# OPTIMIZING FINISHED GOODS WAREHOUSE : A CASE STUDY

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## Declaration page of the candidate & supervisor

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Name of the supervisor: Ms. Harishani Liyanage

Signature of the supervisor: Date:

**Abstract**

Topic of the work was the improvement of the current space utilization and efficiency in the company finish good warehouse. As per LEAN concept storage is the one of non-value add activity in the company's supply chain but it is necessary for continue business process. The purpose of the research is deciding changes to increase the overall performance of the bearing by identifying performance factors. One of main goal is to analyze the current state of optimization. A comprehensive literature review is present for the optimization of the finished goods warehouse. The problems classified according to the basic warehouse functions and areas. The literature in each category have described with emphasis on the features of different decision support models. It also reviews inventory optimization issues and operational issues as a conceptual optimization model. First, the overall structure of the warehouse described and Secondly, the floor plan and the use of space in the warehouse characterized with special consideration in this research. Thirdly, the warehouse information systems for warehouse operations briefly mentioned and Forth, the optimization of warehouse operations depending on the technical and operational structure described. Fifth, this paper shows the management principles discussed with stock optimization, and finally the contribution of equipment and machine utilization to inventory optimization. Finally, layout strategies simulated and improved to manage warehouse utilization and truck turnaround time. And this implementation effect on waste reduction, improvement of speed and efficiency, flexibility and reliability management also discussed and finally effected as a cost saving for the company.

**Key Words:** Warehouse, Finished product, Optimization, Layout, Operation, Space utilization.

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# CHAPTER 1 INTRODUCTION

## 1.1 Introduction

The propose of this chapter is to introduce background of research topic, history and general overview of industry and case study organization. The problem and objective of research built up in third chapter. Then overview of thesis and conclusion presented in last chapter.

### 1.1.1 Background of industry

Soft drinks are now the most popular beverage in the world, but its history has not properly studied yet. However, the history of people has been a basic study and consumption of soft drinks in the history of humans. At the middle of the 17th century, Sweet Water and a mixture of lemon juice can be found in 1676, the French monarchy in Paris, after that the company joined with government and the company was established to produce lemon drinks (Frazelle, 2002). Then the History says that the company's tanks were packed with bottled drinking cups but did not use carbon dioxide (Frazelle, 2002). The first carbonized drink discovered in Europe by Joseph Priestley, who was the founder of the soft drinks production. Here, as a result of his experiments, in 1772 (Sule, 1994), in London, a improvements was added to carbon dioxide and mixing water, resulting in the use of tannin carbon dioxide in a drinkable mix Then mineral salts and various flavors were added to enhance the effect of carbon dioxide in soft drinks and refined as a sweet drinks. As a result of huge experiments, the soft drinks industry has become one of the leading industries in the world in 20th century. But by the 21st century, carbonated drinks the popularity is less than the forecasted amount. This means water, fruit juices and milk like natural drinks that will coming to high in demand upward. But with the population growing soft drinks demand are growing, for example, in the soft drinks market in 2013, it was US $ 25,500, which was $ 34,761 million by 2019. However, this does not mean that always drink or not drink soft drinks in all over the world. Consumption of soft drinks varies nationally and culturally because of that, non-consensual pattern in consumption of soft drinks with economic development can demonstrated. According to the 2008 Global Soft Drink Consumer Reports, around 552 billion

liters of soft drinks were consumed worldwide in 2008 and could be equal to 82.5 liters per person per year (ReVelle, 1993). This is the soft drink historical summery from initial point to present situation with those industrial revolution force generated to human to develop warehouses.

### 1.1.2 History of warehousing

Looking back on the past, people in the prepared to store excess food. The concept of storing is initially rooted in the creation of warehouses for the storage of excess food for emergency use such as hunger and drought. Then storage of goods in warehouse has gradually increased over the world during the past and present. With the development of civilization people started to prepared goods store in national and international levels. Goods transportation, trade, and production interconnection started during this period. In the Middle Ages, the advancement of the knowledge and technology of the people led to increased international trade, which led to the increase in the volume of goods and the management of goods. The first cargo storage facility built near a mainland in Venezuela's main seaport. But by the end of the 19th century, transport by sea reduced and then it conducted by trains. However, when railroads began to expand in highly then a railway depot was established in 1891 (Salema, 2007). Therefore, The American Development Association (ADA) called for the establishment and control to railway transportation. The increase in railroads was legally limited by the government in 1906 (Wesche, 2012). Further, the government led control of the train until to the end of World War II. As a result, storage facilities spread around all area of country. In this time recommended height were about 12 feet (12 m) in height in good storing warehouse. Then these storage facilities have used to store war equipment during the World War II. After that, with the Industrial Revolution, a large production come out from the manufacturing process, then increased the need and the demand for efficient and productive warehouses. Currently the store storage height increases up to 30 feet in height and has an increase of 300%. This has resulted in large-scale production of storage systems, starting from mid-sized to a large scale, from domestic stores to well-established international warehouses. Since the development of the technology in the world since the 1970s, technology improvements have introduced for automated

storage and automation systems (AS / RS) storage complexes. At same time, good stores have been fully automated. Storage control system of warehouse is programmable software controllers it supports to measures automatically and coordinate the storage management system (WMS) and computerized database in automated storage. This data used for storage operations and making administrative decisions.

### 1.1.3 The purpose of warehousing

The store is a large commercial building that stores items and goods. Storage is the most important thing in a warehouse. Usually, when ordering items delivered, for that you must first send them in for a request. The main objective of most stores is to store and distribute products when the supplier supplies goods. It must be satisfied in the least satisfactory manner with the customer. However, this is no longer true, because for most companies there is a high storage cost. However, in practical terms, there are key factors such as customer needs and aspirations. In response to these questions, companies address integration issues with new e-commerce technology, quick responses, timely procurement, and responses from end-users. Can solved by storing and maintaining.

### 1.1.4 Carbonated soft drinks industry in Sri Lanka

In the past, Sri Lanka is a tropical country that can have an impact on water consumption, and cultural habits have a significant effect on this, resulting in little consumption of drinking water. Therefore, easy access to drinking water can obtained for drinking water market. All types of beverages including mineral water, along with other countries in the world, considering that 18 liters for one person per year if we comparing with in other country usually 45 liters for consumption in Malaysia and 80 in Indonesia,100 liters used in Thailand. In Sri Lanka carbonated soft drink is the highest consumable drink from others but there is slow growth in the present situation. In addition, had the highest growth in Sri Lanka during the last two years was seen in fruit juices, milk and bottled water, which is attributed to the increase in the number of people today who are eerie.

### 1.1.5 Case study company background

Company A is a Sri Lankan company that produces carbonated beverages. The company is one of the leading soft drinks market brands in Sri Lanka, despite having a competing race with companies that produce globally carbonated beverages such as Coca-Cola and Pepsi. The company's history, the company was in Colombo in 1866 established as the first ice maker. In 1868, the company introduced the first ice cream production in Sri Lanka, and the company started commercial ice cream production in Colombo. The company has a warehouse for finished goods. Three manufacturing centers produces soft drinks to meet their daily needs. The main storehouse supposed to distribute across the country is this high-end store. Soft drinks vendors or retailers sell them. Sellers will transport them to their own places by themselves. These areas monitored by regional managers in each area. The supply chain is from where the product will eventually reach its end user.

## 1.2 Problem Statement/Need for the study

The storage is the critical point in supply chain for soft drinks manufacturing company. The inventory management needs to improve to minimize inefficiencies and improve the accuracy of goods movements, and enable product accumulation, merger, and integration. To minimize storage costs, the warehouse space should use to the maximum extent possible. Usually from 2% to 5% percent of the company's turnover allocated to warehouse cost it used to increase the cost of space use and to improve customer satisfaction. Storage generate results in a large production loss in storage due to damage of storage goods and irregular storage habits. Also, due to the unproper storage plan, at high production and sales season the storage capacity is insufficient therefor extra capacity must rent. Also, the storage process at the warehouse operations will be completion of one truck by 6 hours, it is reflecting the inefficiencies in warehouse processes. Therefore, the focus of this research is to optimize the use of storage space and to promote the storage plan and optimized the storage process in the warehouse.

### 1.2.1 Research Question

This research can achieve answers for following questions.

- What are the methods of warehouse optimization?
- Which methods most applicable for selected warehouse?
- Current warehouse optimization level?
- What are the ways of developing a warehouse optimization plan for a finished product warehouse?

## 1.3 Research Objectives

The objectives of this study identified problems of current warehouse operations in case studying company as well as level of current optimization. Then preparing warehouse optimization plan to improve current optimization level. For achieve those objectives fallowing steps required.

- Review about finished product warehouse and warehouse optimization methods.
- Analyzing current warehouse optimization level
- Identifying optimization areas
- Identify problems in each areas of selected warehouse
- Model and analysis current warehouse layout

## 1.4 Research Summary

This thesis included six chapters from that first chapter present background of the research with research objectives. In second chapter include literature of each relevant research areas with main focused on finished product warehouse and warehouse optimization methods. In third chapter present about methodology of this case study studying. In fourth chapter discussed about relevant analysis apply for warehouse optimization. The findings presented in fifth chapter with appropriate conclusion and all recommendations in this research

# CHAPTER 2 LITERATURE REVIEW

## 2.1 Introduction to warehouse operations

A warehouse is a critical component of every manufacturing company's supply chain since it is the place to store the product until it purchased from the end customer. The main objective and focus of a warehouse are to provide storage facilities with maximizing labor and other resources. The final objective is satisfying customers' demand and supply. The customer satisfaction has been shown to break down a few factors like which means that the quantity of the order, the fulfilling time of the order and the availability goods type at required time, and the number of requests that can be made, those are identified as indicated in the previous study summary. Assort measures to control the storage performance also highlight the effectiveness of efficient running costs. It is important to study labor productivity to analyze the production performance of the product storage environment. In environments, productivity has shown to be more expensive than anticipated. This is effective if you manage a product in this way the operating costs for small quantities are higher than for common operations. If there are 48 boxes for transporting 10000 paper sheets, if each box can be manually handled A single person can do it efficiently, but with using 24 people it has less work, it can be completed with less time but not cost effective. If quantity is high, then managing cost for one item is get less. It is dependent on the type of working method and the number of people in store. For example, according to the previous studies types of storage can divided into three main groups. First one Raw materials store, Intermediate material stores, finished goods warehouses those to use for storing goods in manufacturing company. The raw material stores used for storing raw materials which said to store pre-processed material or basic raw materials. Otherwise, an intermediate product storage facility for semi-finished products or uncompleted products mentioned. Other one is the finished product storage stored. In general stores used two main methods of previous studies have indicated. Last in first exit method used at the bottom of the earliest deck, and the ending arrays firstly sent out. The second goods moving method is the first come of the product that was first out. This method plays a key

role in a warehouse, which means that it sells the old stock first because of that most warehouse use first in first out method.

### 2.1.2 Functions of the finished good warehouse

The warehouses of finished products are the most important part of each supply chain. Previous studies have shown that the main function of the finished product store is to take into account the variability of demand due to the seasonality of the product market and the formation of the product group, thereby reducing the disruption to the final product flow through the supply chain. For this purpose, the warehouse also provides product logistics, consolidation of products from multiple suppliers, and customization of additional services such as kits, pricing, labeling, combination, separation and product customization for the joint delivery of bands to customers. (Teo, 2001). This study focuses more on the departmental store of finished products. The supply chain of finished products consists of all functions related to transport, reception of finished products from the production plant, storage, and shipment to the point of sale. As a summary of the previous study, the finished product warehouse had only a few essential functions, such as warehouse goods movement, warehouse information management, warehouse space and movement planning, protection of goods and security and value-added process. Then, we will discuss each function separately in this literature review (Shen, 2003).

Storage of Goods -According to earlier studies storage of items is one of the most important tasks in a warehouse. It is said that the entire area of the warehouse can be used to store goods as a storage tank and a cubic meter of capacity, but that cannot be done, since it cannot be read so that other space can be stored in addition to storage (Gao, 1994).

According to preliminary study reports, the storage of goods can categorize is in two ways: short-term regular storage and long-term or extended storage. Short-term storage means the proper storage as required to meet the regular consumer needs. Each stock should be kept for a period after entering the store (Hansen, 1957). However, this storage time depends on the production rate of the product on the production process, on the demand fluctuation, and on product variations. Long-term extended storage indicated as more efficient storage than normal storage. There are

assort reasons for increased storage requirements, immediate demand, product terms, model purchases, discounts. It pointed out that there is a need for additional storage to meet the simultaneous demand at brief time. The manufacturing companies produce and store a large quantity of waste at the same time to reduce production costs. Large-scale production is highly efficient when producing small quantities of waste in less production than in waste and production costs, while lower production is less effective in producing greater quantities at a time. In advertising, such as sales promotion, additional inventory storage is required to increase for full fill brief time demand increases (Vidyarthi, 2007). A storage unit is a smallest unit of production that produces itself as an Edict. A small unit (one bottle) will be used for this purpose for the user, but before the supply chains, the products usually circulate in larger units (Erlenkotter, 1978).

Movement of Goods - Another key function in a warehouse is to move goods as needed. As goods that should move, they must acknowledge, receiving, storing, value add service and loading. The single unit of produced is the smallest unit that can move. For example, a soft drink production company has a soft drink bottle. Then smallest movable unit is one bottle, one type of bottle called a one stock keeping unit. But at the same time, in the warehouse not managing one by one stock keeping unit it has manage more stock keeping unit s at same time. Consumers require a combination of items for a sale in one order (Abdulmalek, 2007).

To accomplish this order, a variety of activities must conduct. This can divide into different processes. The acquisition process is the first action of this process. It used for trucks or in internal transport methods (for a retail business). This stage can check or modify as required goods. The warehouse system can check for registration or filling actions in this stage then Items that stored in allocated area in warehouse. According to previous studies Storage areas may consist of two main components. That is, storage areas where the products stored in a more economical manner (large storage) stored, and the storage areas where storage stored for easy removal by the supplier. The products stored in the exchange area are stored in read-only and that information saved by warehouse management system (Bramel, 2000). For example, the separated rack or area on the warehouse can be plan. In addition, rack can also

have sub-location. They are known as moving goods through warehouse storing and any locations in warehouse. The early finding said to have the option of making the selection process from their store locations. These items are composed of items that can selected by hand or automatically. These elements can categorize and merge sequentially to the process. Integration of the intended goods of that customer. This operation done by the administration of the warehouse. Then the orders are checked, packaged, and loaded into trucks (Jaillet, 2002).

Information management -. The information system can used to check the items stored on or take information about items stored in the warehouse as it has already been in research papers. But furthermore, As the information has already found, the information system will evaluate the information stored in the store, the information stored and saved by it. The data collected by the system sent to the top management for better decisions. This archival information is a main factor in the analysis of the actual and historical data, and the information widely used to make critical decisions in storage operations. Finding the right business decisions is a key to the success of a successful business at any one time. As a result of the surveys and modern techniques, provide a clear and concise outline of any location cloud-based storage management system is introduced (Hakimi, 1964).

Protection of goods & Safety - Storage of warehouse protection, pollution, heat, dust, wind, moisture, thieves, and animals in the warehouse. It has identified that specialty protection contracts must be prepared for various products depending on the type of stock. Most the disasters that occur in storage as a rule the warehouse loaded, and the material is not responsible for the storage prior to storage. The owner of the store is responsible to the warehouse keeper when goods transferred for download, the responsibility for these items transferred to the store owner. Accordingly, the storekeeper risks the damage to or damage to the goods stored by the storekeeper. The storehouse bound to return excellent quality goods is required to take all necessary precautions to prevent accidents (Gao, 1994). A warehouse considered another safety feature to protect warehouse occupations. This feature should be extremely important in the manager's actions and control list. In addition to providing the safety needed for security in the warehouse, senior managers should

indicate that good occupations can adopt good practices to improve the safety culture (Meyerson, 2001). according to previous studies, the stores and all the equipment and its operators and their operators must be in their possession and certified for certification, approval, and regular inspection. Compliance with a better protection culture protects the company from unnecessary litigation and prevents fines and fines on OSHA and other government agencies.

Financing - In the case of updated previous study reports, when a supplier supplies goods in the store, the supplier must obtain the receipts of the items from their receipt. The inventory storekeeper should be issued to the inventory's owner. This receipt is property that can distributed and shared valued. Therefore, the value of the supplies that the trustee has placed in the custody similarly, businesspeople can get this receipt. This allows banks to borrow from other financial institutions (Vidyarthi, 2007). In some cases, depositors may obtain insurance for their goods by themselves, it is said that they are compulsorily insured by a bank or a financial institution for the warehouses for the warehouse goods. The other financial aspect is cost. In details about warehouse cost will discuss by separate section in this literature review (Santoso, 2005).

Value add Processing – The companies produce the products in their production process, but they not sent for the directly to sale. because company request to make the minor changes. For example, after storing, packing of extra layers or packing is removing and re packing, combining two goods, marking promotion tips or label, and branding It is said that this activity can be carried out by warehouse for the owners. In the case of the owner of the luggage, the employees of the warehouse may collect items such as the classification of the product and the branding process (Shen, 2003). The wholesale or freight vendor request to facilitates the mixing, mixing, and packaging for the simplicity of good before to selling such items. Some companies advertise their activities in the seasons, so it is said that these owners participate in value-added activities when certain activities, separation and amalgamation of certain activities engage in warehouse (Eppen G. , 1988).

### 2.1.3 Finished good warehouse operations

Warehouse operations is an integral part of the business strategy of the company. Efforts to effectively store a warehouse can help the company to store or recover the necessary resources for production or stock shipment, which is timely manner. It is no coincidence that if a warehouse is pursuing a series of good practical activities, that store is an efficient warehouse. Process engineers calculate the theoretical standard time for storage operations and observe how the operations are performed and study movements. Store operations are different from manufacturing processes because they do not repeat them like manufacturing processes. However, in recent past studies, there are several ways to measure the performance of each activity in a store, after which they are discussed afterwards (Nozick, 2001). As noted in recent study reports, the operations of the warehousing consist of the following key activities: acceptance, removal, cross-order, tiling, loading and distribution. Next, each of these activities will be discussed in detail.

Receiving process - It is the responsibility of the receiving process to ensure that the quality and quantity of the carrying cases for the store is correct and that the approved papers conform. According to previous studies receiving process can be summarize as below regarding manufacturing finished product warehouse, the company's manufactured regularly produce products (Meyers, 1993). The trucks use to transfer product from the manufacturing plant to the warehouse. At the loading platform of the production plant, an inspector conducts a checking and sends it to the finished goods store. Receiving a warehouse is to ensure that documents from the production plant are inspected by the receiving supervisor in the warehouse and that the goods sent by the factory are received in the same manner (Üster, Integrated warehouse location and inventory decisions in a three-tier distribution system, 2008). When the goods are taken over from the truck driver, they will sign the bulk of the goods in the wholesale copy. When goods arrive to the warehouse, they are in line with the standard payment regimen. After losing it to the warehouse all instructions must obtained from the inventory coordinator. All settings and storage of all the finished products should performed efficiently, and if problems arise during operations, issues must resolve quickly. After the receipt of the receipt by the receipt,

Forklift drivers roll down the truck and count the number of pallets. The rate of delivery of the machines must correspond to the manufacturing process. Each item must inspect well, and the number of items received must calculated accurately. After finished counting process the count compared with the bill. If there is a difference, the products can express in the order. The production department checks the quality of the product spot accurately in the production department. Before sending it to the warehouse, the manufacturer checks all the items (Gao, 1994). The products can used for the disrupted production of items, and the damaged product can replenish by replacing damaged products. Documents must take for the goods damaged by the manufacturer or the supplier, and the documentation warehouse must provide for the goods damaged before the warehouse left. The warehouse staff will inform the production department of the goods to store at the warehouse number. The warehouse manager will be entered into the entire database and synchronized with all other departments that require this information, including the customer service department, consumer services department, sales department, and the department of finance. Conserving written documents such as invoices and packing lists for audit purposes are conserved (Crainic, 1998).

Put away - To carry the luggage, the finished products to brought to the best place to get the goods introduced. For the storage of material, goods conducted by forklift. The best practice in storage management is that many companies are doing this job to manage the area, based on this approach, calculating the resources and space needs of the company on the expected revenue and cost. This means that the products to be stored on the same day will be recommended as well (Tcha, 1984). It should be stored in the appropriate location on the day of arrival in the luggage warehouse, this does not affect the storage space, so it is noted that going to storage at the same time without overloading, other errors in the transaction and the increase in production loss. This can be difficult to perform in a container store, other than preparing, filling, distributing, and loading. However, this can be a disturbing for any other activities in the store, Storage can used to put the lanes on hold, resulting in traffic jams in the receiving area. The same can done assort times later, which can damage the production, and these documents can move with a high priority. Order collection,

shipping, follow-up process, and proper staffing must do in the store. In the long term, this improves and redacts the way it is leading to the success of the archive. But here the resources need to be used for outsourcing (Meyerson, 2001). Tracking and tracing processes are performed in the following manner: Finished goods are produced from the manufacturing plant, where the loading area or storage location is determined by date, code number or product date. This can do the most efficiently, the storage place is sent to the last site of the factory's production area, which is said to be used by the best companies. This process requires at least the storage space and the storage product can be re-used as soon as possible. It is said that a more complex storage management system needs to be better operational for this system. Automatic server systems are used for location positioning and direct positioning within the warehouse (Geoffrion, 1974). The most advanced and experienced companies say they are using their storage management system to save time. Thus, the best positioning paths can be selected, which results in the ability to plan for road shortest paths and low road traffic to plan for road construction.

Cross docking - Cross-docking refers to changing or storing inventory as a product of direct marketing to consumers or retail stores. Cross-docking usually occurs in a distribution docking terminal within the store. Usually there are large doors in the outer and outer sides of the storage room with storage in the cross-docking terminal. It is said that the cross-loading of the outer cartoon into the outboard container with the process of getting the product through the loading point is easier for the cross-docking facility (Sule, 1994) Cross-docking Place is an intermediate place where inventories are left undamaged. From the finished goods manufacturing factory to the central warehouse or to the cross-docking station, they are then sent into the distribution trucks for distribution (Eppen G. , 1988). This new cross-docking concept can reduce the storage space of all finished warehouses. It is revealed that this cross-docking concept is widely used by warehouses from Europe and the West countries. For example, this concept was implemented to provide the products of other countries, such as America, soon. The Asian tendency for this cross-docking concept is extremely low (Teo, 2001). Vietnam is the only country in Asia where action is introduced to introduce the cross-docking concept to the distribution of coke

beverage products. Therefore, this study will help analyze the first possibility to implement a cross-docking system in a ready-to-use warehouse.

Oder picking - It may be necessary to order picking at any time in a finished product store. All these orders said to be the collect deferent goods form stores. Some orders are said to be loaded at the same carrier or on the same distribution line at the same time (Erlebacher, The interaction of location and inventory in designing distribution systems, 2000). If there are any parallels between the orders that are loaded into the jar when storing in the warehouse, they should be used at the same time for the picking. As a rule, it is expected that orders will be completed in a day to complete the collection of goods in a timely manner. Apart from the general selection method, there are two more common methods of choosing and grouping and selection of areas. Select multiple orders at once to select group selection. The area selection method is used to divide the storage zones into zones of each region, to match them with one or more individuals selected in the region. In addition, it is said that the zone can be divided into regions and zones. Serial zone selection the parallel flows are selected in the flow-line mode. Finally, the pickle men in each region carry the products they added from their region and are put into the basket. Then the basket will be sent to the next area. Another method of selecting is the selective grouping of similar sections in each zone. But this is not limited to one region. In the selection of a parallel zone, the vehicles in each region are assembled at once, and a list of selected items for proper packaging is selected for proper packaging. After harvesting, the cans are sent for processing and packaging. The process of processing divided into assort methods: single preparation, group classification in preparation, post-order sequencer preparation, sequential sequencing with one preparation, guessing in a solution, zoning without solution. These methods described as regional zoning with solution. These studies performed to select one of these. If you have compiled the samples in each of your samples, it has indicated that there are assort types of systems that can classified according to the number of orders. The general efficiency of the method used can be measured by various criteria, such as the normal daytime work, long and delayed orders (Daskin M. , Network and Discrete Location: Models, Algorithms, and Applications, 1995).

Loading & Distribution - Generally, trucks are said to be used in container handling. Most finished stores have commercial and industrial buildings. Loads vary according to the passion of these goods. However, the maintenance of the transport corridors is advantageous, and it is advisable to have an exceptionally appropriate level of access to the warehouse. It is necessary to use correct methodology in store operations. It shows that the correct machine can be loaded without loading the correct machine. The craft that must be joined must end up with a few and have different methods for storing for a variety of reasons (Stull, 2004).

### 2.1.4 Why need warehouse Optimization

Our warehouse operations are the foundation of our business. It is affects everything from row material to finished product of the doors of our customers. Whether it is a small business or a large corporation, warehouse optimization should be the main concern. No other business area has greater potential for overall improvements in efficiency, accuracy, speed, and budget. To make sure that our warehouse is working successfully, we need a well-designed warehouse scheme and find out how our warehouse plan affects our ability to process orders efficiently and how we can improve this to optimize our operations. If we manage the warehouse, we need to understand the number of movements that they cover. Thus, it may seem impossible and overwhelming to run it all the time. However, if we single out the common pain points in the warehouse, we can get a clear idea of how to optimize each of them. Here list out our problems that warehouses face and already identified.

- Disorganized layout
- Inaccurate order processing system
- Lack of team communication

## 2.2 Methods of warehouse optimization

This section focuses on the theoretical background as well as the realistic background of overall storage optimization methods. The research also examines the various pragmatic studies conducted by other researchers on the warehouse space and warehouse operation optimization as well as the conceptual framework adopted for the research framework, which are relevant to this research. Further, there is a

summary of the research findings of other researchers, which can be summarized as follows, Space Utilization by Lay out, Space Utilization by racking, Cross Docking for optimization, Lean concept for optimizing, Warehouse Management System optimization etc. The methods of overall warehouse optimization are vast area therefore to reach this research objectives on overall warehouse optimization and only relevant topic have been covered and fallowing topics are structured as fallows.

- Overall Structures
- Layout plan
- Information System
- Operation Strategy
- Equipment Selection
- Management Principal

### 2.2.1 Overall Structures

The one of key success factor for effective warehouse is proper building location and plan at warehouse design stage. Unless unproper plan create problems therefore first need to finalized material flow path and according to material flow then arranging building structure and other utility building location with avoiding obstacles to main material flow. This flow diagram should be completed at design stage cause after finishing construction building relocation or rearrangement is high initiative cost projects there for some time it is not cost effective.

Material Flow Planning in Warehouse Layout

It is said that designing a warehouse is one of the most principal factors in warehouse design. One of the advantages of managing the warehouse with a proper design is the ease of tracking the location of the warehouse and the handling of the equipment. This information shows the ability to better manage the warehouse. There are two

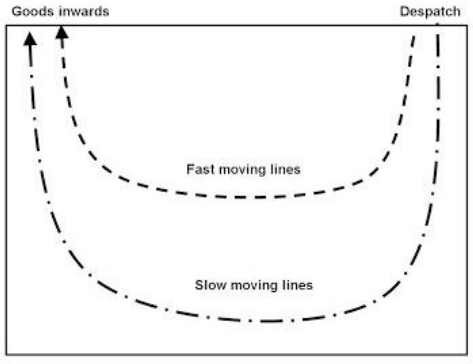


Figure 2.1: U flow Layout

Source: (Rother, 1999)

main types of transportation plan of a commodity: the 'U' flow and the 'through' flow (Johnny, 2007).

The bundle flow method is used as the U-flow method when the goods are received and loaded at the same end of the store. It is pointed out that the goods will be referred to the warehouse located behind the finished goods depot, which will then be sent to the reception point near the reception area on the same side as the loading of the warehouse. Here is an example diagram of this U-shaped flow configuration system design. The advantages of the U-flow structure should be explored. The following advantages can be found in the following reports: loading pools, loading, and unloading pools for greater use of pool resources for truck receiving and loading operations. Adjacent, for ease of cross-border operation, storage and other functions Instead of increasing the use of the equipment and work ț able to integrate, easy to use, because the monitoring can be done, because only one side of the building entrance and exit to provide security, the advantages of this particular flow is

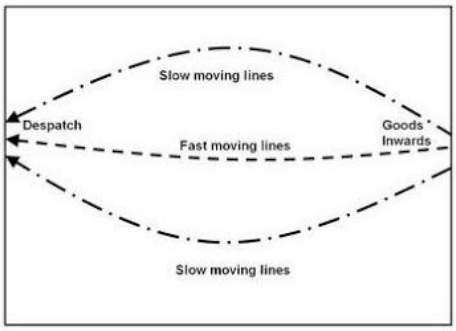


Figure 2.2: Through flow Layout

Source: (Rother, 1999)

gradually Windows Unutilized said.

The other way of designing inventory flow in a warehouse is through the flow method, in which the goods are transported across the store and there is a separate position for loading the goods. Once the products arrive at the reception area, they will then be sent to the warehouse and sent to the storage area and then sent out to

the load area after the outer cartooning process will be dispatched to the same straight-line. The longer the items are in the center of the store, the shorter the distance to travel. The figure 2.2 shows an example of a layout implementation with through flow layout. The main disadvantage of the throughflow structure is that the commute must cover the entire length of the warehouse. It takes time, efficiency and effectiveness will be reduced, and it will be difficult to control the activity of the garbage and reduce the flexibility of the bulk carrier (Miranda, 2004).

### 2.2.2. Layout Plan

This section focuses on the warehouse internal layout arrangement as well as the vertical space utilization and optimization methods. Therefore, first discuss about standard utilization calculations. The calculation of the storage bin utilization of the finished product is a straightforward process. Start by calculating the total volume of your warehouse. Then subtract any areas that you use for purposes other than offices or restrooms. This measure indicates the percentage of actual used space relative to available space. This indicator helps to assess land use and warehouse optimization. (Piasecki, 2002)

$$\frac{\text{Total storage space in use}(m^3)}{\text{Total storage space available}(m^3)} \times 100\%$$

A high-level storage plan-material, people, and energy-is efficiently and effectively used to promote the storage and use of materials, as a storage plan. The main objectives of the Warehouse Plan are to identify unit cost reduction, improvement of quality and lifetime, promotion of people's efficient use, equipment, space and energy, employee convenience, security, cost control of the warehouse and respect for objectives. You can The Excellent Warehouse Planning process consists of the following steps: First, gathering the necessary data and information, then identifying continuous operations and support services, flow analysis and then designing the plans. (Frazelle, 2002). To get the most out of the design, you need to set separate places for each task. A maximum storage plan can be created by maximizing the two variables such as the amount of storage and the number of luggage kits. Store and store items in the best store schedule in a lesser area of

storage Efficiency and productivity are mentioned. All the space allocated to tools and bundles in a warehouse is reduced day by day. Scheduling and collection respectively / special conditions Once the test procedures have been completed, all of these will be sent to the cross-dock area or into the loading area as same time, with new facilities, analyzes and prepares data for activities carried out in the data in the current and projected projection of the warehouse (Nozick, 2001).The storage locations and more, and the details of the recipient's stores are also supported through the information system through this process. The principles of the final product storage system have a well-defined common vision of a plan and performance, Use the most appropriate and easy to use unit trust, maximize space in storage, design unnecessary movement, control movements and location, create a safe environment, and minimize total operating costs. Also, in the case of storing goods for storage of goods, the following items should be stored in accordance with the following principles: maximize the use of storage space, maximize the use of equipment, maximize the use of individual labor, maximize access for all items, maximize all goods It is a good thing to do it. Although the goals of optimizing the stock configuration for finished products are easy to see, problems with stock configuration for large varieties of products that need to be stored for the various storage spaces required should focus on abrupt changes. demand for products. For this reason, the location of these problems is necessary to complete storage. The start of warehouse planning is one of the most appropriate moments for the entire decision-making process and determines the requirements for all warehouse requirements. The house branch should replace the letter that meets the needs of clients throughout the construction process, to avoid complications and increase the efficiency of warehouse operations. It is not only about how to effectively use the space of the largest building in rotation, but, for example, about the effective use of the quantity of goods received and the number of receivers for the space of small boats and the calculated sides of reception. Doc The whole pack received. It is frequent practice to use the space in the warehouse behind the platform to match the doors of the forklift, and the load on the truck is worth the result. The processes in other areas considered in space planning include cardboard collection, storage of pallets, collection of defective cardboard boxes, packaging and unification,

customization, and overload. Bearings should also be designed for current and future expansion in order to adapt to the changing growth and size of the business, the size of the offices and warehouses in the building, and the integration of new SKUs and new products (ReVelle, 1993).The objective of optimizing the partition configuration for each function in a finished warehouse is to create a large product warehouse without causing changes to the storage. Demand for the products varies greatly. For this reason, reserved space needed to minimize storage problems. The initial stage of a store's initial planning is the best time for its overall decision-making process, and it is important to make decisions on all storage needs at that time. A storage environment should replace with stock configurations to avoid complications of storage operations to meet the storage needs of the construction process to increase the efficiency of operations. The number and size of the store's considerable number of bands is a crucial factor in planning how to best use the large space in the store. The complete design of the warehouse should be designed to fit the forklift, and it is customary to use the front or rear space of the warehouse for the unloading platform to accommodate the truck's load. Another area of consideration when designing storage space, the other areas of operation include cardboard collecting, pallet storage, defective cardboard boxes, packaging and integration, customization, and overloading. The number of offices and warehouses in the building depends on the growth and size of changes in the future of the business Plans must be drawn up for current and future expansion to integrate new SKUs and new products into the space (Fransoo, 2000). It is said that the warehouse area should be easily adaptable to modify or add new features, such as offices, data centers, lighting, industrial manufacturing, and other special places on the ground or in the building. It should note that configuring the truck and forklift parking space for the work of the volume of goods to supplied in the future will significantly change the storage space. Functioning as a Carrier System It is stated that in order to use a system that is designed to be simple and efficient, there must be a basic wide choice in the design of an abortion, as well as a continuous path from the center of the warehouse to the warehouse. The storage model provides all the details for the future for the ability and processing of equipment. A store's fire protection systems are designed to maximize the disposal of separate materials, especially when stored in a high content

plastic container, such as welds and pallets wrapped in plastic, so that even the most flammable material will not burn. In a warehouse, you need to use a higher level of space, in which to ignore other returns, and improve the advantage of the property (Erlenkotter, 1978). For example, you may need to have tools to protect yourself from the fire in the design and use it for other designs. Different companies use unique designs to store the same product. It is said that different external factors influence the basic design and layout of the store. But the optimal level of these external two elements should be considered in designing the overall layout. When designing a warehouse, the size and configuration of the warehouse area should be designed so that the equipment and vehicles needed to access the warehouse can be accessed. Specifically, the volume must be set to make it accessible to all types of vehicles in the store. It is stated that the initial development plans of a store will have a significant impact on the organization's development plan. When planning to use an existing building as a warehouse, it is important to take into account the location characteristics of the drainage and soil areas as well as the financial, rent, maintenance costs, investment grants and construction factors (Nagy, 2007). These are key factors that should be considered when designing a warehouse distribution facility in a warehouse. These are important factors that can improve the layout of the store and increase its efficiency, giving access to all items without tightening the movement of the equipment, identifying the bulk and code. , Store location, inventory transfer rule (FIFO), testing facilities, timely inventory Refilling of Stocks Transport of goods in and out of the warehouse is a matter of supervision, security, warehouse security. Interworking roads in the finished warehouse should have a well-planned design that is designed to maximize the use of storage space to plan one of the goals of the store. The width of the roadways and the design of the forklift or other equipment for travel should be sufficient. The best way to do this is to plan separate routes for pedestrians and forklifts. Some areas of the warehouse should be allocated for other storage purposes, such as storage areas, staging or temporary storage areas, as follows Required office space, washroom and lunch room, areas for repackaging, labeling and marking, areas for storage and maintenance of equipment, and areas reserved for hazardous or high value items. From inventory operations, reserve stock to the main repository, forward ordering and logging out There are five

main areas of virtual storage operations, the details of which are as follows, upon receipt of the goods, the receipt is checked and then temporarily detained for inspection and inspection. The goods are then inspected. Then the location of the product is determined. By doing this, the process is terminated, and afterwards we must negotiate actions (Edward, 2002). After the WMS operation, we must ensure that the location of the goods is located. To locate items in the reserve storage areas, it is necessary to confirm the positioning of the items. In addition, the items selected for consumer orders should be placed to fill the loading stock. Packages should be packaged and evaluated the goods must be assembled according to the vehicle or vehicle (Baita, 1998). These areas and operations can be illustrated in the fig 2.3:

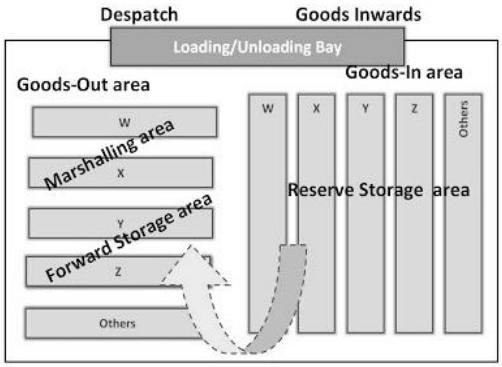


Figure 2.3: Typical Warehouse Layout Plan

Source: (Rother, 1999)

Space Utilization by Racking System

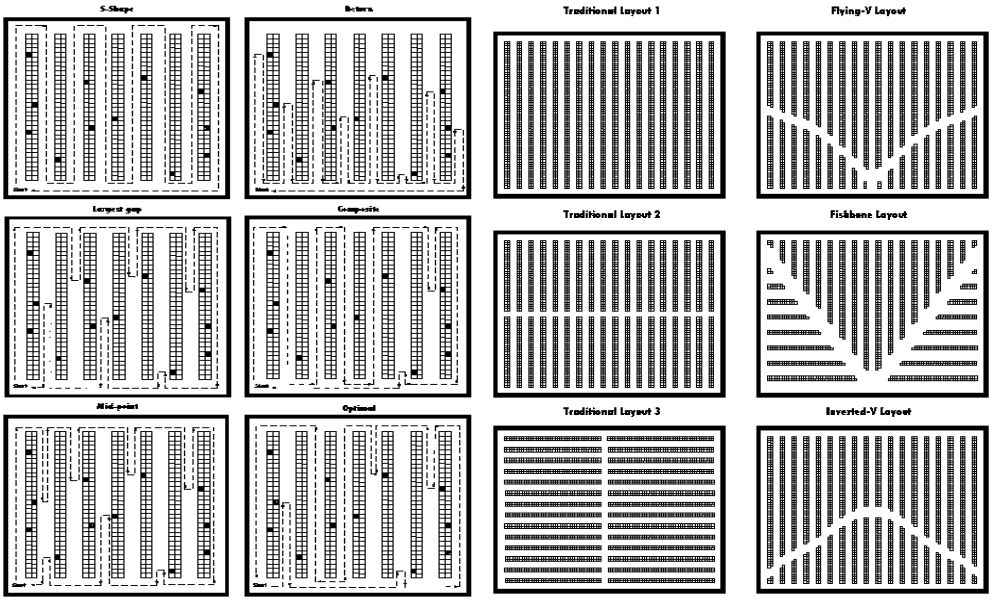


Figure 2.4: Type of Racking Layout plan

Source: (Rother, 1999)

It said that one of the key elements of optimizing the store layout of the warehouse is that it has a significant impact on the selection and handling of the warehouses in the warehouse. The studies have suggested that the warehouse storage design affects more than 60% of the total travel distance. These tools come in three types of storage layouts. In the first, the parallel pavements have introduced, and it is a useful design. The layout is usually rectangular, and the palette is easy to manage. Historical studies report that several key factors must be considered when designing the structure of the warehouse for storage, for example, the number of blocks, the length and width, the number of rods, the number and shape, the number of shelves, and the number of doors to the store Which is important (Meyers, 1993). The second method introduces the V-shaped and the new small-bore barcode, which can reduce runaway speeds from 10% to 20%. It presents an analysis of the bundle order and the structure of the warehouse structure suitable for double orders. When two orders are placed simultaneously, the worker arranges the goods in the order and sends them to the warehouse, then returns the goods to his place of delivery. Improvements in this method can save 3% of distance and time. (Stull, 2004). The layout of store shelves is usually a narrow pitch. It is said to have more storage space with less space and is likely to increase costs and increase operating costs. One of the most common methods is to choose the most appropriate of these strategies. A warehouse partition unit (SKU) used in storage is one of the smallest physical units in the range of a storage representing one of the units. It said to be used as a storage packaging, internal packaging, cartoons, and single boxes that can be made into large units. It stated that each company manages of the Anne's inventory management systems according to their SKUs. One SKU is the number used to store stocks in a warehouse and assigned a number assigned to the type of production unit for a product for the purpose of storage. The companies use this code to identify a specific product unit. For this reason, each product item must have an SKU number, and each SKU number represents only one container. (Gao, 1994). There are types of shelves that can used in pallets to store finished products in a store. The most common are continuous racking systems, deep racks, double deep racks, and push-pull racks. A brief description of each of these shelves can be summarized as follows, one of main racking system is flow rack system, this racking system consists of two main

components, the racking rails and the dynamic flow structure in a fixed component. The rack runs on the rails with the roller system. It stated that the gravity generated by the gravity made to move from one end of the siding to the end by weight. Each lane of the rack contains a flow rate regulator which controls the rate of movement of the bands. The back of the rack used when unloading into the store's shelves. And this type of rack system only must use one direction when delivering items. But this inventory control makes it quite easy to manage inventory when using these shelves. The cost is minimized, and the cost of equipment is only required for initial loading and eventual disposal, thus saving time and effort so that the warehouse staff can perform the procedure and focus on other tasks. This method automatically reduces the traffic in the store. These shelves have been shown to increase the storage capacity of the store by increasing the storage space. (Johnny, 2007) Single-deep Rack is One of the most common use racks This is a rack configuration where all the pallets belong to the pallet at the same time (Hansen, 1957). This rack configuration is used to store items in all industries today. In this way, the warehouse can be used efficiently, as it uses truly little storage space and instantaneous access to all the necessary storage items and items. The height of the shelf system of a store is determined by factors such as the height of the roof or the roof of the store during installation. The rack frame is made up of horizontal and vertical frames that carry all the weight based on these horizontal parts of the floor. These frames are made up of high-strength horizontal beams connected by front and rear columns, which allow the rack to be resilient or unstable. This shelves plan is best suited for the simple and quick selection of storage. The main advantage of this method is the bulk goods. This method is not suitable for a store. (Erlebacher, The interaction of location and inventory in designing distribution systems, 2000) Double deep rack is a rack system that is almost identical to the shape of a single deep rack, but the difference is that there are two loading points. The advantage of dual deep shelves is that two shelves can be used together to make storage room more efficient than single shelves and maximize storage space. This rack configuration is most used when the SKU requirements of a store are high, and the product is frequent. This method is most appropriate when it comes to the store. Also, it is important to consider the storage racks in this rack system type, since not all lift machines can be used to reach the rear

sufficiently for loading. (Wesche, 2012) Push-back Rack is A pushback rack system is designed with a carrier that guides each pallet. For this to be done, the pallets with the following containers should be pushed inside the bundles on the rails below. It is said that Push Back Rack uses common input and output in a system. In this case, the luggage is inserted into the rack and retracted in one place, so it should be used for maximum use. Each storage channel has its own pallet holder set and operates separately. The pallet, with the last shipment, is placed on the tracks, and the pallet with the first loaded pallet is located inside the shelf. Booting is done in the opposite direction in the loading procedure, so the first entrances will have to be over. This is because the shelf system is suitable for non-storage purposes. (Bostel, 2007)

### 2.2.4 Information System

There are two types of computer systems in a warehouse: Storage Management Systems (WMS) and Storage Management Systems (WKS). A warehouse management system is defined as managing the operations of the warehouse and dealing with the warehouse. The normal operation of a storage management system in the warehouse involves the exchange of trade data and the deposition of such data. Most storage systems currently have a new module with modern Enterprise Resource Planning (ERP) systems and SAP systems, but this method requires separate applications. One of the key functions of a warehouse management system is to work as a high-level hosting system and obtain, provide, and manage information about day-to-day storage operations. At present, most systems do not need to be updated by storing staff information, because modern technology enables them to automatically add all that information to the system. Any storage control system usually has an operational level interface capable of managing people and equipment. The functionality of the storage control system includes the following basics: the ability to transmit information and manage all automated equipment and machines, the ability to schedule and process processes in the entire warehouse, performance monitoring and record performance, Having a graphical user interface for simple viewing, Other The ability to interact with management information systems. Realizing these factors can help you determine the key factors such as store efficiency, effectiveness, utilization of space and the following, The

latest tools should be integrated into information management systems, such as WMS Warehouse Management System), LCS (Location Control System), AS / RSs (Automatic, Storage and Retrieval Systems), IS AIS (Automated Inventory System), MS RMS (Record Management System), F RFID (Radio Frequency Detection)

### 2.2.3 Operation Strategy

As an operation strategy work force planning is an essential factor for warehouse operation optimization therefore most commonly company admire to establish performance indicators on this. The basis of workforce planning should be to evaluate the current situation and analyze history data to focus on improving the future situation rather than the present. The main plan should be prepared as follows:

- The right number of people,
- With the right skill sets,
- In the right location,
- At the right time,
- At the right cost,

Labor Productivity

Labor productivity is a measure of the maximum amount of output an employee can provide. The measurement calculates from the production produced in relation to the person-hours devoted to the production of this production. This measure helps to evaluate the optimization of finished goods warehouse operations and represents the effectiveness of skills and work.

$$\frac{\text{Output (amount of handelled annually MT)}}{\text{No of man Hour (annually)}} \times 100\%$$

Overall Equipment Efficiency

As per previous study summery utilization rate of machinery and equipment can be measured using the overall equipment efficiency (OEE). The metric that examines globally and multiform the degree of use of equipment and machinery in the warehouse. The OEE measures the overall use and efficiency of finished product storage facilities in a calendar year. The measure (OEE) can be divided into four

main categories. They are the four obvious and individually measurable parts: Load, Availability, productivity, and quality. (Cedarleaf, 1994).

$$\text{OEE} = \text{Loading}^* \text{ Availability}^* \text{ Productivity}^* \text{ Quality}$$

$$\text{Availability} = \frac{\text{Scheduled Time}}{\text{Available Time}}$$

$$\text{Productivity} = \frac{\text{On Time}}{\text{Available Time}}$$

$$\text{Quality} = \frac{\text{Maximum Operating Time}}{\text{Available Time}}$$

### 2.2.4 Equipment Selection

The main objective of finished product warehouse is storing and distribute finished product efficiently and effectively to achieve this objective should be optimized several areas. Under this topic, discussed about adoption of equipment and technologies for optimizing finished product warehouse.

In a day-to-day operation, a store uses a variety of tools to perform individual activities. Upon arrival at the warehouse, you can optimize the functionality by using technology and specialized equipment in the process of storing the goods, selecting the brands as needed, and loading the selected cargo. The key factor is determining the right storage equipment for the purpose. It is necessary to consider what kind of product bands are stored here. Equipment using a standard finished warehouse usually consisted of easy-to-use technical and static components for easy positioning and moving of products. (Baita, 1998).

From start to end point of goods movement have been combinations of activities and steps. As a first step after receiving finished goods to warehouse should be unloaded from receiving vehicle for that mostly use unloading forklift if use palliates to storage goods. The equipment that can be used for unloading goods can be changed with type of finished product it like be automated crane, conveyor system or unloading bin like that. The optimized warehouse should be select most suitable equipment to unloading finished product considering type of material. After

receiving goods to warehouse boundary, the second step is placing storage of goods by using suitable equipment as shelves, boxes, containers or pallets, archive cabinets. The handling equipment size, type of equipment and numbers of equipment is depending on the range of product placing on the stock.IN warehouse process the order picking take as a third activity. For order picking can be use assort types of equipment and technologies to achieve picking efficiency. According to type of finished product the warehouse uses deferent type of picking methods to fulfill customers' orders like zone picking, wave picking, claustra picking, batch picking. The selection of picking method depends on type of goods and type of equipment and method that using to piking goods. Most commonly pallet truck, forklift, hydraulic stacker, heavy range lifting crane, mid- range lifting crane, weighing machine are using for those warehouse operations. The selection of equipment for warehouse operation is main factor to optimizing operation as well as equipment allocation plan is second factor to optimize warehouse operations. Therefore, available equipment should be carefully plan and allocate to each activity as fully utilized in each equipment (Sourirajan, 2009).

The properly panned equipment should be support to warehouse activity, but then equipment does not meet the desired requirement then the situation of warehouse is getting worse. The same of most frequent problem can be list out as below.

- Not enough of machinery
- Machinery used for a wrong purpose
- Lack of maintenance
- Unlabeled shelves
- Inflexible storage equipment

### 2.2.6 Management Principal

With development of industrial technologies companies' trend to acquire new management concept to optimize warehouse. In present world have been developed more efficient and effective management concept as usual to any type of warehouse. Therefore, under this section discussed about most relevant principles to finished product warehouse.

Lean Strategy for Warehouse Optimization

It is critical to make the supply chain of any organization more efficient and effective. It is said that all the manufacturing processes of the company are completed only after the product has been delivered to the end customer (Sourirajan, 2009). It is evident that the role of band storage, which is one function in the supply chain of any organization, plays a significant role in the entire supply chain. Here is the product bundle of the manufacturer. From the factory to the end consumer. It said to carried safely. Older study reports show that the operational cost of a finished warehouse is high because the operations do not create added value in the operation of the warehouse. Therefore, the main need of the warehouse is to increase the cost and efficiency of the warehouse by adding value-added activities to all operations and eliminating other activities. The key to this is the use of core elements of the Lean concept of activity value mapping. It means that all the value-added and non-process-all processes used in the process of obtaining the product through the process of the store taken together in the same way. After a value chain analysis of operations from the beginning of the store to the end-to-end customer journey, the entire repository is processed to eliminate non-value-added processes such as acceptance, storage, processing, and ordering. (Rother, 1999) A previous study showed that 55% of all average warehouse costs for a finished warehouse are for non-performing activities. (Abdulmalek, 2007) Therefore, minimizing the number of activities that have not added value to an archive, can reduce the additional cost within the store, thereby keeping track of the goal of operating costs.

Total quality management in warehousing operations

TQM is a management technology that helps to build the quality and storage of the store to achieve long-term goals. According to past reports, TQM can have a significant impact on products and stores. Depending on the quality of a warehouse, this can be divided into several major factors: the first factor is the reduction of product waste. These two problems are due to wasted storage space or unnecessary waste disposal. The company is well known for its ability to prevent waste generation by transporting and storing it through rigorous inspection and supervision throughout the company's supply chain. If a defective product arrives at the

warehouse from the manufacturing factory, it should be disposed of as waste and disposed of as soon as possible. TQM's main concept is to minimize product shortages at the same time the product is manufactured, since these items cannot be used for major operations as these defective items have to be retained in the store until they are disposed of. It is imperative that an excellent quality control process be used to evaluate the entire process, from the raw material to the product to the storage of the finished product. All products must correspond to a quality process or product. If an item is out of specification, it must be rejected immediately during the production process and in the store (Nozick, 2001).

Iso certification for a warehouse

ISO is a quality certification that states that a store or company is committed to the quality of the store. This also makes it possible to measure the progress of the company's continuous improvements in the storage infrastructure and to ensure its quality. If a company wishes to obtain this certification, everyone in that company should be aware of what is involved, and all should contribute to its implementation. Getting this certification will improve both the credibility and quality of the company assurance will help improve the relationship between suppliers and customers. It helps people gain the confidence and knowledge of the product and helps new companies achieve ISO quality standards. It is said that increasing the knowledge and confidence in the factors directly impacting on this certification will increase the operational efficiency and operational control of the store. (Üster, Benders decomposition with alternative multiple cuts for a multi-product closed-loop supply chain network design model, 2007) In addition, good housekeeping should be an essential part of the first-class store, and the abysmal, disconnected, or unclean storage place is said to be improper. Poor cleanliness of the store is responsible for the formation of massive quantities of waste resulting in damage and safety problems. Problems caused by poor cleaning conditions at the warehouse include additional movements, time spent searching for things, delays due to faults, malfunctioning, and hazards to the storage and efficiency of the warehouse. Therefore, creating a safe and efficient warehouse requires the creation of a well-managed, basic operating environment in a warehouse (Jaillet, 2002).

Key performance indicators

By doing so, a warehouse KPI system is maintained. This is to increase the competitiveness of each other. Thus, by setting key performance indicators based on the critical success factors in the warehouse, the business can achieve even higher growth momentum. A correlation between KPI and CSF can be identified. When developing a KPI system by a company it should be based on these principles, it is necessary to identify the appropriate CSF for the finished warehouse and then analyze the core competencies and core competencies of the warehouse compared to the CSF, then combine those basic skills and new skills It says that you need to benchmark the store's competing benchmarks, and then you go with KPI. For a firm to gain a competitive advantage, they first differentiate between the core competencies and goals of their warehouse. It is essential to identify KPIs that will develop the basic skills and core competencies for warehouse operations and warehouse management. (Wesche, 2012). In general, the following eight performance indicators are used for the basic functionality of a store: the most important goal of a store is to deliver customer service by delivery trucks. Performance indicators include product quality, selection accuracy, punctual loading, shorter loading time, security of storage products, open quality performance, acceptable cost, and meeting the client's needs. These elements are as a prerequisite for the KPIE in an 8 store. Therefore, Decisive points for the improvement of the store are that they understand the performance indicators 8 on how to correctly identify and identify the KPIs for improvement and management (Sourirajan, 2009).

# CHAPTER 3 CHAPTER - RESEARCH METHODOLOGY

## 3.1 Introduction

This chapter explaining with illustration of define philosophy and methods of use to approach research objectives. This chapter structured as fallowing, first sections discussed about theoretical research design and theoretical research frame work, then discussed about data collecting methods according to full fill research frame work requirement and then discussed detail about analysis that best suit for this research and finally discussed limitation of this research by analyzing demographics factors.

## 3.1 Research Design

The main objective of this study is to improve the efficiency of the storage space of the warehouse and to improve the efficiency of the existing warehouse. Quantitative technology is used to make assumptions about the impact of the store's current receivables, store layout and inventory, and to describe the data required. In

addition to six-factor optimization, the methodology was designed to be based on these six factors, but operational optimization is a separate optimization in this study. Based on the above findings, which were obtained in the context of this research.

### 3.1.1 Research Framework

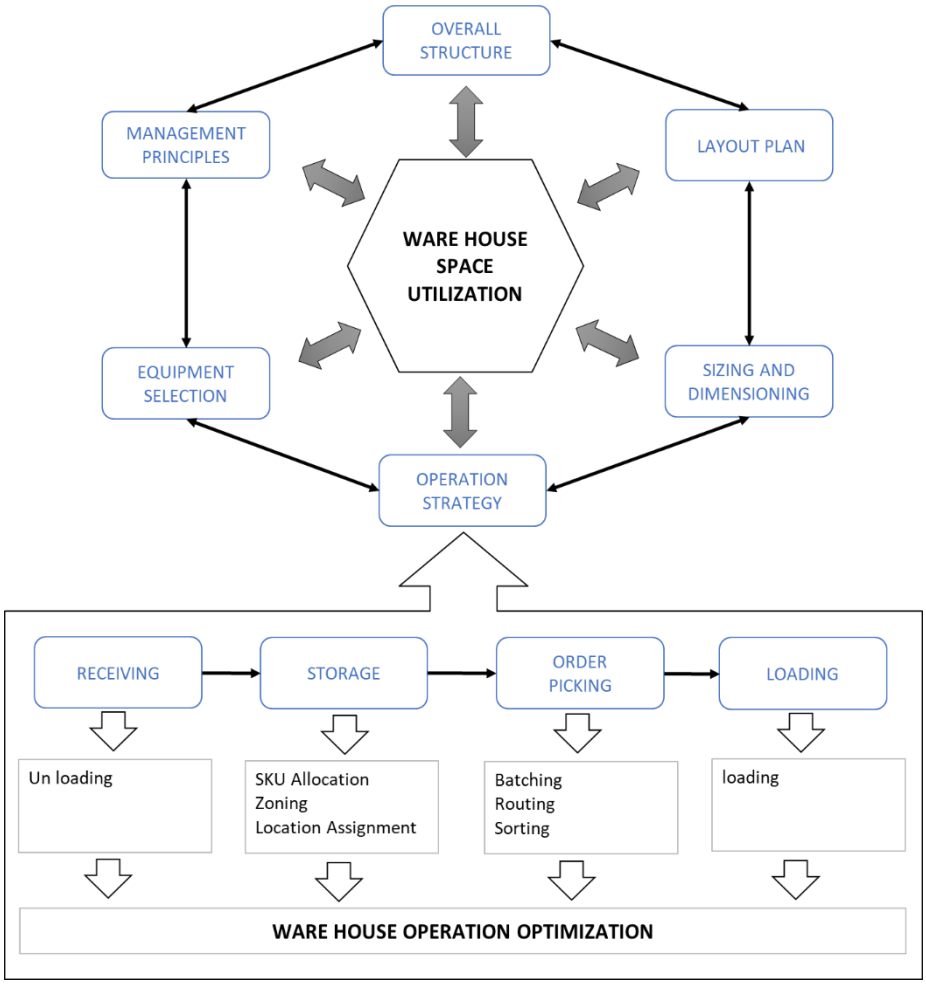


Figure 3.01: Research Framework

Then the worst case in the relevant warehouse case must be determined by analysis of the questionnaires and secondary data can be identified, with the focus on the next stage. Since the research framework that builds up has six major factors that are important to warehouse optimization, these are those factors

1. Overall Structure
2. Layout plan

3. Information System
4. Operation Strategy
5. Equipment Selection
6. Management Principal

### 3.2 Data Collection

To make this study a success, data were collected as primary and secondary. Primary data were collected using a questionnaire to obtain information about the conditions of the store. The questionnaire is made up of eight sections. The first part included questions on the quantitative other sections with questions about the specific objectives of the study.

#### 3.2.1 Primary data

Primary data is collected from the questionnaire. The questionnaire design for the consideration of warehouse staff to gather information about warehouse activities, time consumption, operations, and behaviors. Questionnaire was also developed to extract information about the degree of current storage optimization as well as the challenges of optimization plan in this company. The most appropriate optimization method for the selected department store is determined using this questionnaire. The camp population is 20 and the sample is the total population.

Overall Structure of the questionnaire – Appendix 1

#### 3.2.2 Secondary data

Secondary warehouse data collect from historical and ongoing data records. Consider last three years data records extract required data for this analysis as below list,

1. Warehouse space capacity, Overall plan, Drawing
2. Inhouse layout plan
3. Available SKU details
4. Daily Production input details
5. Daily sales Output details
6. Available Handling Equipment details
7. Available workforce details

8. Current loading unloading process
9. Semi-truck turnaround time details
10. Other historical warehouse operational data

### 3.3 Data Analysis

In this study, two phases were explored in the first phase to identify factors relevant to inventory optimization, based on the case study "Warehouse for this study". For this reason, the information collected is used to provide a comprehensive analysis using two methods of data analysis. The two methods are quantitative data analysis and factor analysis using qualitative statistics, ratios, and correlation analysis. Efficiency and productivity ratios were calculated to determine the level of optimization currently used in this company's warehouse. Correlation analysis was used to identify the relationship between the layout of the store and the current level of optimization of the store, and factor analysis was used to analyze the challenges currently facing this company's store. Questionnaire data and analyzing by using both qualitatively and quantitatively methods then presented with using tables and pie charts. Twenty individuals are supposed to fill questionnaires were distributed to all warehouse employees in company and 18 replies were received, representing a response rate of 90% in the study and only two individuals did not respond.

#### 3.3.1 Demographic factors

The first phase of the research was aimed at identifying factors for the optimization of the warehouse for finished products of the company A. To find out, the study conducted a case study on Company A's finished goods warehouse and collected questionnaire data from warehouse staff. The demographic characteristics of the respondents included in the survey included their length of service in the company, the nature of their work, the warehouse system used, and the equipment used in the warehouse, and the level of education. The purpose of this analysis was to identify features of case study optimization and then, in a second phase, to develop an optimization model for most of the critical factors by establishing the framework for research in Phase 1. In this study, 67% of men and 33% of women and their ages

surveyed 56% between 25 and 35 years, 28% between 35 and 45 only 17% under 25 years. The employee's work experience to find out how long the warehouse has worked in its position, as shown below.

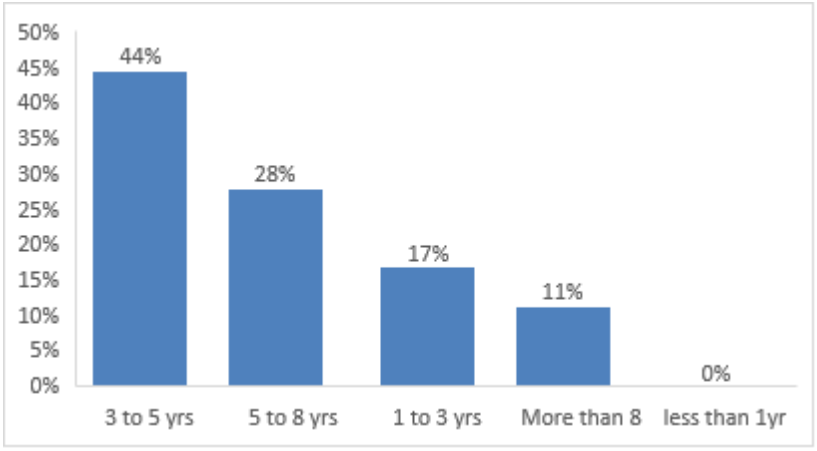


Figure 3.02: Experience Level in warehouse staff

Looking at the results of this research, it was found that 44% of test respondents worked for 3 to 5 years and were actively involved in the tasks and decisions of the store. About 28% of respondents have worked in this company for 5 to 8 years and about 11% of respondents have worked in this company for more than 8 years. Only 17% of respondents had less than 3 years of experience. These results clearly indicate that the staff at the store have sufficient experience and that the information obtained by these people for the study is an accurate and reliable source of information.

The research also examined the level of training of the staff. The company A found out that out of a total of 20 employees in the warehouse, 44% only had A / L, 33% had a degree to completion and only 6% had masters. Research findings that found that the knowledge level of the 44% field personnel does not have critical knowledge also influenced the composition of the staff in terms of storage decisions. The use of casual or contract staff facilitates the reduction of overhead because of storage costs.

However, over-reliance on casual labor leads to inefficiency due to the limited experience of employees in decision-making.

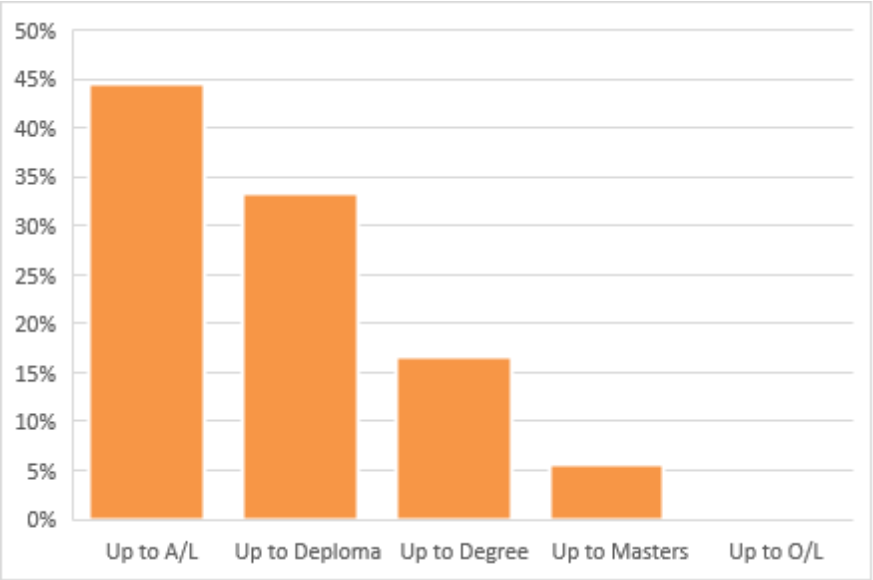


Figure 3.03: Education Level in warehouse staff

# CHAPTER 4 RESEARCH ANALYSIS

## 4.1 Introduction

This chapter presents the findings of this research, and the findings made by comparing the results of the questionnaires to the appropriate analysis. The answers given by the respondents were analyzed using factor analysis. These analyzes were conducted using reliability analysis using probabilistic statistics, and detailed statistical studies were conducted using the Statistical Package for Social Sciences (SPSS) and Excel. The results presented in the following order.

## 4.2 Descriptive Analysis

The descriptive analysis conduct by using several analytical methods, as a first method, Factor analysis use for identifying major constituent of optimization as per research framework and quantify effectiveness of each factor by respondent's experience and their knowledge. Then six constituents analyzing one by one separately with using suitable analyzing methods to determine in detail about factors

### 4.2.1 Factors analysis of Warehouse optimization in Company A

This research focused primarily on knowing the factors of optimizing finished goods warehouses at company A Ltd to understand the effectiveness of each factor and how it contributes to the degree of optimization in the warehouse. The study found that 33% of the effectiveness layout and 21% are about the operation. However, 19% of the company A stock must implemented in the information system and 12% in terms of the overall structure. Management principle and device selection are influenced by 9% and 6%, respectively, during storage optimization. The study found that company A's finished product store should focus on various levels of optimization for each factor.

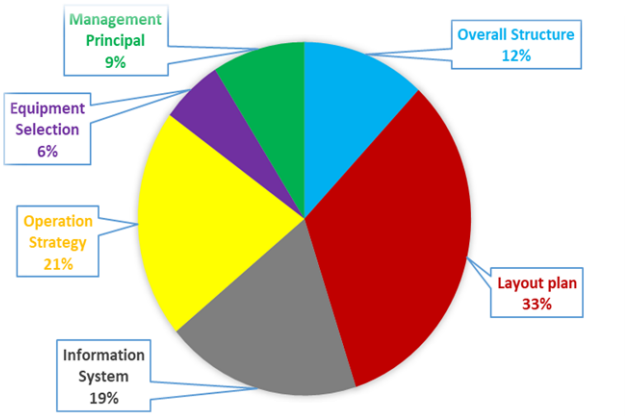


Figure 4.01: Factors of Warehouse optimization

### 4.2.2 Analysis of Warehouse Design in Overall structure

One of the main factors of six is the overall design, including plot area, number of buildings, street access, type of building, design of the building and the study that was established, although the warehouses are located in a larger plot area and therefore a rental space is available High-cost, low-demand operation can be replaced by expanding the existing warehouse. As research shows that 66% of the total area of land is not a buildable area, it can used for a warehouse expansion project and be more profitable than renting storage space outside the parties. This decision can be taken after the correct calculation of the cot to pursue the further direction of this research. The aim of the study was to determine the degree of optimization in the finished goods warehouse. The research therefore inquired about security systems that already built a warehouse. It is 87% not perfect, but good for product safety.

### 4.2.3 Analysis of Layout plan

This study focused primarily on optimizing warehouse layout by examining warehouse utilization to link the layout design strategies in Company A's finished product house to the level of optimization achieved. To do this, the study compared the total space used with the total available space. The study found that 25% of this space had use. As a result of research that the calculation of the use of space is an unused warehouse, the factor analysis showed that 33% of the site plan was the highest percentage affected. The current warehouse layout plan shown below.

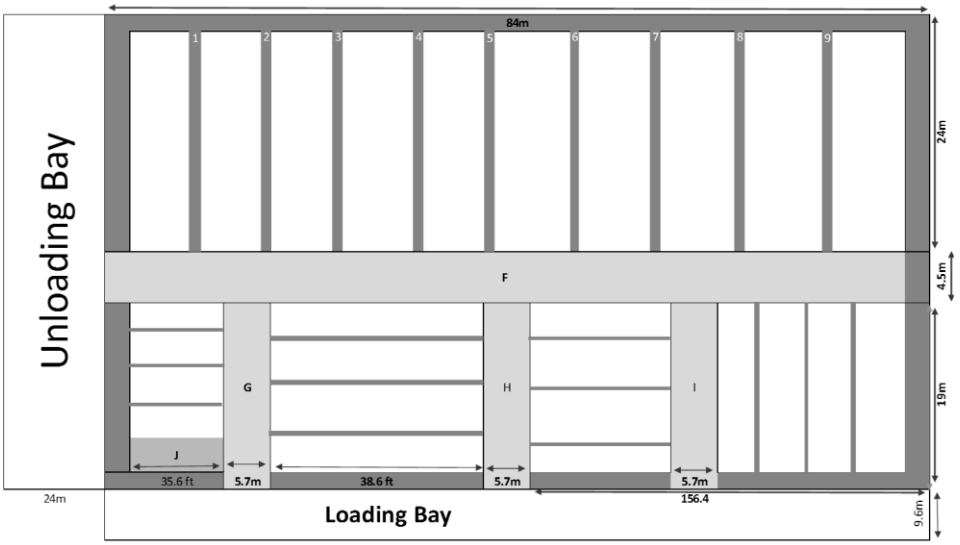


Figure 4.02: Current Layout of warehouse

In order to cascade the degree of layout optimization in the department store of company A for finished products, a cascade of factors and efficiencies was assumed for each factor, which are determined by the descent. According to the pirate analysis, the lack of cargo space is significantly influenced by the layout factor, and the second highest drivers are access and distance, as attempted in this study to further modulate the layout plan optimization model. Under layout optimization factor the questionnaire can be further drill down to below constituents and by using factor analysis method quantified each constituent based on respondent experience and knowledge.

Table 4.2: Factors of Layout optimization

| Factor | Percentage (%) |
|---|---|
| Lack of space Unloading Area | 6% |
| Lack of space Storage Area | 14% |
| Lack of space Loading Area | 25% |
| Regarding Access | 19% |
| Regarding Distance | 16% |
| SKU Categorization | 12% |
| Arrangement of Area location | 8% |

### 4.2.4 Analysis of Information System

The search referred to the information system currently used in the warehouses as a basis for understanding the process depicted below. Research has shown that both SAP and paper documents are the most used to collect and transmit information. However, research has shown that time worked twice, and time wasted. Research carry through factor analysis 19% influences the overall optimization of the information system. The further analysis to determine the correlation of factors affecting the information system, which requires 9% to make the staff more user-friendly in relation to the SAP system and the implementation of the SAP interface and the SAP system, is 23%. Need to redesign the authorization and accountability matrix, which is about 26% affected by the optimization of the entire information system (Annex 2 for the flowchart)

### 4.2.5 Analysis of Equipment Selection & Machine Utilization

This study resulted in an analysis of the type of equipment used in the bearings as a basis for understanding the chosen layout. The investigation found that forklifts are the most used equipment in the company warehouse at over 61%, followed by trucks, hand fork, pellets, cages, and cranes at 21%, 3%, 19%, 11% and 2% as shown below. The widespread use of mechanical devices in contrast to automatic devices enables flexible storage design and lowers operating costs. This study, which assesses the degree of utilization of machinery in Company A finished goods warehouses, uses the Overall Equipment Effectiveness (OEE) metric, which is

used to investigate the capacity utilization of facilities in the warehouse in a technical and diverse manner. OEE use to measure the overall utilization and effectiveness of storage facilities on an annual, monthly, or daily basis. This measure can divide into three parts as measurable components, availability, productivity, and quality. The load time indicates time amount can be allocated to the task. The scheduled load time is based on the total calendar time available. The loading time consists of the time of the efficiency of the time axis and plans to exclude the process. The investigation found that company A camps operate on weekdays in an eight-hour shift and on Saturdays in a four-hour shift (44 hours).

Loading Time = [(5days*8 hours) + (1 day*4 hours)] / (7 days*24 hours) = 26%

Availability of OEE metric A percentage of available devices is available at the scheduled time of the company. Availability is a mere measure of load time to exclude the effects of quality, quantity, and performance events. Planned downtime. 8 hours, as the provision of the warehouse for daily use is provided in the warehouse of the company A. (480 minutes), if the scheduled 60 minutes between lunch and dinner and the unscheduled downtime of the devices take the daily 60 minutes. The operating time was found:
(420 min Scheduled - 60 min Unscheduled Downtime – 60 Lunch & Dinner) = 300 minutes), and the availability metric from company A equipment and even 300 minutes / 420 minutes = 71% of the Performance of the OEE Metric represented the speed at which such equipment designed the percentage of warehouse and hardware. It excludes, therefore, the speed of the operation of the equipment to measure, for example, of the Metric Performance and effect may Availability.

In order that in this way he assumes that all equipment of granaries, as requested, with the uniform metric the course of the investigation was getting ready for a warehouse, with the very swift adopts, folk life. Riding suddenly cured scheduled to company A warehouses 8-hour (480 minutes) with 60 minutes break scheduled shift. Therefore, operating time is 360 minutes. The warehouse typically receives about 500 inventory per day and managed by the equipment in the warehouse. Research shows that the maximum time required to perform the task is

about 3 minutes per trip. The total time it takes to manage the inventory is 1500 minutes.

Performance (productivity) therefore was 1500 minutes / 3600 minutes = 41.66%,

Measuring the quality of storage equipment is another aspect of measuring the effectiveness of the entire equipment in the store. It assumed that the operator's damage is not significant compared to the total number of units managed here. This measure measures the percentage of securely managed brand units. The research established that Company A finished product warehouses managed 150,000 pellet per year out of which around 200 pellets were damaged. Handling quality therefore is (150,000- 200) / 150,000 = 99.86% Overall the study established that on average the level machine utilization in Company A was; Loading (26%) *availability (41.6%) * productivity (71.4%) * quality (99.86%) = OEE of 7.4%. The level of machine utilization found to extremely low and the research contributed it to the fact that the aisles were narrow to enable efficient use of the machines.

### 4.2.6 Analysis of Management Principal

The study also asked respondents about the management principles of how warehouses behave when they try to optimize their bearings on a 5-Liker scale. To identify the challenges, the research posed 11 questions, as shown in the questionnaire. The study also found that the level-of-management principle presented in the table below used to identify management principles.

Table 4.2: Factors of Management Principal

| Management Principal | Percentage (%) |
|---|---|
| Level of implementation of 5s Concept | 12% |
| Level Of implementation of TQM practices | 27% |
| Level of ISO standards Practices | 23% |
| Level of Practices in KPI & CSF | 38% |

### 4.2.7 Analysis of Operation Strategy

The level of labor productivity in the store further investigated in this research. Labor productivity measured by the amount of work an employee can do or

the amount of output that can made. In conducting this research, the daily output of each section calculated and the number of hours it took to produce the output. To clearly identify the objectives of this research, the number of items managed by each

Table 4.3: Labor Productivity

| Section | Man Hours | Number of pallets per day | Productivity (Pallet per MH) | % |
|---|---|---|---|---|
| Un loading | 16 | 480 | 30 | 39% |
| Put away | 16 | 480 | 30 | 39% |
| Oder Picking | 32 | 250 | 8 | 10% |
| Loading | 32 | 300 | 9 | 12% |
| Total | 96 | 1510 | 77 | 100% |

division and the number of people employed measured in human hours in a year. The result is as shown in below table.

Considering analysis of questionnaire most effected factor of warehouse operation optimization is 44% and it is representing by unutilized labor and 37% due to unproper activity plan and 19% due to unskilled operators.

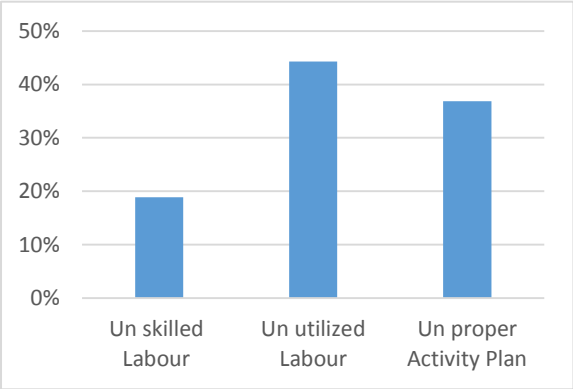


Figure 4.03: Factors of Labour

### 4.2.8 Truck turnaround Time

The study also sought to reduce truck turnaround time and found the activities in warehouses are unusable and therefore take longer unless there is a

turnaround time. The aim of the study was to optimize whether the storage process or a spatial limitation influences the possible degree of optimization. The investigation therefore revealed that an analysis of the storage process required. The activity time of the process and tried to optimize as much as possible to reduce the truck transit time in the warehouse of the company A.

Table 4.4: Composition of Truck Turnaround Time

| Activity | Time (hr) |
|---|---|
| Average idle time before empty bottle unloading | 0.15 |
| Average unloading time | 0.5 |
| Average idle time after unloading | 0.11 |
| Average idle time for GRN | 0.04 |
| Average idle time before NL | 0.15 |
| Average idle time before loading | 1.35 |
| Average of loading time | 1.5 |
| Average of idle gate out time | 0.54 |

The study focused on the process activity in the stores as a basis for understanding the process time. The research then 5 used why the idle time analysis as much as possible is the highest idle time in the warehouse over 1.35 hours before loading the truck. followed by each idle time polled by 5-why analysis, as shown in the following tables.

Table 4.5: 5 Why Analysis

| Why 1 | Why 2 | Why 3 | Why 4 | Why 5 | Process Improvement |
|---|---|---|---|---|---|
| High idle time at gate | Waiting to change order | Errors in amendments to revised invoice | Communication errors between order changes and invoice changes | Staff changing the order and staff revising the invoice are in two various locations | Brought part of invoicing team to FBS |

| Why 1 | Why 2 | Why 3 | Why 4 | Process Improvement |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| High idle time at gate | Delay in credit block release | Delay in credit block release approval | Credit executives are not in office most tie before 8am after 5pm | Mobile a crested for executive to release credit blocks |

| Why 1 | Why 2 | Why 3 | Why 4 | Process Improvement |
|---|---|---|---|---|
| High idle time before loading | Semi-trucks wait in line till the one before gets loaded | No loading space to accommodate all semi-trucks present | Semi-truck traffic peaks on the 10th, 20th and 30th of the month | Staggered loading targets |

| Why 1 | Why 2 | Why 3 | Why 4 | Process Improvement |
|---|---|---|---|---|
| High idle time before loading | Unavailability of proper loading formats with semi-truck drivers/porters | Loading formats are filled inaccurately/not filled at all | Unaware of the format etiquette | Posters and signboard explaining the loading format requirements |

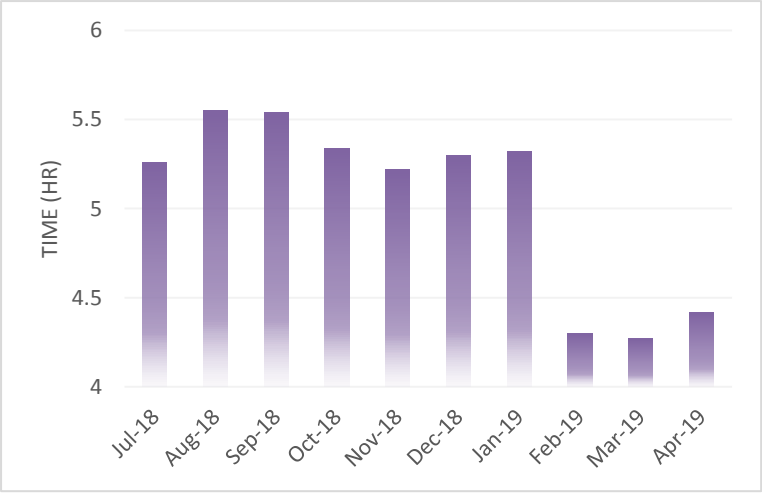


Figure 4.03: Monthly Truck turnaround time

## 4.4 Simulation Model to Evaluate the Layout

### 4.4.1 Introduction

The Company A warehouse for finished products is a block stack warehouse. This is a general cargo storage system where pallets of storage units (SKUs) stacked on top of one another in up to three high lanes. From time to time, the finished product warehouse of the company A changed the arrangement level as required. This storage system requires no storage racks or other storage facilities and can implemented inexpensively in a wide range. Spatial planning in this storage system is a challenge, however. This system operated under the directive for the common storage of finished goods. In this guideline, all article numbers have empty tracks. However, to avoid blocking and moving palettes, an empty track is allocated exclusively to a reserved track when an SKU has once stored a palette of that SKU in the track. This policy uses space more efficiently, but requires a proper layout plan, although the picking process in this system can be on average efficient. This restriction results in waste storage bins when filling or emptying the lanes. For this reason, there are free slots in a lane that are available only for the assigned SKU. This effect is referred to as honeycomb formation and the associated waste accumulates in the system until a lane is filled or empty (Edward, 2002). Gears also affect the total amount of wasted space. Gears not used for pallet storage, but for access to the lanes. To optimize the storage area, the layout must design to minimize two types of waste.

### 4.4.2 Space Optimization Model

As per result of main factor analysis the main constituent from out of six factors is layout optimization it will affected around 33% to aver all optimization. That result come from respondent experience and their knowledge therefore further

drilldown more detail and factors about layout optimization. As a result, 8 constituents can be drill down with quantified by factor analysis. Lack of space Unloading Area is 6%, Arrangement of Area location is 8%, SKU Categorization effect around 12%, Lack of space Storage Area 14%, Regarding Distance 16%, Regarding Access 19% and main factor is Lack of space Loading Area it is around 25% .Considering effectiveness from factor analysis the main three factors selected optimized in in space optimization model those are Space, Access and Distance. The transport times are influenced both by the track depth and the course length. Deep lanes create a layout with few gears and therefore use the storage space more efficiently. However, this influences the transport time since low accessibility conversely for flat lanes generates low space utilization and high accessibility. Therefore, the relationship between space use and transport time should optimized. This research describes simulation model that evaluates both space usage and transportation time for a given warehouse layout. The proposed simulation model accounts for stochastic variations in the main production factors, such as a real situation, for the warehouse layout design problem. This makes it a useful tool that can used together with an optimization algorithm to find an optimal layout in the warehouse for end products in company A.

### 4.4.3 Warehouse simulation layout

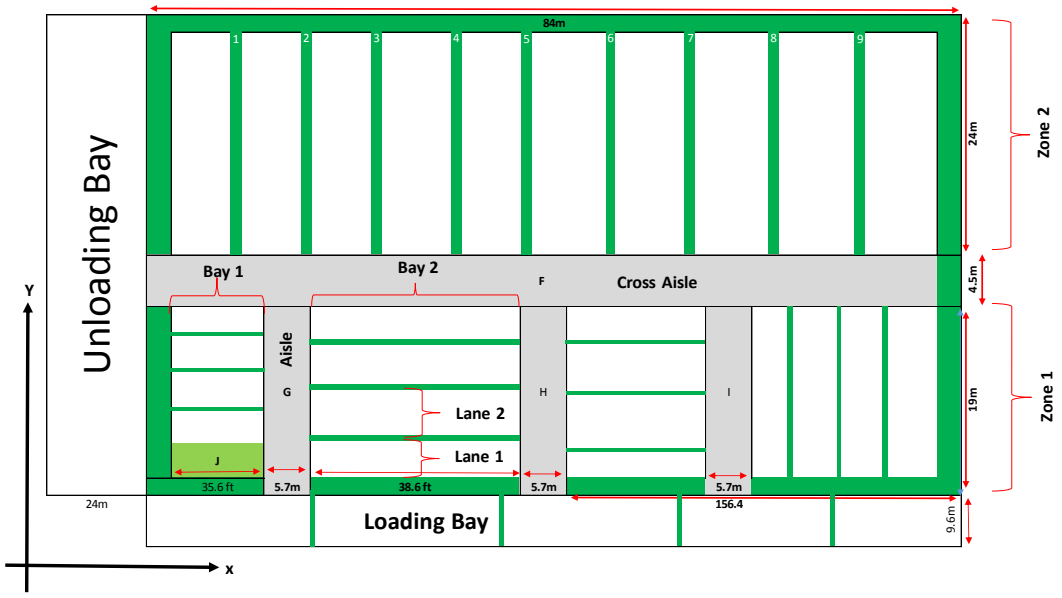


Figure 4.04: Warehouse Layout for simulation

This study simulates a finished production warehouse consisting of a production line, storage lanes, aisles, aisles, outgoing docks, forklifts, and a parking space for the forklift truck. The structure of the bearing given to the model. The model has two storage operations: product storage and truck loading. In a product storage operation, a product pallet picked up by a forklift and delivered to a bottom stack. In a truck loading operation, a truck arrives at an exit dock and a forklift truck sent to pick up the requested pallet from the ground stack and deliver it to the truck. The model has data preparation in four sections, distance calculation, main simulation, and performance evaluation.

### 4.4.4 Assumption for simulation

- The alleys are perpendicular to the left (west) side of the camp.
- To facilitate navigation, all lanes in a bay have the same depth.
- There is an outgoing dock in the middle of each zone.
- The production line is on the left (west) side of the warehouse.
- The forklift parking lot is in the middle of the south side of the warehouse.

- All aisles and aisles are bidirectional and wide enough to accept two forklift trucks
- cross.
- The stacker jam ignored.
- Forklift travel at a constant speed.
- Stochastic variations added to the calculated travel times.

The data preparation procedure makes the simulation input data. It generates the simulation event list from the real or randomly generated production and output load data. The distance calculation method calculates the straight-line distances between the locations of the warehouse between which vehicles travel. All distances stored and used later in the main simulation procedure. The main simulation procedure consists of nine events. These methods simulate the entire warehouse operation. These operations are either a production warehousing operation where a forklift picks up a produced pallet from the production line and delivers it to a storage track, or a delivery operation where a forklift picks up a pallet from the storage area and delivers it to a delivery yard dock. During these operations, the required parameters for measuring the utilization of the storage volume and the transport costs calculated. The performance evaluation process performed after all events have been executed in the simulation event list for the warehouse. It calculates the performance matrices that evaluate the layout in terms of space usage and transportation time. The overall pseudocode of the simulation model shown in Algorithm 1.

### 4.4.5 Input Data

The first step is to collect and prepare the simulation input data. Two types of data collected:

Table 4.6: Input Data

| Warehouse Data | SKU Data |
|---|---|
| warehouse dimensions | number of SKUs |
| number of bays | pallets heights |
| number of lanes | stackable heights |
| number of cross-aisles | Historical production |
| number of aisles | outbound load data |
| number of outbound docks | initial inventory |

| | |
|---|---|
| number of forklifts | |
| forklifts average speed | |

Notations

Table 4.7 Notation for Equations

| Character | Description |
|---|---|
| $n_a$ | number of aisles |
| $n_c$ | number of cross-aisles |
| $n_b$ | number of bays |
| $n_l$ | number of lanes in a bay |
| $n_A$ | number of AGVs |
| $n_o$ | number of outbound docks |
| $a^a$ | aisle width (in units of pallets) |
| $a^c$ | cross-aisle width (in units of pallets) |
| $S^h$ | warehouse height (cm) |
| $S^l$ | warehouse length (cm) |
| $S^w$ | warehouse width (cm) |
| $A^s$ | AGV's average speed (in units of pallets/hour) |
| $b_i$ | depth of bay i (in units of pallets) |
| $T^s$ | total simulation time (in units of hours) |
| $T^w$ | warm-up period time (in units of hours) |
| $r^u$ | total distance traveled unloaded (in units of pallets) |
| $r^i$ | total distance traveled loaded (in units of pallets) |
| $t^u$ | total time that AGVs travel unloaded (in units of hours) |
| $t^i$ | total time that AGVs travel loaded (in units of hours) |
| $W_{ij}^H$ | honeycombing waste of storage space generated in lane j of bay i |
| $O_{ij}$ | occupied space-time in lane j of bay i |
| $\epsilon$ | simulation event list |
| $L_w^p$ | pick-up waiting list for the production line |
| $L_w^o$ | pick-up waiting list for outbound orders |
| $t^p$ | time to load or unload a pallet to an AGV (in units of hours) |
| $t_1^w$ | time that a pick-up request added to either of the waiting lists (in units of hours) |
| $t_2^w$ | time that a waiting pick-up request assigned to an AGV (in units of hours) |
| $E_t$ | epsilon time unit |

### 4.4.5 Initial Stock Build up time - Algorithm 10

The other production events that need to be scheduled in the event list are the production events to create the initial inventory (current status of the system). Therefore, the initial inventory built in the model by making and storing pallets of article numbers sequentially as in a regular production event. Subsequently, the warm-up event executed, and all variables used for the performance evaluation are reset to their initial values. The warm-up time is then set to Tw. The production and output load data added to the event list (Tw + t).

$$T^w > \frac{d^{max}\,(\sum_{i=1}^{n_s} v_i - 1)}{n_A\, A^s} + \in_t$$

### 4.4.6 Distance-calculation - Algorithm 2

This procedure calculates rectilinear distances between the following locations:

- storage lanes.
- storage lanes and the production line.
- storage lanes and outbound docks.
- storage lanes and the AGVs parking.
- outbound docks and the production line.
- outbound docks and the AGVs parking.
- the production line and the AGVs parking.

A rectilinear distance between two locations obtained by summing distances traveled along the x-axis and y-axis. As it shown in Figure 4.04, we used a Cartesian coordinate system and assumed the origin is located at the southwest corner of the layout. We numbered bays from left to right and numbered lanes and cross-aisles from bottom to top. The x-coordinates for all lanes in a bay are identical. For example, they calculated for lanes in bays 1 to 3 in Figure 4.04 as

$$x^l_{1,1} = \cdots = x^l_{1,15} = a$$

$$x^l_{2,1} = \cdots = x^l_{2,15} = a + b_1 + b_2$$

$$x^l_{3,1} = \cdots = x^l_{3,15} = 2a + b_1 + b_2$$

The y-coordinates calculated by defining zones. Traces between two successive transepts form a zone. That is, lanes located between the transepts i and i + 1 create the zone i. Zones determine number of traverses will pass between two lanes when driving. As shown in Figure 4.04, the lanes between the first and second transitions assigned to zone 1, z l =: z l5 = 1, z l6 =:  z l10 = 2, so on. The zone assignment in Figure 4.04 began at the south cloister but can also reversed. Since we have assumed that the transverse courses have the same distance.

Per zone for a bay is

$$n_1/_z = \frac{n_1}{n_2}$$

Where $n_2$ is the number of zones for the sake of simplicity we assume that n1/z is an integer subsequently the assigned zone for lane j is obtained by

$$z_j^l = \frac{j}{n_{l/j}}$$

The y coordinates of the lanes are then calculated by

$$y_{ij}^l = j + a^c z_j^l$$

For the two lanes location in different zone the distance is

$$d_{ijkl}^{ll} = \left|x_{ij}^l - x_{kl}^l\right| + \left|y_{ij}^l - y_{kl}^l\right|$$

But for the lanes located in an identical zone it is the shortest path between the path that connect them from the cross aisle locate at the top of the lanes and the path

$$d_{ijkl}^{ll} = \left|x_{ij}^l - x_{kl}^l\right| + \left|y_{ij}^l - y_{kl}^l\right| - 2(z_j^l \left(a^c + n_{\underline{l}_z}\right) - n_{\underline{l}_z})$$

$$d_{ijkl}^{ll} = \left|x_{ij}^l - x_{kl}^l\right| + \left|y_{ij}^l - y_{kl}^l\right| - 2(z_j^l \left(a^c + n_{\underline{l}_z}\right) + 1 - (y_{ij}^l - y_{kl}^l)$$

$$d_{ijkl}^{ll} = d_{klij}^{ll} = \min\{d_{ijkl}^{ll-}, d_{ijkl}^{ll+}\}$$

Distance between storage lanes and the production line

$$d_{ijkl}^{lp} = x_{ij}^l + (y_{ij}^l + y^p) - 2(z_j^l \left(a^c + n_{\underline{l}_z}\right) - n_{\underline{l}_z})$$

$$d_{ijkl}^{ll} = x_{ij}^{l} + 2(z_j^l \left(a^c + n_{\frac{l}{z}}\right) + 1 - (y_{ij}^{l} - y_{kl}^{p})$$

$$d_{ij}^{lp} = \min\{d_{ij}^{lp-}, d_{ij}^{lp+}\}$$

Distance between storage lanes and outbound docks

$$d_{ijk}^{lo} = \left|x_{ij}^{l} - x_{kl}^{o}\right| + \left|y_{ij}^{l} - y_{k}^{o}\right| - 2(z_j^l \left(a^c + n_{\frac{l}{z}}\right) - n_{\frac{l}{z}})$$

$$d_{ijk}^{lo} = \left|x_{ij}^{l} - x_{kl}^{o}\right| + 2(z_j^l \left(a^c + n_{\frac{l}{z}}\right) + 1 - (y_{ij}^{l} - y_{k}^{o})$$

$$d_{ijkl}^{lo} = \min\{d_{ijk}^{lo-}, d_{ijkl}^{lo+}\}$$

Distance between storage lanes and forklift parking

$$d_{ij}^{lA} = \left|x_{ij}^{l} - x_{k}^{A}\right| + y_{ji}^{l}$$

Distance between outbound docks and the production line

$$d_{ijkl}^{po-} = x_{k}^{o} + (y_{k}^{o} + y^{p}) - 2(z_k^p \left(a^c + n_{\frac{l}{z}}\right) - n_{\frac{l}{z}})$$

$$d_{ijkl}^{po+} = x_{k}^{o} + 2(z_k^p \left(a^c + n_{\frac{l}{z}}\right) + 1 - (y_{k}^{p} - y_{k}^{o})$$

$$d_{k}^{po} = \min\{d_{k}^{po-}, d_{k}^{po+}\}$$

Distance between outbound docks and AGVs parking

$$d_{k}^{Ao} = \left|x^{o} - x_{k}^{A}\right| + y_{k}^{o}$$

Distance between production line and AGVs parking

$$d^{pA} = y^{p} + x^{A}$$

### 4.4.7 Main simulation procedure – event simulation

1. Pallet-production event - Algorithm 3
2. Pallet-pick-up event - Algorithm 4
3. Storage-process event - Algorithm 5
4. Release-AGV event - Algorithm 6
5. Park-AGV event - Algorithm 7
6. Outbound-pick-up event - Algorithm 7

7. Depletion-process event - Algorithm 8
8. Truck-loading event- Algorithm 9
9. Performance-evaluation event - Algorithm 1

The performance evaluation process executed after the main simulation process stopped. The following performance metrics are calculated: average decrease in storage volume (W s), utilization of storage volume (U s), percentage of waste volume (W), average utilization of FTF (UA), total distance traveled (r) and average waiting time for pick-ups (tw) , Among these metrics, Ws, Us and W are used to evaluate a layout in terms of space usage. They show how well the storage area used for storage. U A and r rate the layout in terms of transportation costs. Finally, tw and U A can used to determine the size of the forklift fleet in the store warehouse system.

Average waste of storage volume

$$W^s = \frac{\sum_{i=1}^{n_b}\sum_{j=1}^{n_l} W_{ij}^H + S^h(n_a a^a s_e^w + n_c a^c s^l)(T^s - T^w)}{T^s - T^w}$$

Utilization of storage volume

$$U^s = \frac{\sum_{i=1}^{n_b}\sum_{j=1}^{n_l} O_{IJ}}{\sum_{i=1}^{n_b}\sum_{j=1}^{n_l}\left(O_{ij} + W_{ij}^H\right) + S^h(n_a a^a s_e^w + n_c a^c s^l)(T^s - T^w)}$$

Percentage of wasted volume

$$W = \frac{\sum_{i=1}^{n_b}\sum_{j=1}^{n_l} W_{ij}^H + S^h(n_a a^a s_e^w + n_c a^c s^l)(T^s - T^w)}{s^h s^l s_e^w (T^s - T^w)}$$

Average AGV utilization

$$U^A = \frac{t^l + t^u}{n_A(T^s - T^w)}$$

Total travel distance

$$r = r^u - r^l$$

Average waiting time for pick-ups

$$t^w = \frac{t_2^w - t_1^w}{n_e}$$

### 4.4.8 Simulation Result Study

Data input

- $s_w$ = 4750 cm
- $s_l$ = 8400 cm
- $s_h$ = 4106 cm
- $n_c$ = 2
- $n_A$ = 12
- $n_o$ = 6
- $a_c$ = 2 pallets
- $a_a$ = 2 pallets
- $A_s$ = 20 Km/hour
- truck capacity: 15 pallets
- pallet size: 130 x130 cm

Space utilization for different stock level scenarios.

Zero stock level

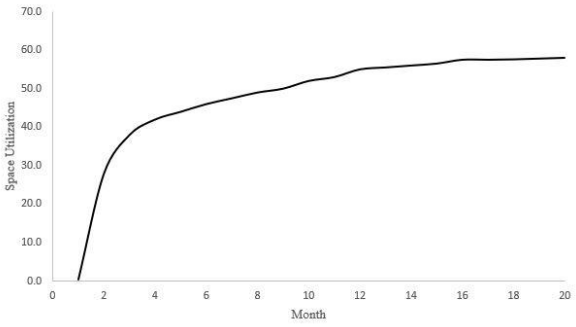


Figure 4.05: Graph Space Utilization for Zero Open stock level

One Month Stock Level

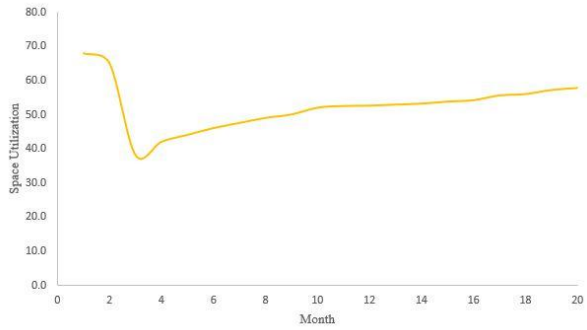


Figure 4.06: Graph Space Utilization for one-month Open stock

Travel Time Vs Space utilization

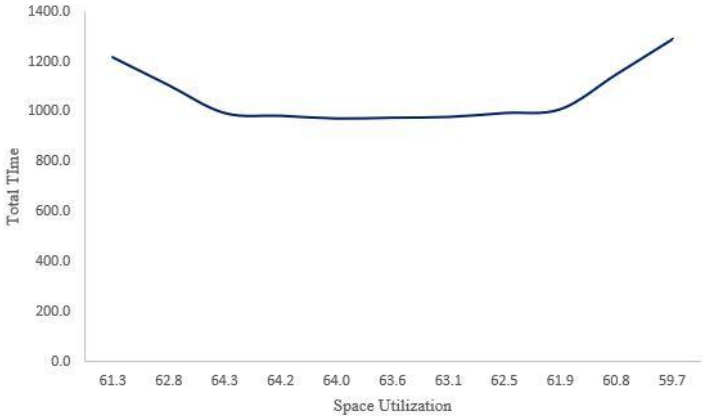


Figure 4.07: Graph Space Utilization Vs Total time spend

Table 4.8 Performance metrics for the layouts with different number of bays

| **No of bays** | Ws | Us | W | r | tw | tR | Tt |
|---|---|---|---|---|---|---|---|
| **2** | 13657.5 | 61.3 | 33.8 | 291.6 | 5.5 | 886.4 | 1216.4 |
| **3** | 13115.1 | 62.8 | 35.4 | 279.0 | 4.3 | 848.2 | 1106.2 |
| **4** | 12572.8 | 64.3 | 37.0 | 266.4 | 3.1 | 809.9 | 995.9 |
| **5** | 12608.7 | 64.2 | 36.9 | 263.9 | 3.1 | 802.1 | 985.1 |
| **6** | 12644.5 | 64.0 | 36.9 | 261.3 | 3.0 | 794.4 | 974.4 |
| **7** | 12802.3 | 63.6 | 36.4 | 259.4 | 3.2 | 788.5 | 977.5 |
| **8** | 12960.1 | 63.1 | 35.9 | 257.4 | 3.3 | 782.6 | 980.6 |
| **9** | 13172.0 | 62.5 | 35.3 | 256.6 | 3.6 | 780.0 | 996.0 |
| **10** | 13383.8 | 61.9 | 34.6 | 255.7 | 3.9 | 777.5 | 1011.5 |
| **11** | 13509.1 | 60.8 | 34.5 | 253.9 | 6.3 | 771.9 | 1149.9 |
| **12** | 13634.3 | 59.7 | 34.3 | 252.1 | 8.7 | 766.3 | 1288.3 |

# CHAPTER 5 CONCLUSION AND RECOMMENDATION

## 5.1 Conclusions

The purpose of this research was defining the overall optimization strategies for the current Company A warehouse. For that identifying and examining the relationship between bearing the research framework and quantifying effectiveness of factors which identified. A case study was conducted on the Company A finished goods warehouse and the warehouse staff was asked about various aspects of warehouse layout and operations management to identify different factors and strategies in each area and identify the challenges associated with them. Warehouse employees watch their work Optimize bearings. The collected data analyzed using 5 Why analysis, Pareto analysis, one-factor productivity ratios, descriptive statistics, and correlation. The survey revealed that most respondents have sufficient knowledge of warehouse management and are actively involved in warehouse management decisions. The results showed that the interviewee was a reliable source of information because he had enough experience to provide reliable and accurate information for analysis. The investigation can therefore conclude that the information derived from the interviewee is valuable, dependable, and up-to-date and can reliably represent the situation in the company A warehouse. In addition, the investigation revealed that company A should own the entire storage area and that third parties rented it. This type of arrangement meant that company A had no extra space and was therefore careful to optimize its operation to minimize waste and cost. It is therefore not surprising that the investigation revealed that company A prefers systematic storage over the rest of the storage system. Systematic storage helped to use every available space, regardless of the type of goods. The goods stored according to the available space on arrival in the warehouse. And wants to introduce a computing system for the finished goods warehouse. This computer storage system complemented by the fact that the warehouses in company A were in the general warehouse. This type of arrangement meant that the decision as to where the goods should be stored, contrary to the order in which the goods had to be stored in a fixed space, was a matter for company A management. The former arrangement generates low level of optimization. The warehouse as the customers only pay for the storage

space occupied by goods so warehouse should optimize as much as possible. The research further deduced that space utilization guarantees higher level of storage space utilization as proposed to the use of optimized layout plane and dedicated storage designs as found out by the analysis of Company A finished product ware warehouses. The research performed factor analysis where a strong positive relationship found between level of optimization and the factors of system should be adopt. The critical findings from the analysis of the bearing structure. The reason that low optimization and low inventory warehouses do not consider future enhancements and technology approaches to initial inventory planning. The research shows that can storage significantly improves labor productivity, which can help campers achieve huge cost savings. Low machine usage is an indication of a lack of knowledge and experience in handling machinery and indicates that employees do not have enough time to learn and train the contracted machinery. The study therefore recommends reviewing this strategy to ensure that the permanent composition of the workforce harmonized so that there is enough and experienced workforce in the camps. The increase in permanent employees for critical positions leads to higher machine utilization and higher workload in the warehouse. Also, for this, the warehouse staff must sufficiently train on the warehouse operation. However, it is extremely easy to adopt either SAP or another system for the warehouse information system. Training on handling machinery and warehouse management systems also cited by respondents as a challenge and is due to the extensive use of contract or casual labor at the Company A department store. The layout optimization as an optimization strategy without consideration of other factors such as the degree of memory optimization. It should note that in the stores where optimization has conducted, the utilization of the storage space was small despite the increase in the division level. The scenario offers a different view that previous researchers have never explored. The layout and operational optimization strategies depend on assorted factors, among which storage space is a critical factor. These challenges are due to the layout strategies used, which on the one hand lead to high utilization of the storage space and on the other hand to overfilling and hinder the movement in the company A warehouse. Research has therefore qualified the results of systems to the effect that the dedicated storage system saves storage time and thus provides a reliable source

for operational optimization. It turns out that it offers little storage space compared to random storage. The study recommends using contemporary layout designs for warehouses such as Fishbone and Flying V, which reduce travel time by 10 to 20% without reducing storage capacity, increasing space use by 10 to 15%.

### 5.2 Research Limitations

The results obtained and analyzed are the result of a case study conducted over a brief period of time that can be distorted based on the level of activity during the period of data collection. Therefore, the study recommends that more studies be conducted on a time series approach to determine the behavior and level of optimization over a period rather than at a time when the sample should be increased. The study also recommends comparing the results of this study with those of other organizations at the local and global level to validate the results as to whether they represent optimization in all camps in the world. When assort people enter the work area, the machine of the home causes the client to make use of a judgment about the use of a match. It is imperative that these constraints, he fortunately sent them the future review and investigation of the discovery of the derivative or its degree of weakness, but he would not change the understanding of himself in influencing the.

### 5.3 Future research Directions & Recommendations

Future research may consider company and industry factors to evaluate storage optimization performance and extend the flexibility test for introducing new storage optimization technologies. Finally, the observations contribute to better management of warehouse operating systems and decision-making on different demand patterns involving soft drink dealers. In addition, there is the possibility of a comprehensive investigation to expand or build a new warehouse to meet future demand forecasts without affecting third-party storage space. The degree of optimization of finished goods inventory in companies A is extremely low since the goal of optimization is to maximize input versus output. However, a high degree of optimization (below 40%) leads to an imbalance due to overfilling and narrowing of the aisles. The scenario leads to serious operational challenges and can pose a safety and accident risk. The study therefore recommends that company A review its operating strategies and distribute its warehousing to warehouses so that it does not

accept too much space. Therefore, the study also recommends the review of the method of space utilization and the guarantee of a maximum use of space. The permanent employees who train the casual workers in handling machines and warehouse management systems. The introduction of a balanced and representative workforce in all areas will result in higher machine utilization, higher workload and, consequently, higher inventory optimization.

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# APPENDICES

**Appendix 1: Questionnaire**

**Optimization of finished product warehouse Operations: The Case of a soft drinks industry, Sri Lanka.**

Dear Sir/Madam,

I am Samith Kumara, conducting a research on "Optimization of finished product warehouse Operations: The Case of a soft drinks industry, Sri Lanka".

This research is conducted to study current Finished product warehouse in Company A, to identify the area of can improve in warehouse operations as well as to find out the impact of factors to improve the warehouse utilization.

All the information will used only for academic purposes and treated as strictly confidential and will not release under any circumstances. Your kind co-operation and genuine response appreciated in making this research success and your individuality will not identified.

Thank you in advance for taking the time to assist me in my educational endeavors. Recognize the value of your time and gratefully appreciate your efforts in completing this questionnaire.

Thank You.

Sincerely,

Samith Kumara

**Section 01**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Sex | 1.Male | 2.Female | | | |
| 2 | Age | 1.18-25 | 2.25-35 | 3.35-45 | 4.Above 45 | |
| 3 | Experience Level in warehousing | 1.less <1 | 2.1-3 | 3.3-5 | 4.5-8 | 5.Above 8 |
| 4 | Education Level | 1.Up to O/L | 2.Up to A/L | 3.Up to Diploma | 4.Up to Degree | 5.Up to Masters |
| 5 | Employee Composition | 1.Permanent | 2.Contract | 3.Casual | 4.Training | |

To what extent do you agree with the following statements concerning the challenges that Company A warehouses? Use the scale of 1. Strongly disagree 2. Disagree 3. Not sure 4. Agree 5. Strongly Agree

**Section 02**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Warehouse information system can be improving than present situation. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 2 | Warehouse operation can be improving than present situation. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 3 | Warehouse layout plane can be improving than present situation. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 4 | Warehouse equipment utilization can be improving than present situation. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 5 | Warehouse building designing, position and location should be change. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 6 | Warehouse management practices should be improving. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |

**Section 03**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Considering overall surface area, do you have free area to further expansion? | Yes | No | | | |
| 2 | Indicate the most appropriate physical controls methods in place to prevent a loss: | 1.Cameras | 2.Guards | 3.Alarms | 4.Watchdogs | 5. Fences |
| 3 | Considering overall layout plan, goods receiving and loading functions are not disturb to each other's | 1.Most Likely | 2.Likely | 3.Nutral | 4.Not like | 5.Never |

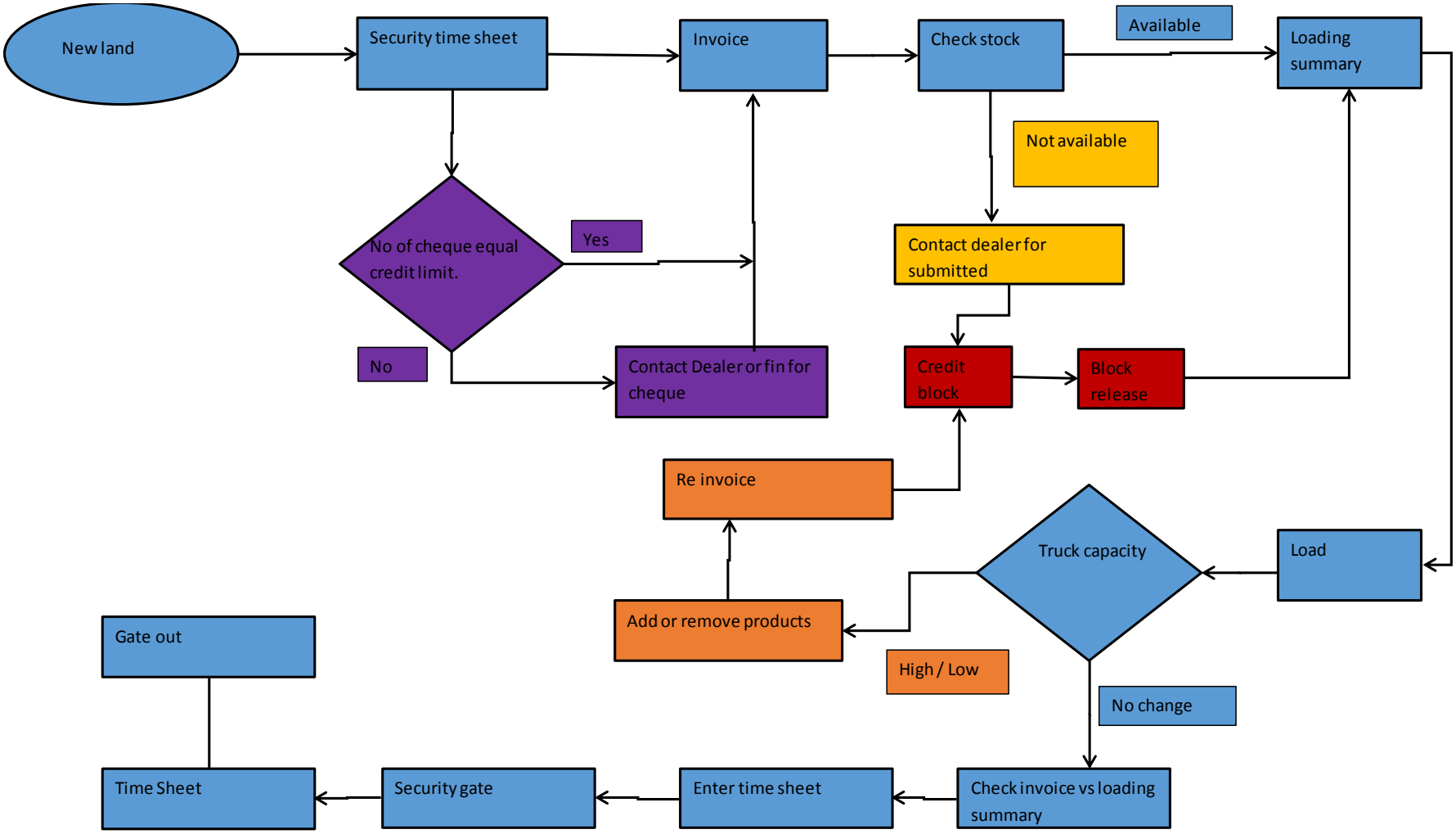
**Section 04**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Considering warehouse internal layout difficult to locate goods in the correct place. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | Each item has specific location to place in warehouse storage? | 1.Most Likely | 2.Likely | 3.Nutral | 4.Not like | 5.Never |
| 8 | It takes time to retrieve an order because they not arranged in a systematic manner. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 7 | It is difficult to conduct a stock take because the goods are not palletized manner. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 2 | Are you have specific location to each activity? | 1.Most Likely | 2.Likely | 3.Nutral | 4.Not like | 5.Never |
| 4 | Difficult to locate goods in the warehouse because layout not displayed. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 13 | Always disturbing to loading activity to other activity? | 1.Most Likely | 2.Likely | 3.Nutral | 4.Not like | 5.Never |
| 6 | Difficult to store or retrieve goods because the goods are too high. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 5 | Difficult to store or retrieve goods because the paths blocked. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 9 | Comparing with overall area the storage area is not adequate. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 10 | Comparing with overall area the loading area is not adequate. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 11 | Comparing with overall area the pathway area is not adequate. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 12 | Comparing with overall area the receiving area is not adequate. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 14 | Distance is extremely high in between loading bay and storage location. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 15 | Distance is extremely high in between Receiving and storage location. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| **Section 05** | | | | | | |
| 1 | The warehouse management (SAP) system is hard to understand? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 2 | The warehouse management (SAP) system is not user friend? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 3 | Is there a complete physical inventory (by count) by monthly? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 4 | The quantities in the warehouse system does not always match to the physical count. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 5 | The System has entered to more reputed information at each stage. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 6 | Have more reputed unless paperwork. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 7 | Always match production qty and receiving qty. | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 8 | Can be track each item from plant to receiving? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 9 | Can be track each item from receiving to storage location? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 10 | Can be track each item from storage location to loading point? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 11 | Do you have proper training about SAP system? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |

| | | | | | | |
|---|---|---|---|---|---|---|
| 12 | There is process in place to prevent creation of a fraudulent transaction where an unauthorized customer can store items in the warehouse without the knowledge of the Applicant? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 13 | Individuals assist in loading items to shipped different from those who act to receive goods from storage? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| **Section 06** | | | | | | |
| 1 | Does the Applicant use its own trucks to transport goods to and from the warehouse? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 2 | Are truck drivers required to identify themselves? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 3 | How many drivers are currently employed? | | | | | |
| 4 | The documentation process of loading goods is time consuming? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 6 | All section always followed first in first out strategy? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 7 | What is most time-consuming activity considering main activities? | 1.unloading time | 2.put a way time | 3.picking time | 4.loding time | |
| 12 | Do you have separate SOP's for each activity? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 13 | Do you have proper training for Equipment operators? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| **Section 07** | | | | | | |
| 1 | Do you have sufficient equipment for loading and unloading of goods? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 2 | Warehouse equipment not loaded at most the time? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 3 | The equipment faults easily? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 4 | Do you have separate equipment to each activity? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 5 | Do you have specific equipment to specific activity? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 6 | Can you improve unloading process by using another equipment? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| **Section 08** | | | | | | |
| 1 | No unnecessary items inside of warehouse and all space well-organized? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 2 | There are demarcated separate places for tool, equipment, good? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 3 | Every day Involves to cleaning, dusting, polishing, sweeping, vacuuming and everything necessary to attain perfect order? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 4 | Conducting regular audit with checklists for housekeeping? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 5 | Do you have training about 5S concept? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | Do you have implemented value mapping and identified nonvalue add activity? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 7 | Do you have any implementation for eliminating wastage? | 1. Strongly disagree | 2. Disagree | 3. Not sure | 4. Agree | 5. Strongly Agree |
| 8 | Do you have work as a team with warehouse employee? | 1.Most Likely | 2.Likely | 3.Nutral | 4.Not like | 5.Never |
| 9 | Warehouse had ISO Certification and continually maintained? | Yes | No | | | |
| 10 | Do you have SMART Goal and KPI? | 1.Most Likely | 2.Likely | 3.Nutral | 4.Not like | 5.Never |
| 11 | Your supervisor Annually review your KPI with management committee? | 1.Most Likely | 2.Likely | 3.Nutral | 4.Not like | 5.Never |




**Appendix 2: Activity Flow Chart**

**Appendix 3: Algorithm coding for Computation**

(1)

```
Algorithm 1 The overall pseudo-code for the simulation model.
call data-preparation
call distance-calculation
while the event list is not empty do
event = the earliest event in the event list
TimeNow = time of event
call the corresponding procedure for the event
remove the event from the event list
call performance-evaluation
```

(2)

```
Algorithm 2 Pseudo-code for distance-calculation procedure.
calculate nl=z
set B = 0; c = 0
for all (i 2 f1; ::; nbg) do
if (i MOD 2 == 1) then
c = c + 1
xl
i;1 = ::: = xl
i;nl = B + aac
else
xl
i;1 = ::: = xl
i;nl = B + aac + bi
B = B + bi
for all (i 2 f1; ::; nbg & j 2 f1; ::; nlg) do
calculate zl
j ; yl
ij using eqs. (6) and (7)
for all (l 2 fj + 1; ::; nlg) do
calculate dll
ijil; dll
ilij using eq. (8)
for all (k 2 fi + 1; ::; nbg & l 2 f1; ::; nlg) do
calculate dll
ijkl; dll
klij using eqs. (8){(11)
calculate yp; zp using eqs. (12) and (13)
```

(3)

```
Algorithm 3 The pseudo-code for pallet-production.
if an AGV or storage space is available then
lane = the open storage lane for the produced SKU
Capacity = capacity of the lane based on the SKU stackable height
TotalInv = on-the-way pallets to the lane + its occupied positions
if TotalInv==Capacity then
mark lane as fully occupied
nd a new lane based on the selection criteria
update on-the-way pallets to the lane by one
nd the nearest available AGV to the production line
set the status of the selected AGV to busy
TravDist=distance from the current location of the AGV to the production line
ru = ru + TravDist
tu = tu + (TravDist=As) + tp
add pallet-pick-up to E at (TimeNow + (TravDist=As) + tp)
else
add the SKU to Lp
w
tw
1 = tw
1 + TimeNow
```

(4)

```
Algorithm 4 The pseudo-code for pallet-pick-up.
TravDist = distance between the production line and the open storage lane
TravInLane = lane depth - occupied oor positions in the open storage lane
rl = rl + TravDist + TravInLane
tl = tl + (TravDist + TravInLane)=As + tp
ru = ru + TravInLane
tu = tu + (TravInLane=As)
add storage-process to E at (TimeNow + tp + (TravDist + 2   TravInLane)=As)
```

(5)

```
Algorithm 5 The pseudo-code for storage-process.
lane = the open storage lane for the storing SKU
update WH
ij and Oij for the lane using eqs. (31) and (32)
Set LaneLastEventTime to TimeNow
increment inventory of the lane by one pallet
increment inventory of the SKU by one pallet
decrement on-the-way pallets to the lane by one pallet
update the status of the AGV to available
update the location of the AGV to the location of the lane
if Lp
w is not empty then
add pallet-production to E at TimeNow for the SKU waited the most
tw
2 = tw
2 + TimeNow
remove the SKU from Lp
w
else if Lo
w is not empty then
nd the SKU with the longest waiting time and non-zero inventory
add outbound-pick-up to E at TimeNow
tw
2 = tw
2 + TimeNow
remove the SKU from Lo
w
else
add release-AGV to E at (TimeNow + t)
```

(6)

```
Algorithm 6 The pseudo-code for release-AGV.
TravDist = distance between the AGV's current location and parking
ru = ru + TravDist
tu = tu + (TravDist=As)
update the status of the AGV to busy
add park-AGV to E at (TimeNow + (TravDist=As))
```

(7)

```
Algorithm 7 The pseudo-code for outbound-pick-up.
if an AGV is available and the SKU inventory > 0 then
lane = the open depletion lane for the requested SKU
TotalInv = Inventory of the lane - sum of on-the-way pick-ups to the lane
if TotalInv == 0 then
mark lane as empty
select a new lane with respect to the selection criteria
nd the nearest available AGV to the lane
set the status of the selected AGV to busy
increment on-the-way pick-ups to the lane by one unit
TravDist=distance from the current location of the AGV to the lane
TravInLane = lane depth - occupied oor positions in the lane
ru = ru + TravDist + TravInLane
tu = tu + (TravDist + TravInLane)=As
add depletion-process to E at (TimeNow + (TravDist + 2   TravInLane)=As + tp)
else
add the SKU to Lo
w
tw
1 = tw
1 + TimeNow
```

(8)

```
Algorithm 8 The pseudo-code for depletion-process.
lane = the open depletion lane
update WH
ij and Oij for the lane using eqs. (31) and (32)
LaneLastEventTime = TimeNow
decrement lane inventory by one pallet
decrement SKU inventory by one pallet
decrement on-the-way pick-ups to the lane by one
TravDist=distance from the lane to the assigned outbound dock
TravInLane = lane depth - occupied oor positions in the lane
rl = rl + TravDist + TravInLane
tl = tl + (TravDist + TravInLane)=As + 2tp
add truck-loading to E at (TimeNow + (TravDist=As) + tp)
```

(9)

```
Algorithm 9 The pseudo-code for truck-loading.
update the status of the AGV to available
update the AGV's location to the assigned outbound dock
if Lp
w is not empty then
add pallet-production to E at TimeNow for the SKU waited the most
tw
2 = tw
2 + TimeNow
remove the SKU from Lp
w
else if Lo
w is not empty then
nd the SKU with the longest waiting time and non-zero inventory
add outbound-pick-up to E at TimeNow
tw
2 = tw
2 + TimeNow
remove the SKU from Lo
w
else
add release-AGV to E at (TimeNow + t)
```

(10)

```
Algorithm 10 The pseudo-code for warm-up.
for all lanes do
reset LaneLastEventTime to TimeNow
reset WH
ij ; Oij to zero
reset tw
1 ; tw
2 ; ru; rl; tu; tl to zero
```