IMPROVEMENT OF WAREHOUSE EFFICIENCY BY A WAREHOUSE REDESIGN: A CASE OF AN INTERNATIONAL FREIGHT FORWARDER

By
THANYARAT NIMKET

A Final Report of the Six-Credit Course
SCM 2202 Graduate Project

Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT

Martin de Tours School of Management
Assumption University
Bangkok, Thailand

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Examination Committee:

1. Asst. Prof. Dr. Nucharee Supatn (Chair) .....
2. Dr. Piyawan Puttibarncharoensri (Member) .....
3. Dr. Vatcharapol Sukhotu (Advisor) .....

Approved for Graduation on: November 9, 2013

Martin de Tours School of Management and Economics
Assumption University
Bangkok, Thailand

November 2013

Assumption University
Martin de Tours School of Management and Economics
Master of Science in Supply Chain Management

Declaration of Authorship Form

I, _ Thanyarat Nimket declare that this thesis/project and the work presented in it are my own and have been generated by me as the result of my own original research.

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I confirm that this thesis/project has been carried out under my supervision and it represents the original work of the candidate.

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(Dr. Vatcharapol Sukhothu)

Date _____

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Thanyarat Nimket
Assumption University
November 2013

ABSTRACT

Warehousing has a critical role in supply chain management and is becoming increasing more important. The objective of warehouse layout design is to optimize warehouse functions and achieve maximum efficiency and space utilization. The implementation of redesign layout by using racking system is one technique to improve existing warehouse layout in warehouse no. 2 in term of the space utilization to increase storage capacity and increase picking efficiency to achieve greater effectiveness and efficiency of warehouse operations.

The purpose of this research is to enhance knowledge and awareness of a layout design that will help the researcher understand Yusen's warehouse operation process. This research presents the result from the data analysis and identifies the problems that the company has been facing and proposes of possible improvements for warehouse efficiency. The secondary data was basically obtained from historical data of company which can support the study. The primary data was mainly gathered from the observation of actual work in the warehouse operation. Tools such as warehouse operation process map-receiving & putting away and loading, inbound & outbound material flow, the relevant data for analyzing the cause of problems are used to understand existing warehouse operation processes. Moreover, an interview with Logistics General Manager was conducted to review the current situation of Yusen Company, the current warehouse layout design, warehouse operation process flow, customer requirement, the critical issues in depth details and objective to achieve future targets.

At the end of the research, the researcher provided guidelines and recommendations for implementation of warehouse redesign by installing the racking system. The new layout design was able to increase potential improvement in term of optimize space, increasing picking efficiency and increasing profit of the company from racking investment.

TABLE OF CONTENTS

Chapter III: Research Methodology

Chapter IV: Presentation and Critical Discussion of Results

Chapter V: Summary Findings, Conclusions and Recommendations

LIST OF TABLES

LIST OF FIGURES

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and hereby certify that the verbiage, spelling and format is commensurate with the quality of internationally acceptable writing standards for a master degree in supply chain management.

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(Asst.Prof.Dr. Sureepong Phothongsunan)

Contact Number / Email address sureepongp@hotmail.com

Date: 11 Nov. 2013

CHAPTER I

GENERALITIES OF THE STUDY

1.1 Background of the Study

Currently, warehousing continues to play a critical role in assuring high levels of customer service and overall logistics performance. Warehousing minimizes the effects of supply chain inefficiencies, improves logistics accuracy and inventory management, and allows product accumulation, consolidation, and customization.
The goal of a warehouse layout design is to optimize warehouse functions and achieve maximum efficiency and space utilization. Warehouses are one of the most important parts of a logistics system in a company; they contribute about 20% of logistic costs (Koster et al., 2007).

This chapter presents an introduction to the business of Yusen Logistics (Thailand) Company Limited. This company briefly described is in the business of providing warehouse and inventory, transportation, distribution and supply chain management services. Firstly the chapter begins with the background of the study, statement of problem, research objectives, scope of the research, limitations of the study, significance of the study and finally the definition of terms will be presented later.

1.1.1 Company Introduction

Yusen Logistics (Thailand) Company was established in 1969. Yusen Logistics provides multimodal transportation service through Yusen global network and NYK Group Thailand. Recently, the situation surrounding international logistics has been changing dramatically. Instead of considering freight forwarding, warehousing and other distribution functions individually, customers tend to adopt a comprehensive logistics strategy that seeks to optimize the distribution process as a whole. Moving

ahead, the Company will pursue an even higher level of service quality better tailored to customer needs in the two key business areas of air/ocean freight forwarding and contract logistics can be seen in Figure 1.1.

Yusen also intends to generate greater customer satisfaction through a host of services according to customers' logistics needs.

Figure 1.1: Yusen Logistics (Thailand) Services

Source: Company profile

Yusen Thailand provides warehousing service both general warehouse and bonded warehouses for various kinds of cargo. Throughput is more than 1,900,000 Metric Ton per year.

The Company's objectives are as follows:

1. Provide both dedicated and shared storage
2. Provide fully equipped warehouses with comprehensive security and fire protection systems
3. Provide various value-added services
4. Serve various kinds of cargo such as Automotive parts, Electronic, Steel, Chemical, and hazardous cargo

Warehouse Services

Yusen provides various types of warehouse services: The warehouse service is provided in major cities of Thailand with over 230,000 m^2. Yusen facilities are strategically located in Bangna, Chonburi, Rayong, Suvarnabhumi airport, Navanakorn and Korat, as shown in Figure 1.2.

Figure 1.2: Warehouse Facilities

Source: Company data

Table 1.1: Customers' Names and Cargo Description in Warehouse No. 2

Customers' Names	Space Capacity/Square(m^2)	Floor Load	Cargo Description
Customer A Customer B Customer C	1,200 m^2 2,400 m^2 1,500 m^2	2.5Ton/m^2	Sporting Products Plastic Resin Automotive Parts
Total Warehouse Space	5,100 m^2	2.5 Ton/m^2	

Source: Company data

Table 1.1 shows the cargo description and types of customers in warehouse no. 2 for three major customers which are A, B, and C with total storage capacity space of 5,100 m^2.

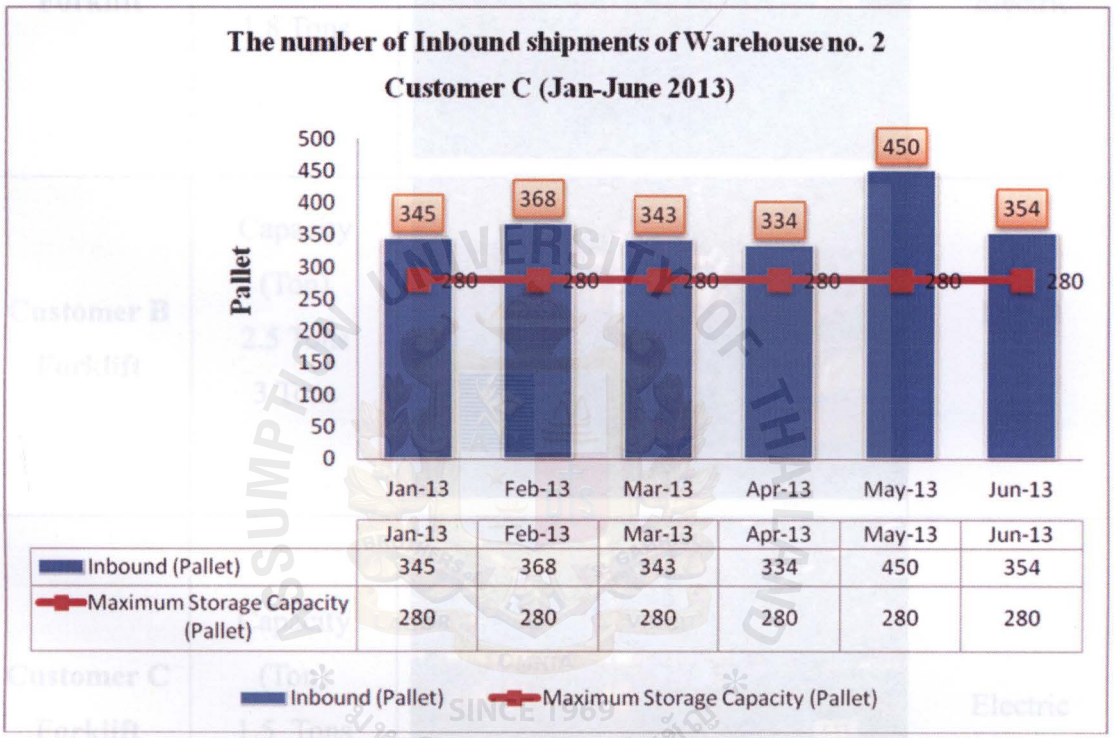
Table 1.2: Warehouse Space (m^2)

Warehouse Space of Customer C		
Warehouse area	**m^2**	**Percentage Space % [a]**
Office area	21	1.40%
Storage area	506	33.73%
Preparation area	70	4.67%
Receiving area	66	4.40%
Staging area	100	6.67%
Forklift way area	737	49.13%
Total warehouse space	**1,500**	**100.00%**

Remark: [a] Percentage Space is calculated by the warehouse area/total warehouse space.

The data in Table 1.2 shows that the total warehouse space for customer C is 1,500 m^2 which is allocated into various areas. It shows the total storage area with an average of 33.73% or 506 m^2.

Figure 1.3: The Number of Inbound Shipments (Pallet) per Month



	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13
Inbound (Pallet)	345	368	343	334	450	354
Maximum Storage Capacity (Pallet)	280	280	280	280	280	280

Source: Company data

Figure 1.3 shows the number of inbound shipments of customer C from January to June 2013 with units of pallets. In this graph, it can be seen that the inbound volume has a peak in May 2013 with 450 pallets while the average number of pallets is 366 pallets per month but the inbound shipment is over the maximum storage capacity by 280 pallets per month, as calculated from January-June 2013. The maximum storage capacity in warehouse no. 2 is 280 pallets per month. For excess cargo volumes, they will be stored at the over flow area.

Figure 1.4: Material Handling Equipment in Warehouse No. 2

Customer A Forklift	Capacity (Ton) 1.8 Tons		Electric
Customer B Forklift	Capacity (Ton) 2.5 Tons 3 Tons		Diesel
Customer C Forklift	Capacity (Ton) 1.5 Tons		Electric

Source: Company Data

Figure 1.4 shows the material handling equipment in warehouse no. 2 including types of forklifts and the capacity of forklift trucks for each customer.

1.2 Statement of the Problem

The goal of warehouse service is to allocate the area to maximize space utilization in order to enhance the best service to meet customer satisfaction.

There are two warehouses which are located at Yusen Bangbor Logistics center which are warehouse no. 1 and warehouse no. 2. The researcher focuses on warehouse no. 2 as a case study, especially on customer C to improve space utilization and increase picking efficiency. The reason why warehouse no. 1 is not selected is because it has already installed the racking system and there is no warehouse layout design problem. Currently, warehouse no. 2 has been providing warehouse service for three main customers; A, B, and C.

There are 2 main problems related to the warehouse operation of warehouse no. 2 of customer C which are:

1. The storage capacity problem in warehouse no. 2 of customer C involving the number of inbound volume increased and not maximizing space utilization.

2. Inefficiency in the picking process leading to slow cargo movement and time consumption, such as the picker spending more time to access pallets in each location.

Currently, Yusen does not have enough storage space to handle increasing inbound volumes to meet customer requirement, which will impact service level. Warehouse space is running out and the cargo volume is over a storage capacity because customers require more space to serve their growing business. There is also the problem of an increase in the number of inbound shipments (see Figure 1.5).

Figure 1.5: The Comparison Number of Inbound Shipments (pallet) in the Year 2012 and 2013 (Jan-June 2013)

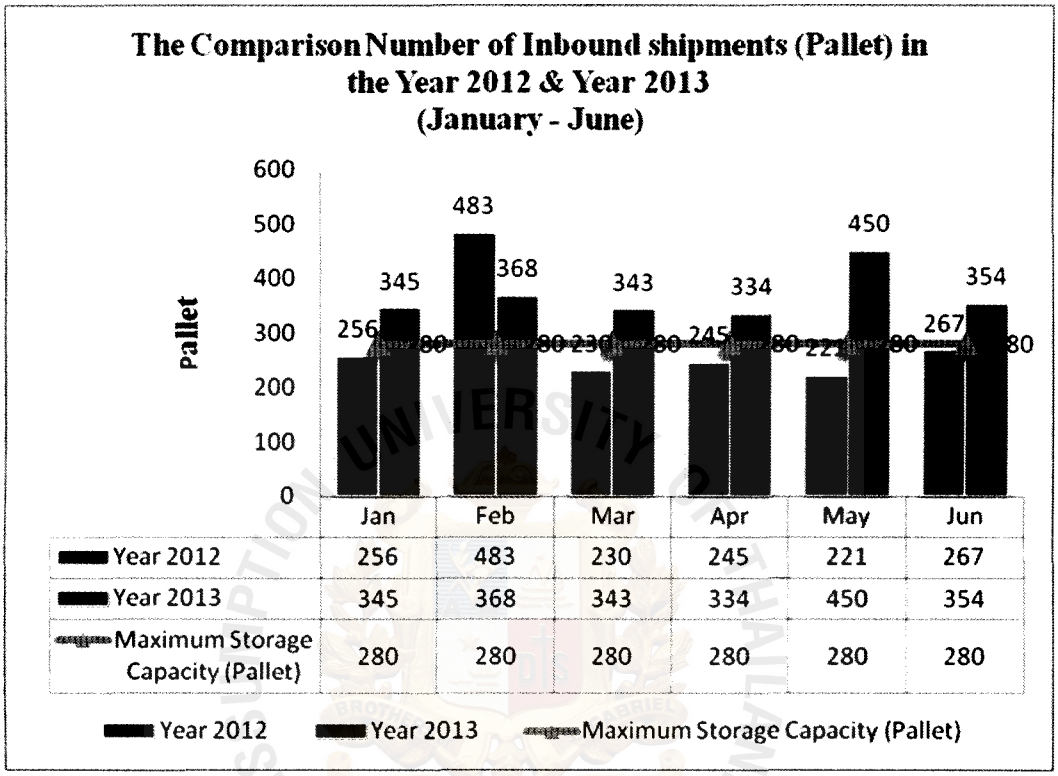


Figure 1.5 shows the number of inbound shipments of pallets of customer C from January to June of the year 2012 and 2013. The numbers are compared and the difference in numbers of pallets is reviewed. Figure 1.5 indicates that the number of inbound shipments has continued increasing and is over a maximum storage capacity by 208 pallets per month when compared that of the year 2012 to 2013 in the same period. As a result, excess cargo volumes will be stored at the over flow area and for slow cargo movement.

Table 1.3: Inbound Shipment Comparison in the Year 2012 and 2013

Month	Monthly Inbound Shipments (Pallet)		
	Year 2012	Year 2013	Increase (Percent)
January	256	345	35%
February	483	368	(-23%)
March	230	343	49%
April	245	334	36%
May	221	450	104%
June	267	354	33%
Total	1,702	2,194	29%
Average inbound shipment per month	305	366	20%

Source: Company data

The data shown in the Table 1.3 is the number of inbound shipments of pallets of customer C from January to June of the year 2012 and 2013. The numbers are compared and the difference in percentage between year 2012 and 2013 is reviewed.

Table 1.3 indicates that the total number of inbound shipments increased more than 30 percent when compared that of the year 2012 to 2013. As a result of inbound shipments increased, it requires more storage space but space is limited.

The researcher found that space utilization of warehouse number 2 is lower than it should be, as shown in Table 1.4.

Table 1.4: Current Warehouse Space Utilization

Warehouse Space Utilization					
Warehouse No. 2: Customer C	**Total Storage Space (m^2)**	**Space Used (m^2)**	**Total Capacity (Pallet) [a]**	**Pallet Size (1.1 x 1.2)**	**Pallet per m^2 (Pallet) [b]**
Current (Before improvement)	506	366.96	278	1.32	0.76

Remark: [a] Total pallet is calculated by space used (m^2)/pallet size (m^2).

[b] Pallet per m^2 is calculated by total pallet/space used (m^2).

Table 1.4 shows current warehouse space utilization in warehouse no. 2 for customer C before improvement. It shows that the total capacity is 278 pallets while the total maximum storage capacity is 280 pallets and the pallet per square meter (m^2) is 0.76 pallets. As the capacity of warehouse space is measured, the researcher found the opportunity to improve the performance of warehouse space.

Another problem of the warehouse operation process in warehouse no. 2 is slow cargo movement because of inefficiency in the picking process. At present, the pallets are laid on the floor without racking systems. The limitation of cargo loaded on pallets which can be stacked two levels high only is that it is difficult for forklift driver to access pallets in each location. They cannot pick up pallets one by one, which is different from cargo storage on racking systems. In case that the picker wants to pick up a specific pallet, he has to move out the outer pallet to get to the inner pallet and then there is a need to move back those pallets to the same location. It requires more time for picking up the cargo to finish all shipping instructions per day and cause slow cargo movement, as shown in Table 1.5.

Table 1.5: Picking Time before Improvement Layout

	Working Time /Day (Hours)	Total Time (Minutes)	Total Time/Day (Minutes)[a]	Average Picking Time/Shipping Instruction/Day (Minutes)	Total Shipping Instruction/Day/One Picker (Job No.)[b]
Before Improvement	8	60	480	30	16

Remarks: [a] Total Time per day (minutes) is calculated by working time per day (hours) * total time (minutes).

[b] Total Shipping Instruction per day per one picker (Job No.) is calculated by total time per day (minutes)/Average picking time per shipping instruction per day (minutes).

Table 1.5 shows the calculation of the total shipping instruction per day per one picker before the improvement layout. It shows an average picking time that one picker spends 30 minutes picking up pallets and the capability of one picker to finish the total shipping instruction is approximately 16 jobs per day, which are lower than the KPI performance target of 30 jobs per day.

As there are problems, this research proposes improving space utilization in warehouse no. 2 of customer C by redesigning a layout and using the racking system to promote using more space, increase storage capacity, and increase picking efficiency to maximize corporate value and the earning trust of customers through quality logistics services.

As a consequence, the research question, **"How does a warehouse layout re-design, using the racking system help improve space utilization and operation efficiency in warehouse no. 2?"** is raised.

1.3 Research Objectives

The researcher focuses on the improvement of the efficiency of the existing warehouse by considering how to re-design a warehouse layout to maximize space utilization and understand the current operations process by using the racking system to increase picking efficiency and material movement. The researcher sets the main objectives as follows:

1.3.1 To study a current warehouse layout of customer C in warehouse no. 2 and warehouse operation processes.

1.3.2 To allocate warehouse space for increasing storage capacity in order to promote the use of space and enhance customer satisfaction.

1.3.3 To propose a new layout design by installing the racking system that will improve the warehouse operation process and improve space utilization.

1.4 Scope of the Research

This research aims to study the current warehouse no. 2, especially of customer C and the warehouse operation processes at Yusen Bangbor Logistics Center to understand warehouse working processes, maximize space utilization and increase picking efficiency. The new layout design will be proposed that will improve space utilization without space extension by analyzing the current process and the company's data on warehouse activities in each area, including the receiving, putting away, storing, picking, packing, shipping and inventory levels. This data shall be supported by other considerations such as process flows, material handling equipment, product types and styles of racking equipment, and special handling requirements. The raking system will be applied so as to improve the flow of materials moves, increase picking efficiency, and improve warehouse operation processes.

1.5 Significance of the Research

The new layout design will help Yusen increase space utilization, solve the problem about running out of space, and improve picking efficiency in order to increase material movement. The company can respond to customer demand quicker. This research would be useful for the company to improve warehouse efficiency and gain more competitive advantage to meet future needs.

1.6 Limitations of the Research

This research is useful for the company to manage warehouse operation processes of automotive parts. This research may not be able to apply to all types of products and other specific customer requirements because the nature of automotive parts and other types of products are different. Automotive parts are fast moving cargo for supporting the JIT system of the automotive industrial. On the other hand, other specific cargo such as raw materials and consumer products do not move as fast as automotive parts in the JIT system.

1.7 Definition of Terms

Freight Forwarder	It is an intermediary who acts on behalf of importers, exporters, other companies or persons, by organizing the safe, efficient and cost-effective transportation of goods (Thompson, 2008).
Material Handling	Material handling is defined as the basic operation that involves the movement of bulk, packaged and individual goods in a semi-solid or solid state by means of a human or machine and within the limits of the facility (Mulcahy, 1994).

Material Handling Equipment	Material handling equipment which can be move to any area of the facility is referred to as variable-path *variable-area equipment. All manual carts, motorized vehicles, and fork trucks can be pushed,* dragged, or driven throughout the plant (Meyers & Stephens, 2005)
Order Picking	Order picking is the process of removing items from storage to meet a specific demand (Frazelle, 2002).
Packing	Packing is an important element of the dispatch function (Gunasekaran, Marri, & Menci, 1999).
Put Away	Put away is the act of placing merchandise in storage. It includes the materials handling, location verification, and product placement (Frazelle, 2002).
Receiving	Receiving is the collection of activities involved in (a) the orderly receipt of all materials coming into the warehouse, (b) providing the assurance that the quantity and quality of such materials are as ordered, and (c) disbursing materials to storage or to other organizational functions requiring them (Frazelle, 2002).
Storage	Storage is the physical containment of merchandise while it is awaiting a demand. The storage method depends on the size and quantity of the items in inventory and the handling characteristics of the product or its container (Frazelle, 2002).

Warehouse	Warehouse is defined as the function of storing a variety of product types (SKU, stock-keeping units) that have a small or large quantity of storage units between time that the product is in supply chain (Mulcahy, 1994).

CHAPTER II

REVIEW OF RELATED LITERATURE

This chapter presents the review of the literature that is related to this study in order to enhance the understanding of a redesign layout of the existing warehouse by focusing on improving space utilization, increasing the flow of materials, and increasing picking efficiency to improve warehouse operation processes.

2.1 Warehouse

Mulcahy (1994) stated that warehouse is the function of storing a variety of product types (SKU, stock-keeping units) that have a small or large quantity of storage units between times that the product is in supply chain.

Gaither and Frazier (2001) stated that warehouse is the management of products and materials when they are in storage. Warehousing includes storing products, designing layout, order processing, managing stocks and inventory control and accounting for all materials and finished goods from the beginning to the end of the production process.

Gunasekaran (1999) stated that the warehouse is a place where the product is stored until it needs to be shipped to the customer.

Warehouses are storage systems whose functions support the efficiency and smoothness of the logistics operations by providing materials and suppliers in a timely and cost effective manner.

2.2 Warehouse Layout

Frazelle (2002) stated that a warehouse layout should be based on the space requirements for and the interrelationships between individual warehouse processes. The first step in laying out a warehouse is to determine the overall space requirements for all warehouse processes. The space requirements for each process should be computed and summarized to estimate the overall building requirements. When considering the layout and operation of warehouse systems, there are fundamental principles that embody a general philosophy of good practice. The principles are:

1. Using the most suitable unit load
2. Making the best use of space
3. Minimizing movement
4. Controlling movement and location
5. Providing safe, secure and environmentally
6. Maintaining at minimum overall operating cost

Successful warehouse layouts must adhere to principles, regardless of material being stored to:

1. Minimize the use of space
2. Maximize the use of equipment
3. Minimize the use of labor
4. Maximize accessibility to all items and maximize protection of all items

Hassan (2002) stated that designing a warehouse layout is a complex task for many reasons as follows. First, the number of design decisions is large and it is difficult to solve the problem. Second, operations (e.g. picking, dual command, cross docking, and value added services) and factors (e.g. demand, physical characteristics of items and unit loads, serving global markets, material handling, and just-in-time(JIT) impact travel time, material handling cost, and throughput in warehouse. Third, the

aforementioned operations and factors interact which each other design procedures suggested in literature cannot be applied to the overall layout of a warehouse.

Canen and Williamson (1998) stated that a facility layout is the arrangement of work space in terms of smoothing the way in order to access facilities that have strong interaction. A facility layout is the way to increase company's competitive advantage. As the result of a good layout, it helps the company to improve its business performance. The plant facility layout planning is concerned with reducing the cost of materials handling. In case of poor material handling, it can generate business problems.

2.3 Warehouse Operations

Frazelle (2002) explained that warehousing is now increasingly important in logistics and supply chain management. A warehouse is a service to all the other areas of logistics. Most warehosue activities are (1) receiving; (2) putting away; (3) storing; (4) order picking; and (5) shipping. The warehouse must be designed to meet the requirements of the customer service. Therefore, warehouse operations have a fundamental set of activities in common.

Mulcahy (1994) explained warehouse operations about the facility layout as consisting of proper arrangement with adequate space for the design and inventory volume, warehouse functions, and distribution support activities. The key warehouse functions and activities are (1) yard control; (2) receiving and staging; (3) opening, counting, and ticketing; (4) internal transportation; (5) storage; (6) order pick and distribution; (7) packaging; (8) weighing and manifesting; (9) customer returns and out-of-season product transfer; and (10) staging and shipping. The other key warehouse functions and support activities will occupy 20 to 30 percent of the total facility area.

Gaither and Frazie (1999) explained that warehouse operations handle all materials that are directly involved with operations, production, sales and marketing and

customer service functions. The types of problems often involved in warehouse operations are ordering problems, stock problems, warehouse operation problems such as checking activities and order fulfillment problems.

Gunasekaran (1999) said that storage is the core activity of warehousing operation and it helps to identify the location where the goods should be deposited and held until goods are demanded for usage. The items are different in shapes and sizes and are also different in usage rates of the storage space. It must be designed to fit each item, or category of items. The warehouse is responsible for linking containerization which helps improve the cost-effectiveness of transportation, facilitate the mechanisation of the warehouse, decrease the amount of packaging material used and save on an expensive recycling scheme. Software and automatic data collection can be realized to improve warehouse operations. As a result of using the barcode in conjunction with software, it can be used to collect data in warehouse operations such as space utilization, return on investment, material handling equipment use, labour cost, order picking and customer service.

2.4 How to Increase Storage Space

Mulcahy (1994) pointed out that there are three possible solutions to increase the storage (cube) utilization in the design of a new facility or in the remodel of an existing facility which are;

Using the Airspace

The first possible solution which helps to improve cube utilization is to use the airspace above the floor. These alternatives are to use freestanding or equipment-supported mezzanines, taller racks, or cantilever racks, to splice onto existing racks or to use stacking frames (portable racks). It helps to increase the number of unit loads, cartons, or single items that are vertically stacked per square foot or floor space.

Using Narrow-Aisle or Very-Narrow-Aisle Vehicles

The second possible solution is to use narrow-aisle or very-narrow-aisle material handling vehicles with tall racks. In a building, material handling vehicles and racks can help to increase the number of rack rows for unit-load storage within the building structure.

Using Dense Storage concepts

The third possible solution is to use dense storage material handling rack storage equipment that uses floor stacks, flow racks, drive-in or drive-in through racks, car-in racks, mobile racks, and two-deep racks which help to increase the number of unit loads and cartons within the walls of the building. It requires fewer aisles than do standard racks.

Expansion

Expansion is the final possible solution that helps to increase the storage capacity by expanding the existing building with the same or new material handling equipment. It can be either above or below ground (Mulcahy, 1994).

2.5 Storage Rack Systems

There are many designs of racks to be used in pallet storage. Frazelle (2002) stated that the most common storage rack systems are the flow rack system, push back racks, and selective racks.

Flow Rack System

The flow storage rack consists of two elements: a static rack structure and dynamic flow rails. The flow rack rails are a track/roller system set at decline along the length of the rack. Flow rails allow loads to move by gravity from the loading end to the

unloading end. Each flow lane should include speed controllers to, gently control the speed of the movement within the flow lanes. As the load is removed, the loads behind it move forward to the unloading position. The flow systems dimensions are limited only by the size of the facility and the capabilities of the material handling equipment. This kind of system is used in situations where storage density and inventory rotation is a priority. The benefits of flow rack systems are: to work for FIFO inventory control, reduce handling costs as it eliminates labor and fork truck operations, reduces handling equipment costs as forklifts are used for initial loading and final unloading, save time and labor. Also traffic is more orderly and employees are more efficient in helping to increase overall productivity. Space savings as storage density can be doubled as well in addition to construction cost savings as the need for new area can be eliminated by increasing storage capacity within existing facilities (Frazelle, 2002).

Selective Pallet Rack System

The selective racking system enables products to be placed and removed without interring with other pallets. As a system which is suitable for a large variety of goods, its economical installation and utilization makes it the idel multi-storage unit. This is the best solution for a 100% access to all pallets stored with the following features:

1. Quick assembly which is easy to install
2. Easy beam adjustments
3. Bolted construction allowing for a replacement of the damaged component

2.6 Facility Layout Methods

Mulcahy (1994) mentioned that a project design team can use distribution design and facility layout methods to make a warehouse and distribution layout. Facility layout methods are (1) a block layout method, (2) standard templates and a layout board method, (3) a drawing method, and (4) a model method.

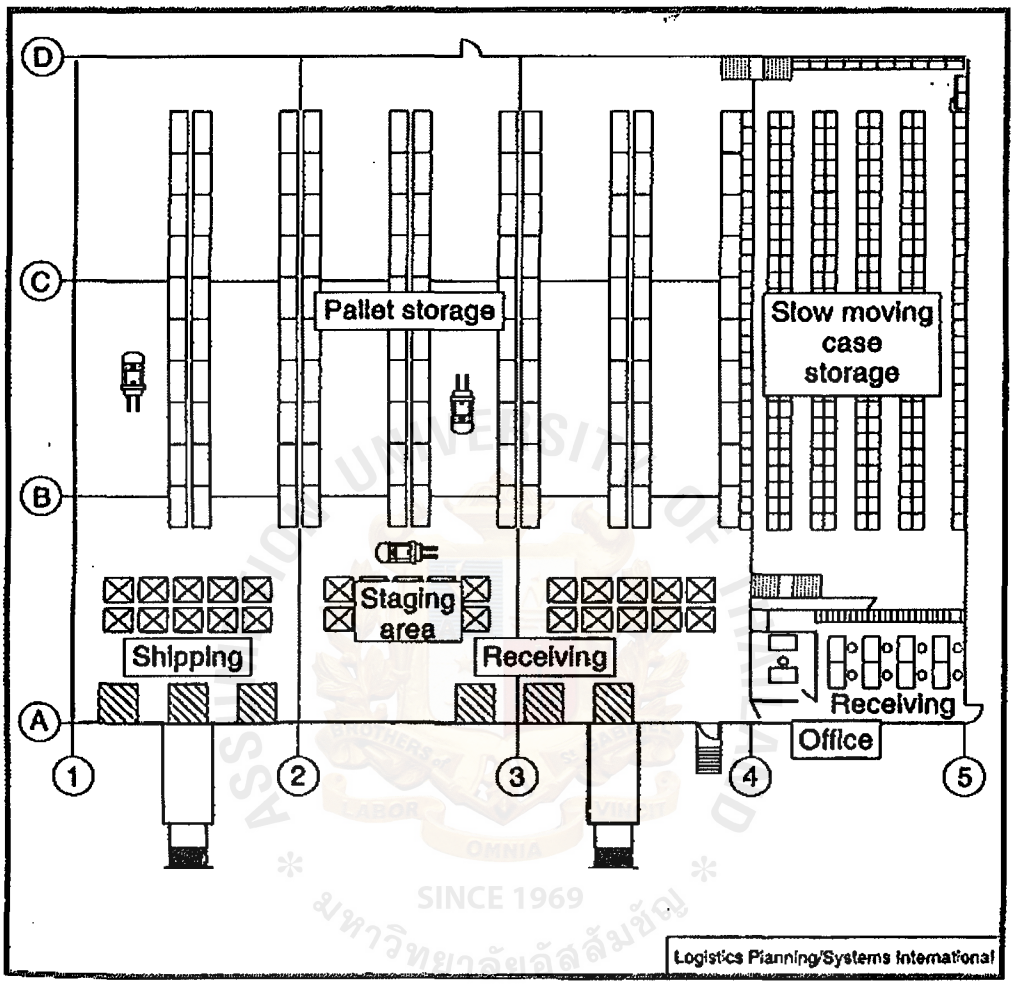
Block Layout Method

The block layout method is a "not to scale" drawing. This method shows the total building size and shows that each area of the building is allocated to a specific warehouse function. This layout method can be used to improve the area size of each function and help to estimate the total building square footage.

Layout Board and Standard Templates Method

The layout board with templates is a two-dimensional and "to scale" representation of their designer's concept for a warehouse or distribution facility that will include the necessary equipment. These layout methods represent the floor which is above or below the floor. After the final template and layout board, the facility design will be transferred to a manually or computer-produced drawing as seen in Figure 2.1.

Figure 2.1: Standard Template and Layout Board by Mulcahy (1994)



Source: Mulcahy (1994)

2.7 Conceptual Model to Improve the Effectiveness of Warehousing Operation

Gunasekaran (1999) said that a conceptual model is under two perspectives which are JIT and TQM. The models help to improve the effectiveness of warehousing operations. The JIT application in warehousing operations is concerned with demand pull, reducing work-in-process (WIP), supplier reliability preventive maintenance, reducing lead time, improving on time delivery of the goods to different destinations and eliminate buffers.

Moreover, JIT aims to improve manufacturing efficiency in the operation system to solve productivity problems by reducing the inventory and through-put time, thus decreasing the number of parts waiting because JIT is a kind of demand pull system. TQM aims to improve the effectiveness and quality control in warehousing operations. The limitation of JIT is that can only work where there is co-operation and trust and need for strong supplier-customer links; JIT requires effective information systems.

2.8 Summary

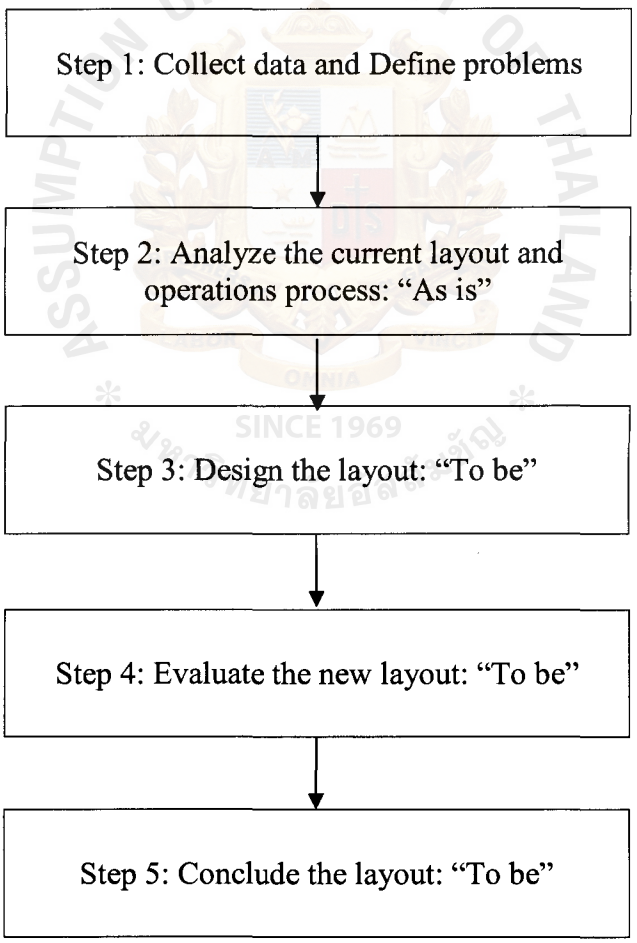
The main purpose of the literature review is to enhance knowledge about a warehouse layout design to improve space utilization of the existing warehouse and use the concept of related literature regarding how to improve the flow of materials to increase picking efficiency and material moves. The comparison shows that a warehouse redesign is a suitable methodology for improving picking efficiency of the existing warehouse.

CHAPTER III

RESEARCH METHODOLOGY

In this chapter, the researcher explains the methodology used in this study by following five steps. The tool for the data analysis is calculated by Microsoft Excel. The following Figure 3.1 presents the research framework which explains the main concept for each step of this project.

Figure 3.1 Research framework and steps



3.1 Data Collection

Data collection is concerned with a warehouse layout design in warehouse no. 2 of customer C to collect data. The objective is to find a source of information for creating and supporting the conclusions of the result and achieving the purpose of study. There are two main types of data collected in this study which are primary data and secondary data.

Secondary data used in this research includes;

1. Warehouse operation process map-receiving & put away and loading
2. Inbound & outbound materials flows

The study of process improvements is additionally collected from journals, articles and text books.

Primary data used in this research includes;

1. The warehouse layout design in warehouse no. 2

This basic data is obtained from observation and collection of information of the actual work in warehouse no. 2. The primary data is collected by using two methods: observations and interviews.

3.1.1 Observation

The data of actual warehouse operation processes and time record used at each stage were collected by observation. The selected main warehouse operation processes were from warehouse no. 2 of customer C at Yusen Bangbor Logistics center. The result of the observation during activities in each stage can enhance an understanding of a warehouse operation process flow and help to explain what is going on, who and what is involved, when and where things happen, how and why they occurred from the standpoint of the participants. In addition, it helps to identify cases of problems and

propose possible improvements for warehouse efficiency in terms of space utilization and picking efficiency.

3.1.2 Interview

In the interview session, the researcher used a face-to-face interview with the logistics general manager at Yusen Bangbor Logistics center. The interview was held in May 2013. The plots of an interview covered three main topics. First, an interview about a current warehouse layout design in warehouse no. 2 of customer C was conducted to ensure an understanding of the warehouse operation process flow including the space utilization method, and cargo movement. Second, the critical issues, a proposal for improvement and goals for warehouse improvement of space utilization and the picking process were analyzed. These topics were concerned with the problems that the company has been facing, what they did to solve the problems or obstacles in the past and fix the weakness of the current operation. Finally, a discussion about the proposed warehouse layout design and the warehouse operation process is formatted. It helped the researcher understand Yusen's warehouse operation process, layout design, design of the facility, and material handling equipment.

3.1.3 Inbound & Outbound Material Flow

The researcher collected the data of Inbound & Outbound Materials flows from January 2013 to July 2013 from the Logistics Department to identify storage capacity and the flow of material movement for six months as indicated in Table 3.1.

Table 3.1: Inbound & Outbound Material Flows per Month (January – June 2013)

Month	Inbound Shipments (Pallet)[a]	Outbound Shipments (Pallet)[b]	Stock Balance of Previous Month (Pallet)[c]	Maximum Storage Capacity (Pallet)[d]
Dec-12			347	
Jan-13	345	348	344	280
Feb-13	368	359	353	280
Mar-13	343	376	320	280
Apr-13	334	342	312	280
May-13	450	378	384	280
Jun-13	354	348	390	280
Total	**2,194**	**2,151**		

Source: Yusen Bangbor Logistics Center

Remark: [a] The data of inbound shipment (pallet) is gathered from company records.

[b] The data of outbound shipments (pallet) is gathered from the company records.

[c] The stock balance (pallet) per month is calculated by (c) + (a) – (b).

[d] The maximum storage capacity (pallet) is gathered from the company records.

Table 3.1 shows inbound and outbound material flows per month from January – June 2013 of customer C in warehouse no. 2. The stock balance per month per pallet is calculated by the stock balance of the previous month plus inbound shipments each month and minus outbound shipments. It shows that the stock balance each month is over the maximum storage capacity by 280 pallets per month.

The warehouse layout shows the starting point, the picking area and the staging area which determine the distance. It can help to improve space utilization.

Figure 3.2: Process Map – Receiving and Putting away

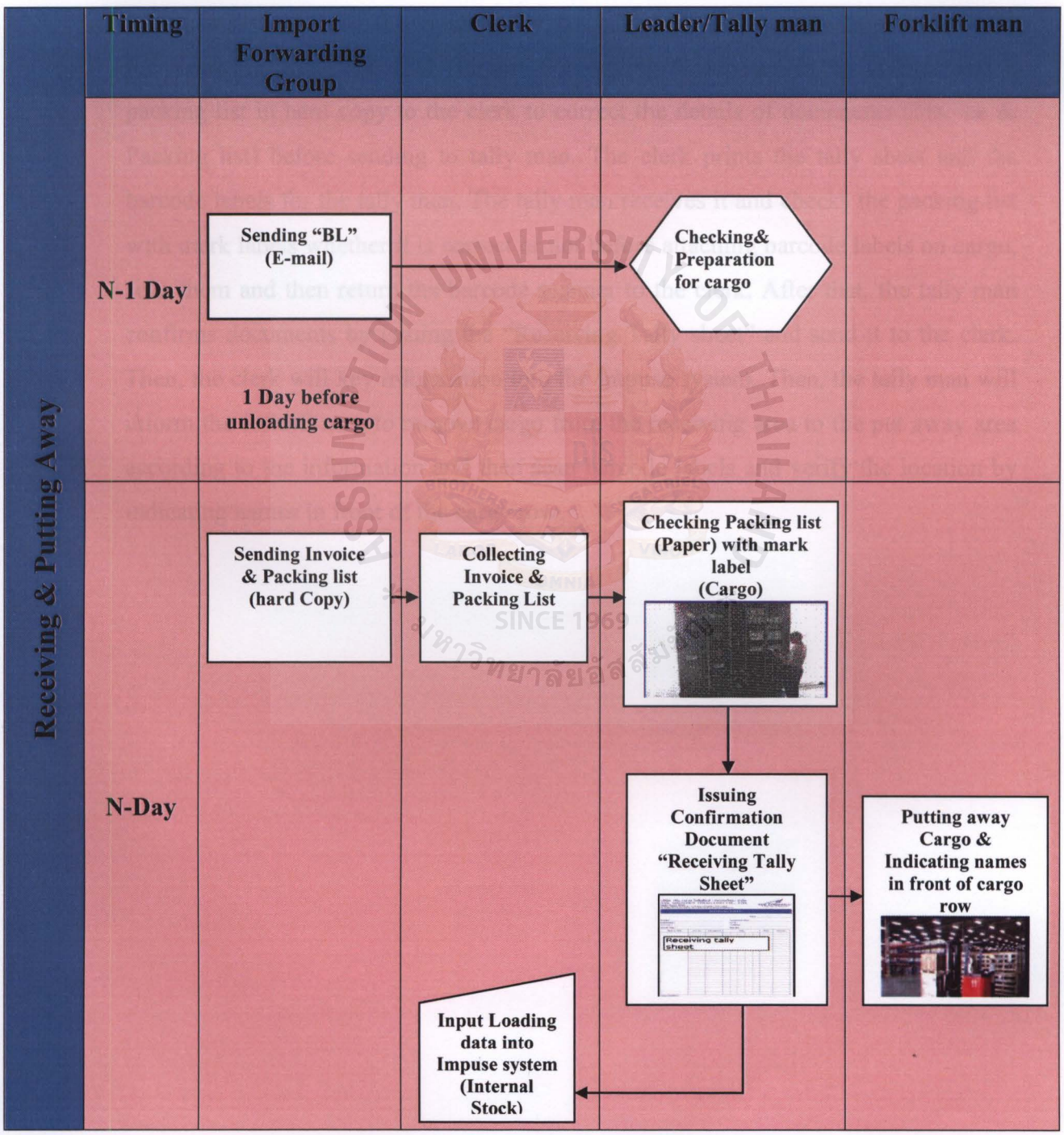


Figure 3.2 explains warehouse operation process map-receiving & putting away in warehouse no. 2 that starts from the Import forwarding group receiving shipping documents from customer C. On the day before the actual unloading day, they send the B/L (bill of lading) to the leader or tally man at YBLC (Yusen Bangbor Logistics Center). The tally man check details of documents and cargo according to BL documents. On the actual unloading day, the tally man moves cargo from the truck to the receiving area. The IFG (Import Forwarding Group) sends an invoice and a packing list in hard copy to the clerk to correct the details of documents (Invoice & Packing list) before sending to tally man. The clerk prints the tally sheet and the barcode labels for the tally man. The tally man receives it and checks the packing list with mark labels whether it is correct or not before attaching barcode labels on cargo, scan them and then return the barcode scanner to the clerk. After that, the tally man confirms documents by issuing the "Receiving Tally sheet" and send it to the clerk. Then, the clerk will key information into the Impuse system. Then, the tally man will inform the forklift man to remove cargo from the receiving area to the put away area according to the information and then scan barcode labels and verify the location by indicating names in front of the cargo row.

Figure 3.3: Process Map-Loading

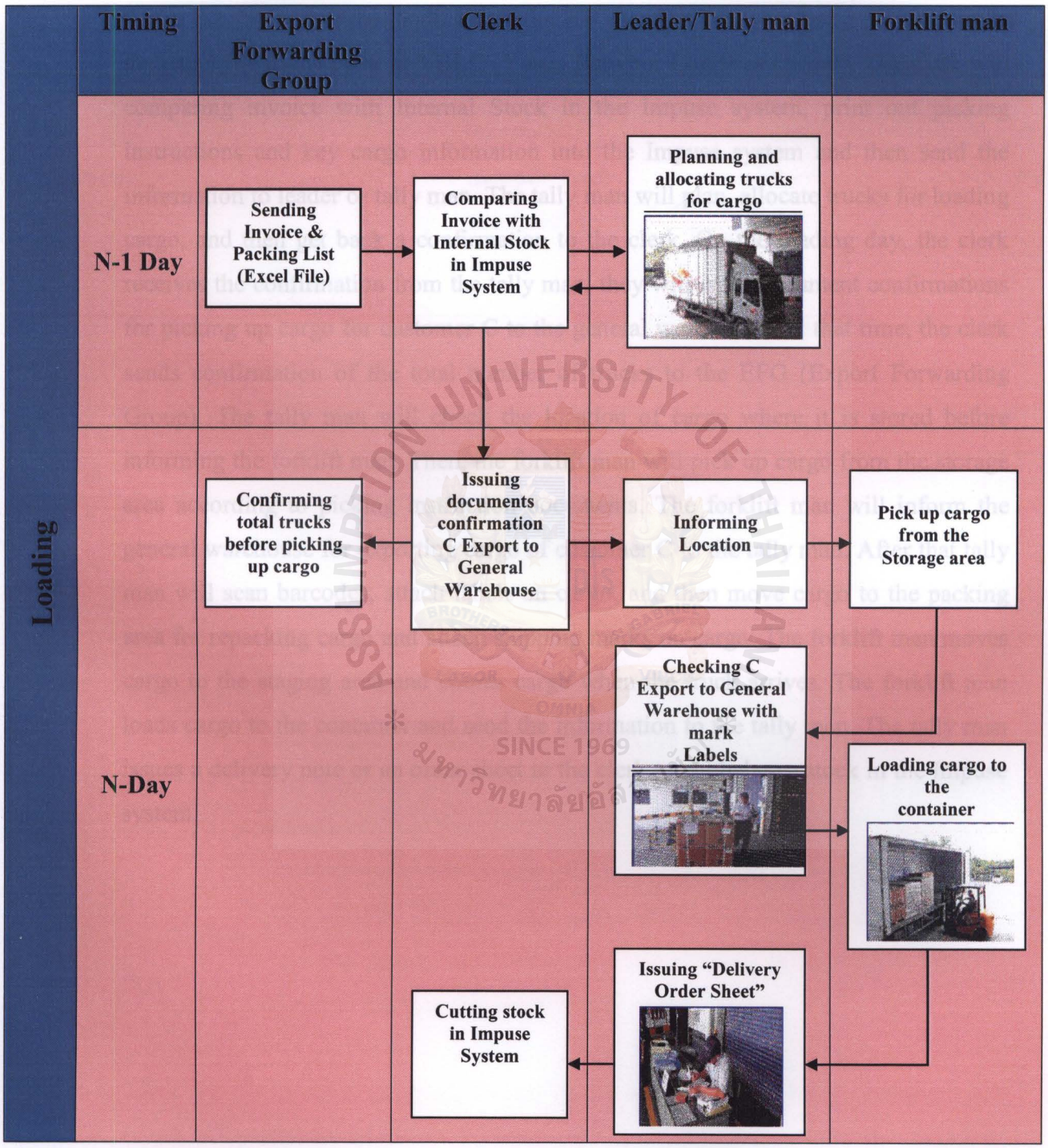


Figure 3.3 explains warehouse operation process map-loading in warehouse no. 2 that starts from the EFG (Export Forwarding Group) receiving documents from customer C. On the day before the loading day, the EFG sends an invoice and a packing list in the excel file to the clerk at YBLC (Yusen Bangbor Logistics Center). The clerk will comparing invoice with Internal Stock in the Impuse system, print out picking instructions and key cargo information into the Impuse system and then send the information to leader or tally man. The tally man will plan, allocate trucks for loading cargo, and then get back a confirmation to the clerk. On the loading day, the clerk receives the confirmation from the tally man, they will issue document confirmations for picking up cargo for customer C to the general warehouse. At that time, the clerk sends confirmation of the total number of trucks to the EFG (Export Forwarding Group). The tally man will check the location of cargo where it is stored before informing the forklift man. Then, the forklift man will pick up cargo from the storage area according to picking instruction documents. The forklift man will inform the general warehouse for exporting cargo of customer C to the tally man. After that tally man will scan barcodes, attach labels on cargo, and then move cargo to the packing area for repacking cargo and attach shipping marks on cargo. The forklift man moves cargo to the staging area and counts cargo when the truck arrives. The forklift man loads cargo to the container and send the information to the tally man. The tally man issues a delivery note or an order sheet to the clerk to cut balance stock in the Impuse system.

Table 3.2: Existing Warehouse Layout Information

Existing Warehouse Layout for Customer C							
Location	**Pallet size (1.1 x 1.2)[a]**	**No. of Row [b]**	**Maximum Pallet per Row (on floor) [c]**	**Total Pallet per Location [d]**	**Stack Level [e]**	**Total Storage Space Required (m^2) [f]**	**Total Pallet [g]**
A-D	1.32	4	5	20	2	52.8	40
E-H	1.32	4	5	20	2	52.8	40
I-M	1.32	5	5	25	2	66	50
N-Q	1.32	4	5	20	2	52.8	40
R-V	1.32	5	6	30	2	79.2	60
W-Z	1.32	4	6	24	2	63.36	48
Total Storage Capacity						**366.96**	**278**

Remarks: [a] The data of pallet size is calculated by W1.1 x L1.2.

[b] The number of row is gathered from the company records.

[c] The maximum pallet (on floor) per row is gathered from the company records.

[d] The total pallet per location (Pallet) is calculated by (b) x (c).

[e] The number of stack level is gathered from the company records.

[f] The total storage space required is calculated by (a) x (b) x (c).

[g] The total pallet is calculated by (d) x (e).

Table 3.2 shows an existing warehouse layout of customer C before redesigning a layout. All pallets are on the floor with no racking system. It shows that the maximum storage capacity of existing layout is 278 pallets and the required total storage space is 366.96 m^2.

3.2 Analyzing the Current Layout and Operations Process: "As Is"

After all data has been gathered, the first step is to analyze the data of inbound and outbound materials flows, the process map, and the existing warehouse layout for customer C. The next step is to analyze the current process or "As Is" in order to improve the efficiency of the existing warehouse in terms of space utilization and picking efficiency. The tool for the data analysis is calculated by Microsoft Excel.

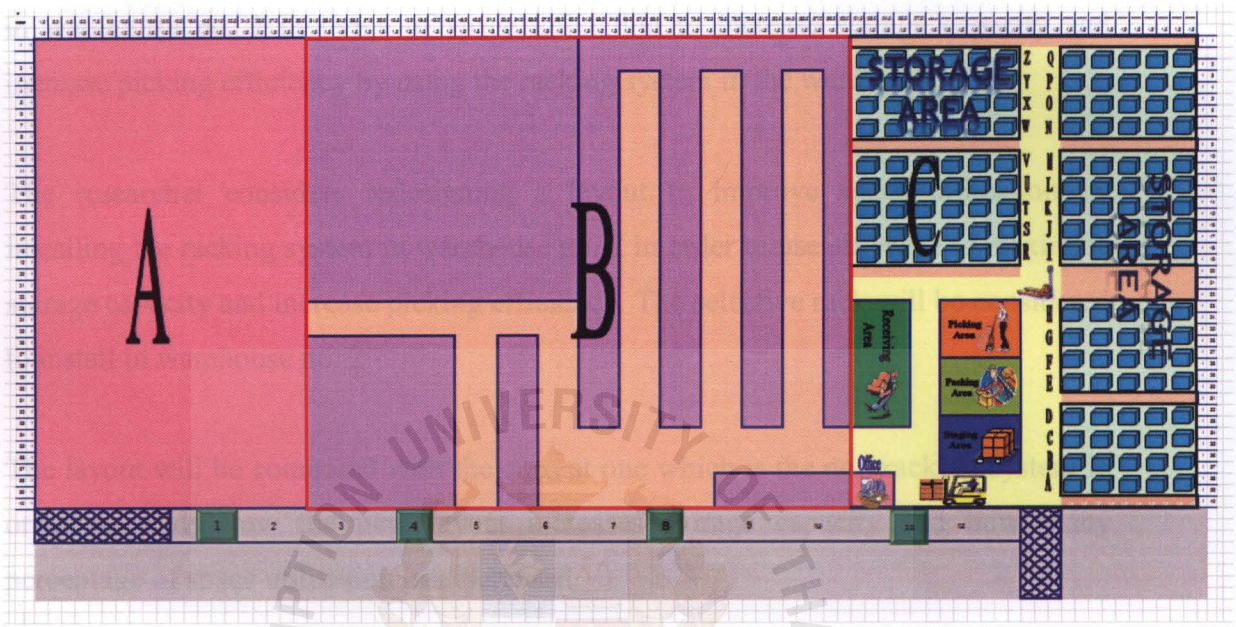
The data of inbound and outbound material flows helps to identify storage capacity and the flow of material movement in warehouse no. 2 in order to allocate space to meet customer demands. The warehouse operation process map is to analyze the existing process and identify causes of slow cargo movement in the picking process that have an impact on the warehouse efficiency. It helps the researcher understand warehouse operation as well. The data collected by observation and interview techniques are analyzed to find out the problem in warehouse no. 2.

After studying the warehouse operations process map, the researcher found that the picking process has low efficiency that impacts slow cargo movement in the current warehouse layout because number of shipping instruction per day is only 16 jobs per day and the forklift driver spends more time for picking up cargo from storage area. He spends 30 minutes to complete all shipping instruction per day due to he cannot pick up the pallets one by one that is different from storage cargo on the racking system.

The current warehouse layout is analyzed to identify space utilization in warehouse no. 2

The current warehouse layout design at Yusen Logistics Bangbor Center can be seen in Figure 3.4.

Figure 3.4: The Current Warehouse Layout Design for Customer C in Warehouse No. 2



Source: Company Data

Figure 3.4 shows the current warehouse layout of customer C in warehouse no. 2. This composes of 6 main processes which are receiving, putting away, storing, picking, packing and dispatching.

The researcher found that the current warehouse layout in warehouse no. 2 is running out of space because the cargo volume is over storage capacity and the pallets are laid on the floor can be stacked only two levels high which is difficult for the forklift driver to access pallets in each location. The forklift driver cannot pick up pallets one by one, which is different from cargo storage on racking systems. In case that the forklift driver wants to pick up a specific pallet, they have to move out the outer pallet to get the inner pallet and then there is a need to move back those pallets to the same location. It requires more time for picking up the cargo which is the cause of slow cargo movement.

3.3 Designing the Layout: "To Be"

The purpose of designing a layout "to be" is to improve the existing warehouse layout in warehouse no. 2 in terms of space utilization to increase storage capacity and increase picking efficiency by using the racking system in the warehouse.

The researcher considers redesigning a layout to improve space utilization by installing the racking system in warehouse no. 2 in order to use air space to maximize storage capacity and increase picking efficiency. The selective rack will be considered to install in warehouse no. 2

The layout will be compared with the current one which is the non-racking system in order to study how the new layout increases storage capacity and how many percentage of space utilization has increased.

Therefore, the layout after installing the racking system "to be" will increase space utilization and picking efficiency.

3.4 Evaluating the New Layout, "To Be"

Before the new layout or the new process is proposed, this new layout will be evaluated using Microsoft Excel. If the new layout is improved when compared with the current process, the new layout will be proposed accordingly.
The warehouse layout design offered potential improvement by trying to optimize space, promoting effective use of the people, and equipment, and increasing picking efficiency. The design eliminates as many steps as possible, combining steps, increasing picking efficiency, and improving the warehouse operation process.

3.5 Concluding the Layout: "To Be"

After the new layout has been evaluated and the result is improved when compared with the current process, the new layout shall be proposed. With the above

framework, methodology and steps, the researcher believed that this study will be useful for an international freight forwarding company in terms of space utilization, and increased picking efficiency to enhance customer satisfaction.

CHAPTER IV

PRESENTATION AND CRITICAL DISCUSSION OF RESULTS

The collected data and relevant information from observations and the warehouse operation process in warehouse no. 2 at Yusen Bangbor Logistics center will be analyzed by redesigning a layout. There are five parts of the analysis which are analyzing warehouse space utilization, picking time, the design layout "to be", evaluating the new layout "to be" and concluding the layout "to be". Finally, a comparison of total cost of racking investment and racking return on investment from Microsoft Excel is explained.

The objective of a warehouse redesign will improve the existing warehouse layout in terms of space utilization, increase picking efficiency, and improve the warehouse operation process.

4.1 Analysis of Warehouse Space Utilization

From Chapter 3, the problem of running out of space in warehouse no. 2 before installing racking system is the cargo volume over storage capacity and customers require more space. The problem of low warehouse space utilization has impact on the warehouse performance and service level dropped.
The researcher found that warehouse layout redesign by installing racking system that helps the company to improve the existing warehouse in terms of warehouse space utilization which can increase storage capacity.

The comparison between the new layout and the current layout which the non-racking system is analyzed to measure how the new layout increases storage capacity and how many percentage of space utilization has increased as shown in Table 4.1.

Table 4.1: The Comparison of Storage Capacity between the Current and the Racking System

Warehouse Space Utilization						
Warehouse No. 2: Customer C	Current		Racking System		Storage Capacity Increase (Percent)	
	Space Used (m^2)	Total Pallet	Spaced Used (m^2)	Total Pallet	Square Meter [a]	Pallet [b]
	366.96	278	876.48	904	138.85%	225.18%

Remarks: [a] Total percentage of storage capacity (m^2) is calculated by space used in the racking system (m^2) - current space used (m^2)/ current space used (m^2) * 100.

[b] Total percentage of storage capacity (pallet) is calculated by the total pallet of the racking system - current total pallet/ current total pallet * 100.

According to Table 4.1 improvement warehouse space utilization in warehouse no. 2, it is found that the total stored pallet capacity has increased when proposed with a design layout by installing the racking system in warehouse no. 2 for customer C. With the proposed design layout, the total stored pallet capacity is increased from 278 pallets per month to 904 pallets per month. The percentage of storage capacity after improvement layout is an average of 138.85% in m^2 and 225.18% on pallets.

4.2 Analysis of Picking Time

According to the problem of inefficiency in the picking process leads to slow cargo movement and time consumption. The products are laid on the floor without racking systems. It is difficult for the forklift driver to access pallets at each location and spend more time to pick up specific pallets. As there is a problem, they can complete only 16 jobs per day, which is lower than the KPI performance target of 30 jobs per day. The problem of slow cargo movement in the picking process has an impact on the warehouse efficiency.

The picking time per shipping instructions was collected by the count time method. The result presents the picking time per shipping instructions in the picking process which was calculated in average picking time by 170 shipping instructions associated with the number of items and number of cartons (see Appendix 2).

The comparison of average picking time per shipping instructions between before and after improvement by a warehouse redesign can be seen in Table 4.2.

Table 4.2: The Comparison between Before and After Improvement of Picking Time

	Working Time/Day (Hours)	Total Time (Minutes)	Total Time/Day (Minutes) [a]	Average Picking Time/Shipping Instruction/Day (Minutes)	Total Shipping Instruction/Day/ One Picker (Job No.) [b]
Before Improvement	8	60	480	30	16
After Improvement	8	60	480	15	32

Remarks: [a] The total time per day (minutes) is calculated by working time per day (hour) multiply by the total time (minutes).

[b] The total shipping instructions per day per one picker (Job No.) is calculated by the total time per day (minutes) divided by average picking time per shipping instructions per day (minutes).

Table 4.2 indicates that the picking process is improved by changing the new layout design from the non-racking system into implementing the racking system in warehouse no. 2. As a result, picking time is reduced from 30 minutes to 15 minutes or decreased by 50% and this also increased the capability of one picker to finish the

total shipping instructions from 16 jobs per day to 32 jobs per day, which is higher than the KPI performance target of 30 jobs per day. The installation of the racking system is useful for forklift drivers to ease to access pallets at each location and can replenish cargo quicker. They can pick up pallets one by one, which is more convenient and easy for cargo arrangement. Less time is spent for picking up the cargo to finish all shipping instructions per day and there is fast cargo movement after the improvement process. As a result of the improvement layout by installing the racking system, it helps to increase picking efficiency and cargo movement is better than before the improvement.

4.3 Designing the Layout: "To Be"

The purpose of a design layout "to be" is to improve the existing warehouse layout in terms of space utilization to increase storage capacity and increase picking efficiency by using the racking system in the warehouse. The selective rack is the most suitable for installing in the new layout in order to use air space to maximize storage capacity.

The new layout "to be" in warehouse no. 2 for customer C can be seen in Figure 4.1.

Figure 4.1: The New Layout "To Be" for Customer C

Figure 4.1 indicates that the new layout "to be" can improve space utilization by implementing the racking system in warehouse no. 2. It was found that the racking system helps to improve storage capacity by using the airspace above the floor. The new layout is designed to fit the category of product items of customer C. The new layout will be designed to allocate the total warehouse space of 1,500 m^2 in order to use more space as effectively as possible. It helps arrange the storage locations so that these product items can be reached easily and material handling equipment can still function and is not restricted when it comes to space. After implemented racking system in the warehouse, the researcher found that racking system can reduce time consuming in picking process because the forklift driver can pick up pallet one by one

when compared to the current warehouse layout. The cargo movement of racking system is faster than the current process even though without changing the warehouse operation processes map. After redesign the new layout, every activity in warehouse operation process still be the same but the cargo movement will be changed to be better and faster than the current layout. As a result of warehouse layout redesign, it helps to improve picking efficiency in terms of number shipping instruction that has increased from 16 to 32 jobs per day and picking time will be reduced from 30 minutes to 15 minutes or decreased by 50% when compared to the current warehouse layout.

This warehouse layout is to create space for rack storage while providing sufficient circulation paths for 3 meter forklift trucks. The warehouse has allocated space into 6 main processes to support warehouse operation in order to increase space utilization and improve the warehouse operation process to enhance customer satisfaction.

The selective racking system is the most suitable to be implemented in warehouse no. 2 because it enables products to be placed and removed without crashing with other pallets and it also increases convenience for forklift drivers to access pallets at each location easily.

The figure of the selective racking system can be seen in Appendix 1. The new layout is designed to fit the category of product items of customer C which are automotive parts. As a result of the installed racking system, the results show that storage capacity is increased and warehouse efficiency is improved as shown in Table 4.3.

Table 4.3: Improvement of Storage Capacity after Implementing the Racking System in the Warehouse

Storage Capacity of Selective Rack							
Location	**Pallet Size (1.1 x 1.2) [a]**	**Maximum Pallet per Column [b]**	**No. of Column per Bay [c]**	**No. of Bay per Row [d]**	**No. of Row [e]**	**Total Storage Space Required (m^2) [f]**	**Total Pallet [g]**
1-9	1.32	2	4	5	8	422.40	320
10-15	1.32	2	4	6	6	63.36	280
16	1.32	2	4	7	1	73.92	56
17-22	1.32	2	4	5	6	316.80	240
Total Storage Capacity						**876.48**	**904**

Remarks: [a] The data of the pallet size is calculated by W1.1 x L1.2.

[b] The maximum pallet per column is gathered from the company records.

[c] The number of columns per bay is gathered from the company records.

[d] The number of bays per row is gathered from the company records.

[e] The number of rows is gathered from the company records.

[f] The total storage space required is calculated by (a) x(b) x (c) x (d) x (e).

[g] The total pallet is calculated by (b) x (c) x (d) x (e).

Table 4.3 indicates that space utilization of the new layout "to be" after redesigning a layout by installing the selective racking system is improved. As a result of layout improvement, storage capacity is increased from 278 pallets per month to 904 pallets or by 225% and the required total storage space is 876.48 m^2.

The new layout design can increase potential improvement in terms of optimizing space, promoting effective use of the people and equipment and increasing picking efficiency.

Table 4.4: Warehouse Operational Staff

Number of Employees	Unit
Chief	1
Clerk	1
Tally Man	3
Forklift Driver	1
Worker	1
Total	**7**

According to Table 4.4, warehouse operational staff after the improvement layout in warehouse no. 2 for customer C is shown it indicates that warehouse operation can be improved by allocating appropriate numbers of employees to increase the effective use of people, and select the right equipment in order to increase picking efficiency. This project requires 7 employees to support the warehouse operation process including chief, clerk, tally man, forklift driver and worker.

Table 4.5: Summary of Warehouse Space Allocation and Material Handling Equipment after Layout Improvement

Warehouse area	Unit
Office area	21 m^2
Rack storage area	876.48 m^2
Preparation area	70 m^2
Receiving area	66 m^2
Forklift way	396.52 m^2
Total warehouse area	1,500 m^2
Floor load	2.5 ton per m^2
Ceiling height	5 meters
Dock leveler	1 unit
Forklift truck: Reach truck	1 unit

Table 4.5 shows warehouse space allocation of the new layout in warehouse no. 2 for customer C and material handling equipment required. The reach truck is the most suitable forklift truck to be used in warehouse operation. This project requires only one unit of forklift truck.

Therefore, it implies that the number of pallets stored in the racking system can increase if the company is proposed the new design layout by installing the racking system.

4.4 Evaluating the New Layout: "To Be"

After the new layout has been evaluated by using Microsoft Excel, the researcher found that the new layout has been improved when compared with the current layout; the new layout will be proposed. As a result of improvement, the new layout design can offer the potential improvement and help to optimize space, promote effective use of the people and equipment and increase picking efficiency. The design can reduce time consumption in the picking process and increase storage capacity as a result of improved space utilization which helps the company improve the warehouse operation process and increase customer satisfaction.

4.5 Concluding the Layout: "To Be"

The new layout "to be" can improve the existing warehouse layout of the company in terms of space utilization, increase storage capacity and increase picking efficiency by using the racking system in the warehouse. The selective rack system is the most suitable for installing in warehouse no. 2 because it's appropriate for the nature of cargo of customer C which is the automotive part and specific customer requirements. Moreover, the selective racking system can increase flexibility in terms of cargo arrangement and increase picking efficiency because it helps forklift driver to access pallets at each location easily with less time. They can pick up pallets one by one which is better than the current layout. The selective rack can be seen in Appendix 1.

4.6 Analysing Investment Cost for Racking Implementation and Racking Return on Investment

According to the analysis of investment cost of racking implementation and racking return on investment, there are five elements that are necessary to calculate before making a decision to design a layout by installing the racking system as follows:

1. The comparison of value revenue increase between the current and the racking system
2. The revenue forecast after racking implementation
3. Racking cost investment in warehouse no. 2
4. Racking return on investment and year of return on investment from the value revenue increase
5. Total profit and profit margin (percent) after racking investment

4.6.1 The Comparison of Value Revenue Increase between the Current and the Racking System

The value revenue increase of the company and its explanation are described in Table 4.6.

Table 4.6: The Comparison of Value Revenue Increase between the Current and the Racking System

Storage Capacity				Storage Revenue		Value Revenue Increase	
Current		Racking System		Current [a] (Baht/Day)	Racking System [b] (Baht/Day)	Monthly [c] (Baht)	Yearly [d] (Baht)
m^2	Pallet	m^2	Pallet				
366.96	278	876.48	904	1,467.84	3,505.92	61,142	733,709

Remarks: The average storage revenue is 4 Baht per m^2 per day gathered from the company records.

[a] The storage revenue per day before improvement is calculated by the current total storage space required (m^2) multiplied by the average storage revenue per m^2 per day.

[b] The storage revenue per day after installing the racking system is calculated by total storage space required of the racking system (m^2) multiplied by the average storage revenue per m^2 per day.

[c] The value revenue increase per month is calculated by the storage revenue of the racking system per day minus the current storage revenue per day, then multiplied by 30 days.

[d] The value revenue increase per year is calculated by the value revenue increase per month multiplied by 12 months.

Table 4.6 indicates that the value revenue increases per month and per year are calculated by the variance of storage revenue per day from 278 pallets to 904 pallets between the current and the racking system. It shows that the company can generate additional revenue per month and per year after implementation racking system. As a result, the value revenue has increased by 61,142 Baht per month or 733,709 Baht per year.

4.6.2 Calculating Revenue Forecast After Racking Implementation

The revenue forecast consists of storage capacity, the pallet size and the average storage charge per m^2 per day. The company will estimate warehouse utilization at 80 percent of full capacity. The components and calculation of this revenue forecast for warehouse no. 2 are described below.

Table 4.7: Revenue Forecast after Racking Implementation

Storage Capacity		Warehouse Utilization (Percent)	Pallet Size (1.1 x 1.2)	Average Storage Revenue Per m^2 Per Day (Baht)	Revenue Forecast	
Total Storage Space Required (m^2)	Total Pallets				Monthly [a] (Baht)	Yearly [b] (Baht)
876.48	904	80%	1.32	4 Baht/ m^2/ Day	114,554.88	1,374,658.56

Remarks: [a] The revenue forecast per month is calculated by the total pallets * the pallet size * 80% of warehouse utilization * the average storage revenue per m^2 per day * 30 days.

[b] The revenue forecast per year is calculated by the revenue forecast per month * 12 months.

Table 4.7 indicates that the revenue forecast after installing the racking system is calculated by estimation of warehouse utilization at 80 percent of total 904 pallets. As a result of investment, the company will gain around 114,554.88 Baht per month and the revenue per year is 1,374,658.56 Baht.

4.6.3 Calculating Racking Cost Investment in Warehouse No. 2

The racking cost investment consists of total number of pallet, racking cost per pallet and the percentage of warehouse utilization. The calculation of racking cost investment is described in Table 4.8 below.

Table 4.8: Racking Investment in Warehouse No. 2

Total Pallet [a]	Racking Cost per Pallet [b] (Baht)	Racking Cost Investment [c] (Baht)
904	2,086	1,885,744

Remarks: [a] The number of total pallets is gathered by the company records.

[b] Racking cost per pallet is gathered by the company records.

[c] Total racking cost investment is calculated by (a) x (b).

According to Table 4.8, after redesign a layout by installing the racking system, it shows that the result of racking cost investment is around of 1,885,744 Baht based on racking cost per pallet and the total pallets given.

4.6.4 Calculating Racking Return on Investment and Year of Return on Investment based on Value Revenue Increase

There are consisting of two primary sources of warehouse revenues which are storage revenue and handling revenue. Storage revenue is the revenue from storage cargo in warehouse. The warehouse operations cost will not be used to calculate storage revenue. Handling revenue is the revenue that is calculated by the warehouse operational cost.

The calculation racking return on investment and year of return on investment from value revenue increase of the company in warehouse no. 2 is described in Table 4.9.

Table 4.9: Racking Return on Investment based on Value Revenue Increase

Value Revenue Increase		Total Pallet	Racking Cost Investment [a] (Baht)	Racking Return on Investment (Baht)			
Monthly (Baht)	Yearly (Baht)			1st Year [b]	Cumulative 2nd Year [c]	Cumulative 3rd Year [d]	Cumulative 4th Year [e]
61,142	733,709	904	1,885,744	586,967	1,173,934	1,760,901	2,347,868

As illustrated in Table 4.9, the racking return on investment based on value revenue increase is calculated; the results are as follows:

Remarks: Racking cost per pallet is 2,086 Bah per pallet.
The estimate warehouse utilization is 80 percent of full capacity.

[a] The racking cost investment is calculated by total pallet multiplied by racking cost per pallet.

[b] The racking return on investment of 1st year is calculated by value revenue increase per year multiplied by 80% of warehouse utilization.

[c] The cumulative racking return on investment of 2nd year is calculated by racking return on investment of 1st year multiplied by 2 years.

[d] The cumulative racking return on investment of 3nd year is calculated by racking return on investment of 1st year multiplied by 3 years.

[e] The cumulative racking return on investment of 4nd year is calculated by racking return on investment of 1st year multiplied by 4 years.

The calculation year of return on investment is calculated by racking cost investment (Baht) divided by racking return on investment of 1st year. The warehouse operation expenses are not included in calculation the revenue on investment due to this method is used to calculate only revenue from storage.

Therefore, year of racking return on investment = 1,885,744/ 586,967.04 = 3.2 years.

Table 4.9 indicates the calculation racking return on investment from the value revenue increase. It shows that if the company is making a decision to implement the racking system in warehouse no. 2, total cost of racking investment is 1,885,744 Baht and will get return on investment of 1st year around 586,967 Baht. Therefore, the company will get return on investment within 3.2 years.

4.6.5 Calculating the Total Profit and Profit Margin (Percent) after Racking Investment

The calculation of total profit and profit margin (percent) after racking investment will be explained step by step below.

Table 4.10: The Warehouse Operation Cost in Warehouse No. 2 of Customer C

Cost Type	Cost (Baht)
Reach Truck Cost (Baht) per Month	35,000
Electricity Cost (Baht) per Month	6,600
Forklift Driver (Baht) per Month	17,000
Total Warehouse Operation Cost per Month	58,600
Total Warehouse Operation Cost per Year	703,200

The data shown in the Table 4.10 indicates that the warehouse operation cost in warehouse no. 2 of customer C. It shows that total warehouse operational cost is 58,600 Baht per month and total warehouse operations is 703,200 Baht per year.

Table 4.11: The Calculation of Total Profit and Total Profit Margin (Percent) within 5 Years of Depreciation of Assets

Yearly	Revenue per Year (Baht) [a]	Racking Cost Investment (Baht) [b]	Inflation Rate (Percent)[c]	Warehouse Operation Expense per Year (Baht) [d]	Depreciation Expense (Baht) [e]	Total Profit (Baht) [f]	Total Profit Margin (Percent) [g]
1st Year	1,374,660	1,885,744	4%	703,200	377,149	294,311	21%
2nd Year	1,374,660	1,885,744	4%	731,328	377,149	266,183	19%
3rd Year	1,374,660	1,885,744	4%	760,581	377,149	236,930	17%
4th Year	1,374,660	1,885,744	4%	791,004	377,149	206,507	15%
5th Year	1,374,660	1,885,744	4%	822,644	377,149	174,867	13%

Remarks: The warehouse operation expense per month is 58,600 Baht.

Total revenue per month is 114,555 Baht.

The number of total pallets is 904 pallets.

The racking cost per pallet is 2,086 Baht.

The warehouse operation expense per year of 1st year is calculated by 58,600 x 12 months.

[a] Total revenue per year is calculated by revenue per month multiplied by 12 months.

[b] Racking cost investment is calculated by total pallet multiplied by racking cost per pallet.

[c] Internal rate of return is gathered from the company records.

[d] The warehouse operation expense per year is calculated by previous year of warehouse operation expense multiplied by the inflation rate of 4 percent.

[e] The depreciation expense is calculated by racking cost investment divided by 5 years.

[f] Total profit is calculated by total revenue per year minus depreciation expense and warehouse operation per year.

[g] The percentage of total profit margin is calculated by total profit divided by total revenue per year.

Table 4.11 shows the result of the total profit and total profit margin (percent) within 5 years of depreciation assets after installing the racking system in the new layout design. Total profit will be calculated with 5 years depreciation of assets. Depreciation expense is only a cost of racking installation. The warehouse operational expenses are the expenses happen in handling cargo movement in warehouse operation process but it can be applied to calculate handling revenue. As a result of the investment, the company will gain the total profit in 1st year around 294,311 Baht and the total profit margin is 21%. The total profit amount of the next year will vary based on the inflation rate each year.

4.7 Summary of the Financial Analysis Result

The financial analysis result after warehouse layout redesign by installing the racking system shows the result of racking cost investment around 1,885,744 Baht based on the racking cost per pallet and the total pallets given. The racking system can generate additional storage revenue from using airspace that will increase number of pallet from 278 pallets per day to 904 pallets per day. The company will estimate of warehouse utilization at 80 percent of full capacity at total 904 pallets that they will gain revenue forecast around 114,554.88 Baht per month and the revenue per year is 1,374658.56 Baht. The company will get money back from investment within 3.2 years. The calculation of year of return on investment, the company will not use warehouse operational cost to calculate storage revenue because warehouse operational cost is the cost of handling cargo and not involved with storage revenue. Therefore, average storage revenue of 4 Baht per m^2 per day will be used to calculate storage revenue only. This research will not calculate revenue on investment from handling cargo movement but it will show the calculation of return on investment

The warehouse operational expenses will not be involved with calculation of storage revenue.

In addition, the company will get the racking return on investment from the value revenue increase of 1st year is around 586,967 Baht that will increase from variance of number of storage from 278 pallets per day to 904 pallets per day. As a result of the investment, the company will gain the total profit in 1st year around 294,311.20 Baht and the total profit margin is 21% each year.

Although, the company cannot generate storage revenue of full warehouse space utilization and number of cargo volume from customer C has not increased as the company expected, the company can increase storage revenue by find the new potential customer to fulfill blank space in order to use full warehouse space utilization to increase storage revenue from blank space. The company can pay storage charge as actual use.

CHAPTER V

SUMMARY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter aims to discuss the findings obtained from the research question, to present the important issue drawn from the findings, and to provide recommendations for further study. The summary of the findings, conclusions, theoretical implementations, managerial implications, limitation and recommendations for future research to answer the question of how to improve the space utilization and operation efficiency in Warehouse no. 2 are presented in this chapter.

5.1 Summary of the Findings

The reason for conducting this research is to highlight the benefits of the improving the efficiency of the existing warehouse by redesigning a warehouse layout which can help to reduce a storage capacity problem and slow cargo movement in the picking process. The new layout design will be proposed that will improve space utilization. The racking system will be implemented to improve the flow of materials moves and increase picking efficiency.

Yusen Bangbor Logistics center is one of the companies that faced the problem of running out of warehouse space because the cargo volume is over storage capacity and there is inefficiency in the picking process. These problems lead to the research question which is, ***"How does a warehouse layout re-design, using the racking system help improve the space utilization and operation efficiency in Warehouse no. 2?"*** Therefore, the important objective of this research is to create warehouse space as much as possible to improve space utilization and improve the warehouse operation process. The tool for data analysis is calculated by Microsoft Excel.

The causes of the storage capacity problem and slow cargo movement in the picking process are described as below.

1) **Insufficient warehouse space**

The cause of insufficient warehouse space resulted from disorganized warehouse space which cannot provide adequate amount of storage space to support increasing numbers of inbound volumes.

2) **Inefficiency in the picking process**

From slow cargo movement, the pallets are laid on the floor without racking systems. It is difficult for forklift drivers to access pallets at each location and they cannot pick up pallets one by one, which is different from cargo storage on the racking system. Thus, the forklift driver has to spend more time picking up cargo to finish all shipping instructions per day leading to inefficiency in the picking process.

Problems of storage capacity and slow cargo movement are divided into 2 parts. The major concern is the current warehouse layout design in warehouse no. 2 for customer C and the warehouse operation process. Since the data of inbound & outbound materials flow were used to identify storage capacity, the warehouse operation process map was conducted to analyze the existing process and identify causes of slow cargo movement and the existing warehouse layout was conducted to identify space utilization. In order to solve the storage capacity problem and reduce picking time in warehouse operation, a redesign warehouse layout was implemented and summarized as follows:

1) **Over Storage Capacity Problem**

Problems of storage capacity in warehouse number 2 could be reduced if warehouse space can provide adequate amount of storage space to handle increasing numbers of inbound volumes with full space utilization. The warehouse layout design could offer potential improvement to optimize space utilization and increase storage capacity.

2) **Inefficiency in the Picking Process Problem**

The problem of the warehouse operation process in warehouse no. 2 is slow cargo movement because of the inefficiency in the picking process.

The pallets are laid on the floor without the racking system. Forklift drivers spend more time picking up specific pallets leading to inability to complete the job per day to meet the KPI target which will impact warehouse performance.

3) The New Layout Proposed

The proposed new layout design would help to improve space utilization to solve the problem of storage capacity and reduce picking time in the warehouse operation process. The racking system would be installed in warehouse no. 2 to improve the existing warehouse layout and increase picking efficiency. After the new layout had been evaluated and the result is improved when compared with the current process. As a result of the improved layout, the number of pallets stored in racking system is increased from 278 pallets to 904 pallets or by 225%. Moreover, the reduction of picking time is reduced from 30 minutes to 15 minutes or by 50% and also there is an increase in capability of one picker to finish total shipping instructions from 16 jobs per day to 32 jobs per day, which is higher than the KPI performance target of 30 jobs per day. Thus, the problem of slow cargo movement and storage capacity shall be reduced.

According to the redesign layout by installing the racking system in warehouse no.2, it shows that the result of racking cost investment is around 1,885,744 Baht based on the racking cost per pallet and the total pallets given. The company can improve space utilization by installing the racking system in warehouse as the racking system can increase 80% of warehouse utilization. Therefore, the company will get revenue around 114,554.88 Baht per month or 1,374,658.56 Baht per year and get return on investment within 3.2 years. As a result of the investment, the company will gain the total profit in 1st year around 294,311.20 Baht and the total profit margin is 21% each year.

5.2 Conclusions

The importance of acknowledging the causes and factors which affect the problem of stock capacity and slow cargo movement in picking process can lead all concerned parties in the supply chain, such as warehouses, suppliers, factories and customers to understand the current existing impacts in the warehouse operation processes. The result of this research provides the causes and effects in order to find out the way to avoid and prevent identified and unidentified problem areas that can possibly have an impact on overall warehouse operation performance. This study will enable the operation managers of the warehouse to continuously improve and cope with the possible causes and factors associated with the warehouse redesign in order to increase warehouse efficiency.

5.3 Theoretical Implications

The objective of this research was to increase the understanding and knowledge of the warehouse redesign so as to improve warehouse efficiency. The researcher could propose the new layout which was studied from the appropriate theories.

The major theory of this research was on warehouse redesign. Hassan (2004) identified that designing of warehouse layout is a complex task for many reasons as follows. First, the number of design decisions is large and is difficult to solve the problem. Second, operations (e.g. picking, dual command, cross docking, and value added services) and factors (e.g. demand, physical characteristics of items and unit loads, serving global markets, material handling, and just-in-time (JIT) that impact travel time, material handling cost, and throughput in warehouse. Third, the aforementioned operations and factors interact with each other. Moreover, Frazelle (2002) stated that a warehouse layout should be based on the space requirements for and the interrelationships between individual warehouse operations. Even though applying a warehouse redesign by installing racking system adds expenses, it can generate more revenue and profit realized from improved efficiency in warehouse operation.

This research uses a warehouse redesign to solve the problem of stock capacity and slow cargo movement in the picking process that occurred in warehouse no. 2 of the company. From this research, it was illustrated that the warehouse redesign provides benefits on the improvement of the warehouse operation. First, the company gain knowledge on how to perform data collection and analysis of the root causes of the problem. Several data collection techniques such as interviews and observation are discussed in this research. The data of inbound & outbound materials flow is used to identify storage capacity problems. The warehouse operation process map is used to identify causes of slow cargo movement in the picking process that have an impact on the warehouse efficiency.

The results of this research showed the successful improvement of the warehouse space utilization and picking efficiency by using the warehouse layout redesign. From this research, the racking system leads to the improvement of warehouse operation.

Further research on how a warehouse layout re-design, using the racking system helps improve space utilization and operation efficiency in warehouse no. 2 is highly recommended.

In summary, applying the warehouse redesign strategy into the existing warehouse leads the firm to have a competitive advantage derived from installing the racking system, improve warehouse space utilization, reduce picking time, and improve warehouse operation. The warehouse redesign improves the warehouse operation process and increase picking efficiency. The proposed new layout improves the warehouse operation process of the existing warehouse more than the current process does.

5.4 Managerial Implications

This research would help the company to understand the problem of storage capacity and slow cargo movement in warehouse no. 2 for customer C and solve problems by using the warehouse layout redesign.

The researcher expected that the company would have an awareness of improving a warehouse layout, understand potential benefits and factors related to effectiveness of applying the warehouse redesign. Moreover, there are benefits from this study in identifying the root cause of the problem in the warehouse operation process and redesigning the new layout to improve warehouse efficiency. The improvement of the warehouse layout can lead to maximum warehouse space utilization and reduce picking time to meet the KPI target of the company.

In summary, the researcher expects that this research would enable the efficiency of warehouse no. 2 to identify problems and increase the opportunity to improve the performance of the existing warehouse.

5.5 Limitations and Recommendations for Future Research

The research data was collected only for the company to manage the warehouse operation process of automotive parts. The problem and the solution in this research could not be applied to all types of products and other specific customer requirements because the nature of automotive parts and other type of products are different. Future research might be conducted in order to find the results of implementation of a warehouse layout design by installing the racking system and checking whether the increase of warehouse space utilization would improve the existing warehouse and reduce picking time and storage capacity problem or not.

Another limitation of this study is the use only a single concept which is warehouse redesign to demonstrate the solution and some data in warehouse no. 2 may not be sufficient and is not readily available for potential or future design. In reality, there are many strategies to solve this problem. Future research may explore more on the result of other strategies in order to improve warehouse efficiency by the warehouse redesign concept.

This research proposed only the expected result. It is useful to apply this proposed warehouse redesign technique in the future research. Therefore, the company should continuously review warehouse performance every quarter.

The recommendations for future research are recording information and reviewing the cost parameters in detail after determining a suitable designed warehouse layout by installing the racking system in warehouse no. 2 of the company as follows:

First, the analysis of investment cost of racking implementation and return on investment are reviewed. It would help the company to calculate racking cost investment, return on investment, the total profit and profit margin.

Second, cost of warehouse and labor can be changed. It could be higher or lower depending on the warehouse space and the market price at the period of time. This study provided the racking cost per pallet not over 2,086 Baht per pallet and the forklift driver cost is fixed at 17,000 Baht per month. The company can use this research to be a baseline to compare the total investment cost before making a decision.

Third, revision of average storage charge per m^2 per day could be negotiated with the warehouse operation manager after warehouse space is allocated. The picking time is reduced. On the other hand, the fuel cost and the forklift driver cost depend on the market price at a period of time.

Finally, these parameters should be considered before implementing the proposed new layout design by installing the racking system. It would help the new layout by providing more appropriate and accurate solutions.

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APPENDICES

APPENDIX 1

Selective Rack

APPENDIX 2

The Picking Time Record of Shipping Instructions in the Picking Process

SI No.	SI	Item	Carton	Start (Seconds)	Finish (Seconds)	Total Time (Seconds)
1	1	6	900	15:00	16:00	60:00
2	1	6	255	16:20	17:15	55:00
3	1	6	200	17:20	18:05	45:00
4	1	4	129	18:10	18:40	30:00
5	1	3	10	13:05	13:13	8:00
6	1	1	1	9:04	9:08	4:00
7	1	6	48	9:25	9:40	15:00
8	1	2	60	9:00	10:05	65:00
9	1	2	55	9:50	10:05	15:00
10	1	1	60	10:15	10:26	11:00
11	1	3	255	10:16	10:22	6:00
12	1	11	67	11:05	14:40	155:00
13	1	5	12	11:15	11:30	15:00
14	1	5	33	11:30	11:45	15:00
15	1	4	7	13:05	13:16	11:00
16	1	8	62	13:20	13:40	20:00
17	1	2	8	13:53	13:58	5:00
18	1	1	10	13:35	13:41	6:00
19	1	2	13	13:39	13:46	7:00
20	1	3	5	13:44	13:52	8:00
21	1	1	1	13:50	13:56	6:00
22	1	11	28	14:35	15:00	35:00
23	1	2	210	15:20	15:28	8:00

APPENDIX 2-2

The Picking Time Record of Shipping Instructions in the Picking Process

SI No.	SI	Item	Carton	Start (Seconds)	Finish (Seconds)	Total Time (Seconds)
24	1	7	107	17:15	17:37	22:00
25	1	2	11	17:39	17:46	7:00
26	1	4	19	17:44	17:55	11:00
27	1	3	3	17:53	18:01	8:00
28	1	5	51	17:59	18:13	14:00
29	1	3	5	11:00	11:08	8:00
30	1	8	25	11:06	11:22	16:00
31	1	5	44	11:40	11:51	11:00
32	1	2	10	13:05	13:12	7:00
33	1	10	46	13:12	13:45	33:00
34	1	13	77	14:03	14:35	32:00
35	1	1	2	14:57	15:04	7:00
36	1	1	95	15:02	15:14	12:00
37	1	1	2	15:15	15:21	6:00
38	1	1	1	13:48	13:53	5:00
39	1	1	10	13:50	13:58	8:00
40	1	4	1	13:51	14:00	9:00
41	1	3	3	14:10	14:16	6:00
42	1	5	3	14:15	14:23	8:00
43	1	5	13	14:20	14:31	11:00
44	1	11	47	13:30	14:55	85:00
45	1	7	54	15:46	15:51	5:00

APPENDIX 2-3

The Picking Time Record of Shipping Instruction in the Picking Process

SI No.	SI	Item	Carton	Start (Seconds)	Finish (Seconds)	Total Time (Seconds)
46	1	2	4	15:48	16:00	12:00
47	1	1	6	15:50	15:55	5:00
48	1	3	22	15:55	16:06	11:00
49	1	1	23	17:28	17:33	5:00
50	1	4	43	17:30	17:41	11:00
51	1	4	16	17:40	17:48	8:00
52	1	4	20	17:50	17:58	8:00
53	1	7	71	9:35	9:46	11:00
54	1	7	1590	9:46	10:05	19:00
55	1	7	139	10:17	10:30	13:00
56	1	3	22	10:31	10:39	8:00
57	1	7	15	10:34	10:55	21:00
58	1	2	400	10:56	11:03	7:00
59	1	5	5	11:27	11:38	11:00
60	1	2	10	13:03	13:11	8:00
61	1	1	15	13:09	13:17	8:00
62	1	2	20	13:16	13:25	9:00
63	1	2	30	13:23	13:34	11:00
64	1	4	27	13:38	13:49	11:00
65	1	8	49	14:00	14:20	20:00
66	1	5	902	14:25	14:45	20:00
67	1	8	40	11:20	11:31	11:00

APPENDIX 2-4

The Picking Time Record of Shipping Instructions in the Picking Process

SI No.	SI	Item	Carton	Start (Seconds)	Finish (Seconds)	Total Time (Seconds)
68	1	12	39	13:05	13:54	49:00
69	1	2	27	15:42	15:53	11:00
70	1	11	66	9:18	9:40	22:00
71	1	6	38	9:55	10:30	35:00
72	1	6	21	10:40	11:00	20:00
73	1	2	2	11:00	11:06	6:00
74	1	5	24	11:10	11:18	8:00
75	1	2	4	11:28	11:33	5:00
76	1	2	2	11:33	11:37	4:00
77	1	1	1	11:35	11:39	4:00
78	1	2	37	11:40	11:45	5:00
79	1	1	1	13:00	13:05	4:00
80	1	1	100	13:01	13:08	7:00
81	1	3	3	13:17	13:23	6:00
82	1	4	11	13:05	13:13	8:00
83	1	9	71	13:20	13:35	15:00
84	1	6	7	13:40	13:51	11:00
85	1	7	24	13:50	14:10	20:00
86	1	6	213	14:20	14:40	20:00
87	1	3	10	14:45	14:53	8:00
88	1	4	127	14:50	15:01	11:00
89	1	1	100	15:10	15:21	11:00

APPENDIX 2-5

The Picking Time Record of Shipping Instructions in the Picking Process

SI No.	SI	Item	Carton	Start (Seconds)	Finish (Seconds)	Total Time (Seconds)
90	1	3	175	15:20	15:35	15:00
91	1	3	26	15:50	16:01	11:00
92	1	5	96	16:00	16:11	11:00
93	1	7	29	9:00	9:25	25:00
94	1	3	36	9:58	10:10	12:00
95	1	3	58	10:10	10:18	8:00
96	1	1	220	10:15	10:23	8:00
97	1	5	9	10:25	10:50	25:00
98	1	8	28	10:55	11:06	11:00
99	1	3	11	11:05	11:16	11:00
100	1	9	79	11:20	11:40	20:00
101	1	1	1	13:40	13:45	5:00
102	1	1	1	13:43	13:48	5:00
103	1	1	1	13:46	13:51	5:00
104	1	3	25	13:15	13:26	11:00
105	1	2	60	13:00	13:40	40:00
106	1	3	30	13:40	13:48	8:00
107	1	8	120	14:10	14:21	11:00
108	1	5	270	14:35	15:00	25:00
109	1	8	40	11:25	11:37	12:00
110	1	12	48	13:15	13:26	11:00
111	1	4	27	15:40	15:51	11:00

APPENDIX 2-6

The Picking Time Record of Shipping Instructions in the Picking Process

SI No.	SI	Item	Carton	Start (Seconds)	Finish (Seconds)	Total Time (Seconds)
112	1	3	15	13:50	13:58	8:00
113	1	1	20	13:40	13:51	11:00
114	1	2	25	13:50	14:01	11:00
115	1	3	5	13:44	13:52	8:00
116	1	1	1	13:50	13:56	6:00
117	1	5	30	14:35	15:00	25:00
118	1	2	210	15:20	15:28	8:00
119	1	7	107	17:20	17:37	17:00
120	1	3	11	17:39	17:46	7:00
121	1	2	20	17:50	18:01	11:00
122	1	3	3	17:58	18:03	5:00
123	1	5	52	17:59	18:13	14:00
124	1	3	5	11:00	11:08	8:00
125	1	7	30	11:05	11:20	15:00
126	1	5	48	11:42	11:51	9:00
127	1	2	10	13:05	13:12	7:00
128	1	18	56	13:10	13:45	35:00
129	1	2	20	10:25	10:33	8:00
130	1	1	50	11:15	11:21	6:00
131	1	5	206	11:19	11:33	14:00
132	1	9	20	14:10	14:23	13:00
133	1	10	89	14:25	14:36	11:00

APPENDIX 2-7

The Picking Time Record of Shipping Instructions in the Picking Process

SI No.	SI	Item	Carton	Start (Seconds)	Finish (Seconds)	Total Time (Seconds)
134	1	6	53	14:48	15:00	12:00
135	1	1	12	15:15	15:23	8:00
136	1	4	16	15:21	15:32	11:00
137	1	4	18	15:33	15:44	11:00
138	1	4	73	15:48	16:00	12:00
139	1	10	77	9:20	9:33	13:00
140	1	3	3	10:11	10:19	8:00
141	1	4	43	10:17	10:28	11:00
142	1	1	2	10:32	10:38	6:00
143	1	6	12	11:02	11:15	13:00
144	1	5	15	13:15	13:24	12:00
145	1	7	7	13:14	13:42	28:00
146	1	7	31	13:45	13:56	11:00
147	1	13	29	14:00	14:25	25:00
148	1	3	49	14:47	15:00	13:00
149	1	4	43	15:11	15:23	12:00
150	1	5	57	14:48	16:00	72:00
151	1	4	65	11:02	11:25	23:00
152	1	5	18	11:30	11:45	15:00
153	1	4	15	13:20	13:28	8:00
154	1	2	2	13:28	13:33	5:00
155	1	3	7	13:35	13:45	12:00

APPENDIX 2-8

The Picking Time Record of Shipping Instructions in the Picking Process

SI No.	SI	Item	Carton	Start (Seconds)	Finish (Seconds)	Total Time (Seconds)
156	1	1	2	14:10	14:14	4:00
157	1	2	5	14:12	14:17	5:00
158	1	2	1	14:15	14:20	5:00
159	1	10	25	14:20	14:35	15:00
160	1	5	41	14:45	14:55	12:00
161	1	5	238	15:20	15:31	11:00
162	1	3	7	15:30	15:38	8:00
163	1	2	20	15:37	15:45	8:00
164	1	3	25	15:48	16:05	17:00
165	1	2	60	16:05	16:25	20:00
166	1	3	30	16:20	16:28	8:00
167	1	8	120	16:27	16:45	18:00
168	1	5	270	16:45	17:00	15:00
169	1	8	40	17:05	17:25	20:00
170	1	12	48	17:25	17:36	11:00