. Riza, H. Hardi Purba, M. Riza, and H. Purba, “THE IMPLEMENTATION OF ECONOMIC ORDER QUANTITY FOR REDUCING INVENTORY COST,” vol. 8, no. 3, pp. 207–216, 2018, doi: 10.21008/j.2083-4950.2018.8.3.1.

[6] K. Sari, “Selection of RFID solution provider: A fuzzy multi-criteria decision model with Monte Carlo simulation,” *Kybernetes*, vol. 42, no. 3, pp. 448–465, Mar. 2013, doi: 10.1108/03684921311323680.

[7] X. Wang, W. Tang, and R. Zhao, “Fuzzy Economic Order Quantity Inventory Models Without Backordering *,” 2007.

[8] M. Riza, H. Hardi Purba, M. Riza, and H. Purba, “THE IMPLEMENTATION OF ECONOMIC ORDER QUANTITY FOR REDUCING INVENTORY COST,” vol. 8, no. 3, pp. 207–216, 2018, doi: 10.21008/j.2083-4950.2018.8.3.1.

[9] M. Bevilacqua, F. E. Ciarapica, and S. Antomarioni, “Lean principles for organizing items in an automated storage and retrieval system: An association rule mining – Based approach,” 2019, *Polish Academy of Sciences*. doi: 10.24425/mper.2019.128241.

[10] M. Alnahhal, B. L. Aylak, M. Al Hazza, and A. Sakhrieh, “Economic Order Quantity: A State-of-the-Art in the Era of Uncertain Supply Chains,” Jul. 01, 2024, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/su16145965.

[11] D. L. Cortes-Murcia, W. J. Guerrero, and J. R. Montoya-Torres, “Supply Chain Management, Game-Changing Technologies, and Physical Internet: A Systematic Meta-Review of Literature,” 2022, *Institute of Electrical and Electronics Engineers Inc.* doi: 10.1109/ACCESS.2022.3181154.

[12] M. H. Chowdhury, T. Ahmed, M. B. Rahman, and A. H. M. S. Islam, “Smart Inventory Management System with Forecasting Technique Applied to Efficiently Handle Industrial Asset,” *American Journal of Innovation in Science and Engineering*, vol. 2, no. 2, pp. 1–5, Apr. 2023, doi: 10.54536/ajise.v2i2.1384.

[13] V. V. Jituri, “RADIO FREQUENCY IDENTIFICATION (RFID) AND EASE OF LIFE,” *International Journal of Research -GRANTHAALAYAH*, vol. 8, no. 8, pp. 49–55, Aug. 2020, doi: 10.29121/granthaalayah.v8.i8.2020.811.

[14] H. Rezaie, M. Golsorkhtabaramiri, and N. Jafari Navimipour, “A radio frequency identification reader collision avoidance protocol for dense reader environments in the context of Industry 4.0,” *IET Radar, Sonar and Navigation*, vol. 17, no. 3, pp. 362–373, Mar. 2023, doi: 10.1049/rsn2.12346.

[15] A. Alwadi, A. Gawanmeh, S. Parvin, and J. N. Al-Karaki, “Smart solutions for RFID based inventory management systems: A survey,” *Scalable Computing*, vol. 18, no. 4, pp. 347–360, 2017, doi: 10.12694/scpe.v18i4.1333.

[16] M. Hehua, “Application of Passive Wireless RFID Asset Management in Warehousing of Cross-Border E-Commerce Enterprises,” *J Sens*, vol. 2021, 2021, doi: 10.1155/2021/6438057.

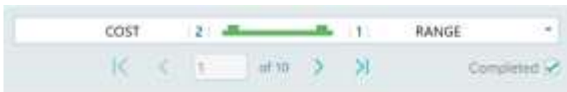
[17] V. V. Jituri, “RADIO FREQUENCY IDENTIFICATION (RFID) AND EASE OF LIFE,” *International Journal of Research -GRANTHAALAYAH*, vol. 8, no. 8, pp. 49–55, Aug. 2020, doi: 10.29121/granthaalayah.v8.i8.2020.811.

[18] V. V. Jituri, “RADIO FREQUENCY IDENTIFICATION (RFID) AND EASE OF LIFE,” *International Journal of Research -GRANTHAALAYAH*, vol. 8, no. 8, pp. 49–55, Aug. 2020, doi: 10.29121/granthaalayah.v8.i8.2020.811.

10 APPENDIX

Appendix 1:

The first step in using Spice Logic Analytic Hierarchy Process was to define the main goal of the analysis

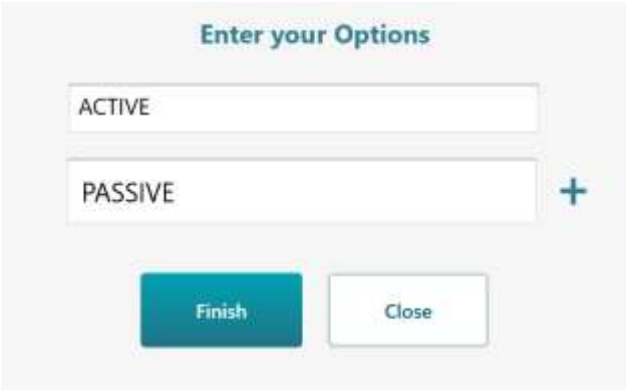


Appendix 2:

A pairwise comparison methodology

Appendix 3:

Next step involved in putting the various alternatives:



Appendix 3:

Evaluation methodology was then diligently applied for every alternative across all established criteria: