AN APPLICATION OF CLASS-BASED STORAGE POLICY TO REDUCE WAREHOUSE COST:
A CASE STUDY OF A THIRD-PARTY LOGISTICS PROVIDER

By

YUICHI TADOKORO

A Proposal of the Six-Credit Course
SCM 7203 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

JULY 2014

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May 2014

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

## Declaration of Authorship Form

I, Yuichi Tadokoro declare that this project and the work presented in it are my own and has been generated by me as the result of my own original research.

AN APPLICATION OF CLASS-BASED STORAGE POLICY TO REDUCE WAREHOUSE COST:
A CASE STUDY OF A THIRD-PARTY LOGISTICS PROVIDER

I confirm that:

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2. Where any part of this dissertation has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;

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**ID:** 552-9540

**ADVISOR'S STATEMENT**

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

Signed ______________________

( A 41(SA Y11 Wayuparb )

Date 6eiVivi110 2.5 2.04

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Yuichi Tadokoro

Assumption University

July 2014

# ABSTRACT

The eventual objective of enterprise activity converges with optimizing profitability through increasing revenue and decreasing costs. The results of the enterprise activity reflect the values for shareholders, customer satisfaction and employee satisfaction. Supply chain management and logistics management are one effective methods to pursue the eventual profit objective. This research focuses on the decreasing cost of a warehouse through the optimizing of traffic inside the warehouse. Warehousing costs have a high commonality in the manufacturing industry from upstream to downstream. The logical approach of eliminating the needlessness contributes to reducing the total supply chain costs.

The methodology of class-based storage policy is studied and applied in this research. Class-based storage policy ranks items in the warehouse depends on cargo volume and frequency. The items in the warehouse are partitioned into several storage classes and assigned storage locations within their own storage class area. The comparison between the random storage policy, a current storage policy and class-based storage policy was worked out using the operational data of substantial logistics company.

The results indicated that applying a proper storage policy reduces the asset level and maintenance costs, which includes the direct and indirect manpower with the warehouse operation and management. The application and improving storage policy does not require a huge investment and idling period of the work days. Management of the warehouse can start studying the storage policy and it can be worked out by using excel spreadsheets. Additionally, the significant relationship between the storage policy and the expense of the warehouse was revealed in this research.

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WAREHOUSE COST REDUCTION BY IMPROVING STORAGE POLICY:
A CASE STUDY OF A THIRD-PARTY LOGISTICS PROVIDER

Mr. Yuichi Tadokoro

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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Date: ______________

# CHAPTER I

# GENERALITIES OF THE STUDY

This chapter presents an introduction to the business of the Company XYZ. The company organization, revenue structure of the company and revenue structure of the warehouse department are firstly explained. The revenue structures indicate which department and team generates the majority of revenue. The statement of the problem, research objectives, scope of the research, limitations of the study, significance of the study and definition of terms will be presented later.

## 1.1 Background of the Study

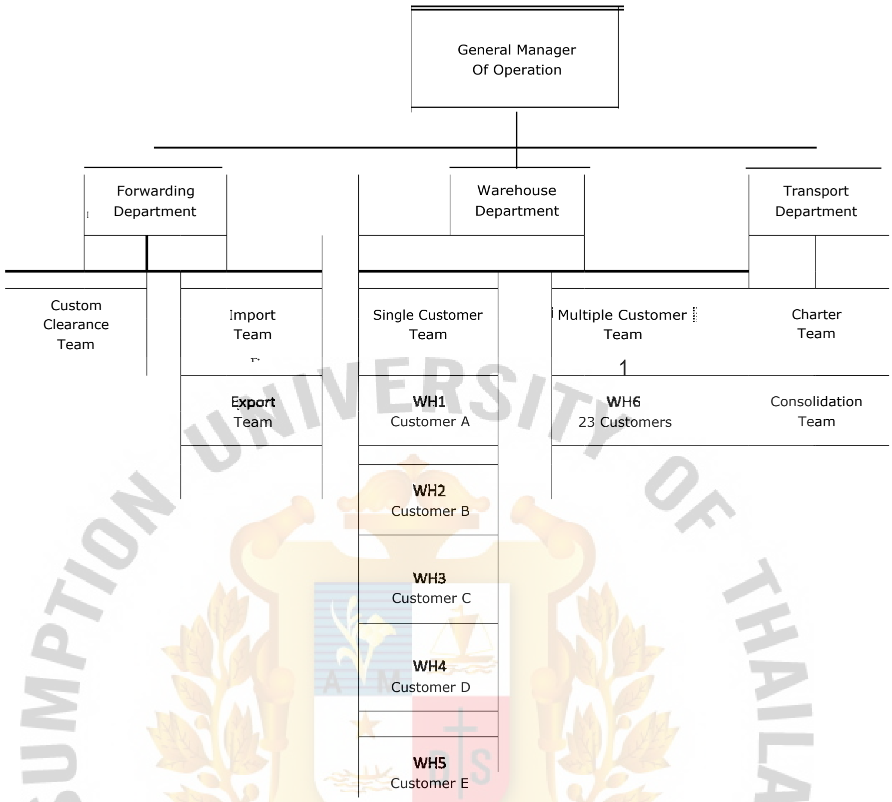
### 1.1.1 Company Background

Company XYZ is the third party logistics provider established in the 1980's in Pathumthani Province, Thailand. Its three major business functions are freight forwarding, transportation and warehousing. XYZ provides the services to various groups of customers such as manufacturers, trading companies and logistics companies who are the prime contractors of original cargo owners. Therefore, a wide variety of the commodities are handled by XYZ, for example, plastic resin supplied to the automotive industry, electrical parts for semiconductor industry, milk powder supplied to the distribution center of department stores, etc. And to win a place in a highly competitive market of the logistics industry, XYZ is setting warehousing services as its core competency of the establishment.

XYZ is divided into three operational departments, i.e., the forwarding department, transportation department and warehouse department as shown in Figure 1.1. The `forwarding department' provides the international freight forwarding service with the custom clearance services. The origin and destination is decided by the customer, however, the majority of it is transported to Japan, Indonesia and Vietnam. This department handles the mode of air export, air import, ocean export, ocean import and also border custom clearance at the Thai-Laos and Thai-Malaysia borders. The `transportation department' provides the charter transportation service and the consolidation transportation service that connects the port, airport, warehouse and customer's place in the major industrial estates in the Thailand. The 'warehouse department' provides the storage services. This department is separated into two major teams based on the type of customers, i.e., single customer and multiple customer teams. In combination, there are six units of warehouses totaling 25,000 square meters. Five units belong to a single customer team and one unit belongs to a multiple customer team.

In addition, XYZ places importance in the collaboration between the departments. For instance, the forwarding department provides the freight forwarding from overseas and does the import custom clearance while the transportation department provides the delivery of the container from the port to the warehouse. The warehouse department stores the cargo and the finally transportation department delivers the cargo to the final end-users by truck. Thus, XYZ realizes the one stop service and provides the total logistics services to the customer and the customer can enjoy the one-stop-service related logistics activity so they can concentrate on their original activities. Moreover, the other department revenue is conducted by the warehouse department. Warehousing service motivates the customers to choose the forwarding and transportation service of XYZ.

**Figure 1.1: Company Organization Chart**

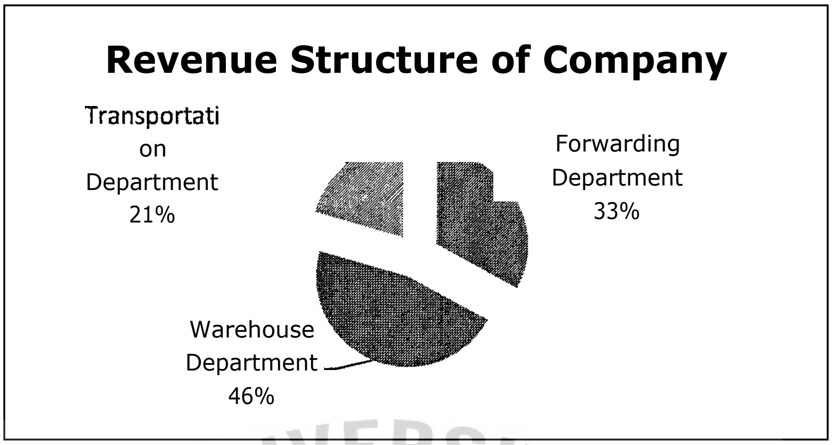



Source: Adopted from company XYZ

### 1.1.2 Revenue Structure of the Company

The revenue is made up of 46% by the warehouse department, 33% by the forwarding department and 21% by the transportation department as shown in Figure 1.2. The warehouse department takes possession of the majority and this distribution of revenue indicates the success of selecting it as the core competency and the importance of the combination among departments.

**Figure 1.2: Revenue Structure of Company, Result of Fiscal Year 2013**

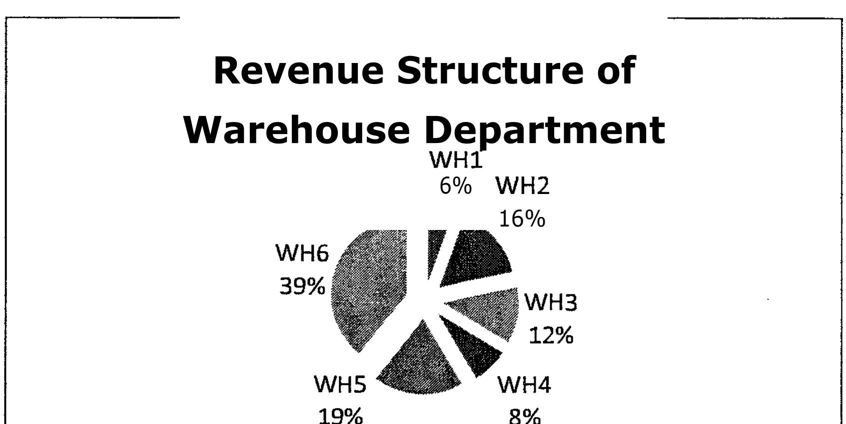



Source: Adopted from company XYZ

### 1.1.3 Revenue Structure of Warehouse Department

The warehouse department has six units of warehouses and it is separated into two teams that are a single customer team and a multiple customer team. The single customer team handles only one customer per one unit of warehouse; and the multiple customer team handles 23 customers in one unit of warehouse. The core revenue is earned by the WH6 that is the multiple customer team as illustrated in Figure 1.3. It is evident from the data that WH6 is the most important team in the company from the view point of the revenue structure. Hence, this study concentrates on the activity of the WH6.

**Figure1.3: Revenue Structure of Warehouse Department, Result of Fiscal Year 2013**



Source: Adopted from company XYZ

## 1.2 Statement of the Problem

This study focuses on improving the efficiency in the worksite operation of Company XYZ, its warehouse department and multiple customer team, named WH6.

The company adopts a random storage policy that applies the empty locations to the incoming cargo with equal probability. This causes problems that high volume and frequent customer's cargo is put away to the long distance locations in the warehouse as well as low volume and frequent customer's cargo is put away to the short distance locations.

As a result, total travel distance in the warehouse is long and it causes a high level of equipment costs and manpower costs. Therefore, this research attempts to answer the question of "How the storage policy impacts the cost of warehouse?"

## 1.3 Research Objectives

The objectives of this research are as follows:

1.3.1 To reduce the cost of the warehouse using the class-based storage policy and ABC analysis.

1.3.2 To reduce the cost of warehouse using ABC analysis to the customer group A and group B.

## 1.4 Scope of the Research

The scope of this research is to study the performance between the random storage policy and class-based storage policy. This will be evaluated in the travel distance from the entrance of the warehouse to the location of storage. The total travel distance between the two policies will be compared and analyzed for its effectiveness to the warehouse cost.

The study focuses on the operation costs that are impacted by the decreasing of the travel distance e.g., quantity of heavy equipment, maintenance cost and manpower cost.

The historical data of cargo volume, frequency and operational cost will be collected from XYZ from January 2013 to December 2013. The scale of the warehouse, layout of the warehouse which defines the distance inside the warehouse was also collected from XYZ.

The slotting process and techniques of ABC analysis will be studied by document review. The slotting process will be applied for deciding the appropriate location for the incoming cargo. ABC analysis will be applied for classing the customers and items.

**1.5 Significance of the Research**

The results of this study motivate the logistics company and internal warehouse of the manufacturer to implement the proper storage policy. The implementer of this method can enjoy the benefit of decreasing expenses and maximizing profits. Furthermore, the implementer can reduce the service charge of warehousing activity to the manufacturer. The manufacturer can then reduce the price of its products.

The study has significance in increasing operational efficiency of the warehouse as well as decreasing the cost of warehouse activities. Warehousing costs have a high commonality in the manufacturing industry from upstream to downstream. The logical approach of eliminating the needlessness contributes to the reduction of the total supply chain cost.

## 1.6 Limitations of the Research

There are limitations concerned in the implementation of this research.

1.6.1 The case study focuses on the selected operational processes of a worksite in the warehouse that has inbound and outbound processes. Thus, other external factors are excluded.

1.6.2 The configuration of the warehouse shape and layout is the method of reducing the travel distance. However, it requires a huge investment and XYZ adopts strict safety policies when operating. Therefore, this study will examine the solution under the range of the current warehouse configurations.

1.6.3 XYZ operates by pallet unit for inbound and outbound cargo by simple backtracking. Therefore, the batching and routing policy that reduces the travel distance of picking activity from multiple locations is not applicable.

1.6.4 The warehouse has four levels of rack systems or two levels of floor storage. The simulation does not include the height of the levels for the distance.

## 1.7 Definition of Terms

| | |
|---|---|
| ABC Analysis | An analytical method for inventory management that categorizes inventory into three classes, that is A, B and C (Flores & Whybark, 1986). |
| Class-Based Storage Policy | Class-based storage policy ranks all items in the warehouse. The items are partitioned into several storage classes and randomly assigned storage locations within their own storage class area (Petersen, Gerald R, & Daniel, 2004). |

| | |
|---|---|
| Popularity | A measure of the number of potential times an operator will visit the location for a particular item (Frazelle, 2002). |
| Slotting | Slotting is the process of determination that optimizes storage mode and location for storage (Frazelle, 2002). |
| Storage Policy | Storage policy is the rule of how to assign the storage location to the cargo in the warehouse. (Petersen, 1999). |
| Travel Distance | Travel distance is the distance from the entrance of the warehouse to the location for storage and from the location for storage to the entrance of the warehouse. Reducing travel distance is concerned with both the layout design and the operating policies (Caron, Marchet, & Perego, 2000). |

# CHAPTER II

# REVIEW OF RELATED LITERATURE

This chapter presents the review of the literature that is related to this study. There are four topics to be described, i.e., the slotting process, ABC analysis, travel distance and the cost of the warehouse. The slotting process and ABC analysis are applied for designing the warehouse operation. Travel distance and the cost of the warehouse are studied regarding its nature and what is the key factor which impacts these topics.

## 2.1 Slotting Process

Frazelle (2002) stated that slotting is the process of determination that optimizes storage mode and location for storage. It results in the substantial impact on all of the warehouse activities. However, some of the research indicates that more than 85 percent of the items in a warehouse are slotted improperly and there is the potential to improve and bottom-up operational efficiency of warehouse activity. Hassan (2002) explained that slotting is an important process in the design of a warehouse due to its impact on workload in the warehouse operations. It is directory combined with labor cost, productivity of picking operation, and traffic congestion.

### 2.1.1 Index of Slotting

Frazelle (2002) and Petersen, Gerald R, and Daniel (2004) emphasized the importance of profiling information before slotting is performed. Table 2.1 present a profile component to perform the slotting process that indicates what kind of information is required to perform. To perform slotting, there are several targets to solve as key questions and the profiling of operational data is analyzed and utilized to find the solutions.

**Table 2.1: The Table of Profile Component to Perform Slotting**

| Planning and Design Issue | Key Questions | Required Profile | Profile Components |
|---|---|---|---|
| Slotting | • Zone Definition<br>• Storage mode selection and sizing<br>• Pick face sizing<br>• Item location assignment | Item activity profile | • Popularity profile<br>• Cube-movement/ volume profile<br>• Popularity-volume profile<br>• Order Completion profile<br>• Demand correlation profile<br>• Demand variable profile |

Source: Adopted from Frazelle (2002)

Petersen et al. (2004) stated that slotting is the method to determine the order or ranking of the SKUs and storage policies which are used to determine how to assign the SKU to the appropriate storage locations. The index is summarized as followings.

(1) Popularity: the number of requests for a given SKU sometimes called the number of hits. The picker and/or forklift must travel to a storage location depending on the number of hits. And Frazelle (2002) stated popularity is the most frequently used slotting measure in practice.

(2) Turnover: the total number of a SKU called during a certain period of time. In other words, turnover is referred to as the demand of an SKU.

(3) Volume: the request for an SKU multiplied by the cube of the SKU. In other words, volume is referred to the cube movement of an SKU.

(4) Pick density: The ratio of the popularity of an SKU to the cube (volume) of the SKU. This identifies the SKUs that have the highest pick activity per a given amount of space.



(5) Cube-per-order index (COI): The ratio of the SKU's total required cube to the number of trips required to satisfy its requests per period. The SKU with the lowest COI is considered to be located near to the shortest travel distance location.

Petersen et al. (2004) concluded that popularity and COI were the best indexes for slotting for reducing the travel distance. Moreover, popularity is easier to understand and apply than COI. Hassan (2002) stated that information of demand of items would be used in making storage assignment decision. Frazelle (2002) stated that popularity is the requests per period and is used with volumes to determine an assignment to storage mode and location that is shown in Table 2.1, a popularity profile or a popularity-volume profile. Popularity is an important measure of the number of potential times of traveling to the location for the item. Most of the workload of warehouse activity is travelling from the entrance to the storage location, from the storage location to the entrance and between the locations. And Frazelle (2002) emphasized that the number of demands for an SKU is a true measure of popularity for defining the location of storage. Nevertheless, many operators of warehouse adopt the wrong measure of popularity such as dollar sales, usages, etc.

### 2.1.2 Storage Policies

There are more than a few storage policies to assign to the location of the cargo. Petersen et al. (2004) presents three types of storage policies that are widely used.

(1) Random storage: The policy which is most commonly used in warehouses today. All incoming cargoes are randomly assigned to vacant locations with equal probability. This policy results in a high utilization of space and reduces the congestion of aisles. However, it requires more travel distance and cargo identification.

(2) Volume-based storage: The policy places high volume items to the nearest location of the pick-up and drop-off point. This policy is effective to reduce travel distance.

(3) Class-based storage: This policy is similar to the volume-based storage policy. However, items are classed by the popularity and the storage zone and classed by the distance from the pick-up and drop-off locations.

Hassan (2002) stated that the warehouse shall be designed by its objective such as distribution center, a manufacturer warehouse, or a public warehouse. Moreover, the selection of storage policies to assign to the location would be impacted by the objective of the warehouse.

The storage policy is the most important term to define in the warehouse operation and is required to be selected by its objective. The volume-based storage policy assigns each SKU to the specific location, class-based storage policy classifies the SKUs and classing of the storage zones. The two storage policies should be creatively used by their purpose and characteristics of the operational usability.

The XYZ Company handles over seven hundred SKUs holding from over twenty customers. And the location for storage exists over three thousand. It is not realistic that the operator identifies the hundreds of SKUs and allocates the cargo to the unique location for the each SKU. Thus, this study applies the class-based storage policy considering operational usability.

### 2.1.3 Zoning

The wording of a fast moving area, slow moving area and a dead stock area is widely used in the warehouse industry. Frazelle (2002) stated that a fast moving area should be the most accessible warehouse locations and used for the most popular items and defined by physical zoning in the warehouse in three classes, i.e., Golden Zone, Silver Zone and Bronze Zone. The Golden Zone is the closest to the travel aisle and nearest to the waist level of the picker.

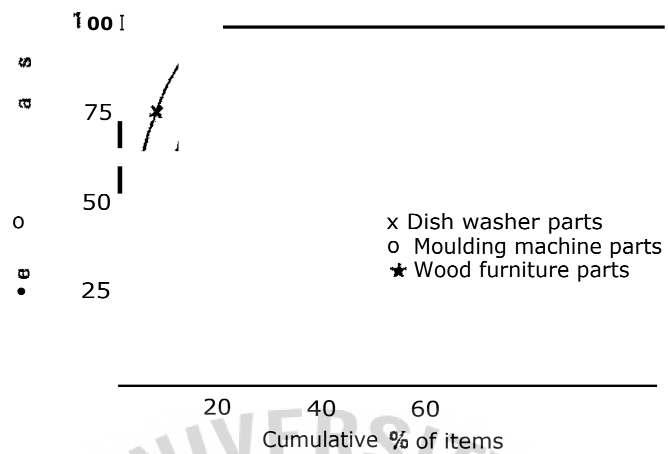
Hassan (2002) explained that high demanded item classes should not be stored in one zone in order to reduce the traffic congestion. Moreover, items of class that are probable to be ordered together shall be allocated relative to their location to reduce the travel distance. And dedicated storage zones should have the compatibility with the randomized storage zone in case some items are required to more from the storage zone.

## 2.2 ABC Analysis

ABC analysis is occasionally called Pareto analysis or the rule of 80/20. This originated from the observation of Pareto that a minority of the persons has a majority of the wealth in the world, e.g., 20 percent of the population owned 80 percent of the wealth or 20 percent of the items occupies the 80 percent of workload in the warehouse operation. The ABC analysis is the technic of ranking and classification the importance for the mass quantities of objects. The ABC analysis is frequently adopted in inventory management to classify the inventory that refers to the activity of ranking for procurement and/or warehouse layout.

Flores and Whybark (1986) stated that ABC analysis is the most commonly used method in inventory management. Items are categorized as A, B and C based on its cost or usage. The study examined the relationship between dollar usage (cost-volume) of the item and item quantity for three companies as shown in Figure 2.1. This distribution is sometimes called the ABC curve, Pareto distribution or popularity distribution. After the distribution has been shown, it helps management to define the alternative strategies to handle the important items (and vice versa) with priority. ABC analysis has a significance in the meaning to reflect what is important to management. The curves verify the minority items which occupy a high usage of the dollars.

**Figure 2.1: Dollar Usage Curves for Inventory Items**

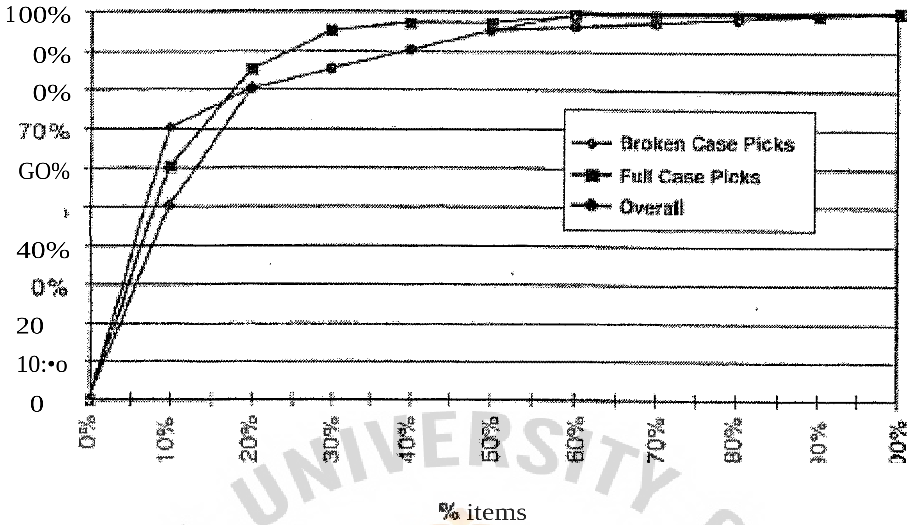



Source: Flores and Whybark (1986)

Regarding to the practical method of classing, Flores and Whybark (1986) described that after the distribution has been determined, the cutoffs for each of class A, B and C must be set by the management. To help the decision of cutoffs, some firms use a rule of Pareto. That is, the number of A items should be the order of 20 percent of the total. The description indicates the firms management should decide the criteria based on the rule of Pareto with consideration for order of priority and the firm's managerial limitations.

Frazelle (2002) examined the association between the percentage of pick and items as shown in Figure 2.2. This popularity distribution indicates that 10 percent of the most popular items represent 70 percent of the picking activity.

**Figure 2.2: Example of Item Popularity Distribution**




Source: Frazelle (2002)

This methodology is applied to classes of items e.g., the top 5 percent of the items (Family A) occupies 50 percent of the picking activity, the next 15 percent of the items (Family B) occupies 80 percent of the picking activity, and the rest of the 80 percent of the items ( Family C) covers the remaining picking activity.

And then Frazelle defined the most popular items of Family A to the most accessible warehouse locations (Class A zone called the golden zone) as alternatives i.e., :

Family A item: Applies to the golden zone (Class A zone)

Family B item: Applies to the silver zone (Class **B** zone)

Family C item: Applies to the bronze zone (Class C zone)

### 2.3 Travel Distance

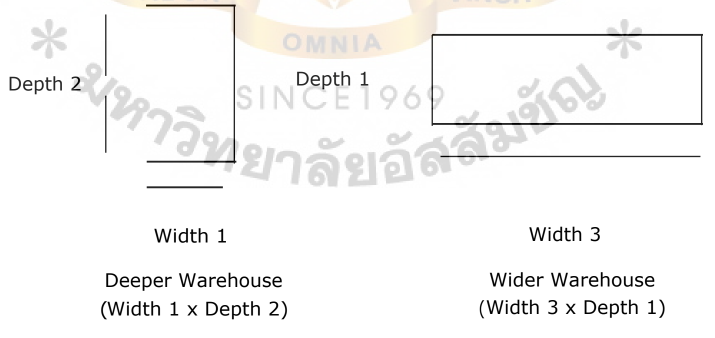
Travel distance is the distance from the entrance of the warehouse to the location for storage and from the location for storage to the entrance of the warehouse. Travel distance in a warehouse is constructed by the motion of horizontal and vertical distance by the picker or forklift. In the warehouse, the operator spends more than half of the workload moving the cargo from place to place. The transportation inside the warehouse is the most time consuming motion (Bartholdi & Hackman, 2005).

Reducing the travel distance has a significance in increasing the productivity of picking operation. Generally speaking, reducing travel distance is concerned with both layout design and operating policies (Caron et al., 2000).
The literature indicates travel distance is impacted by the several issues. These issues affect each other, because once the layout design is changed, the same operating policy cannot be conducted and return the same results.

### 2.3.1 Warehouse Shape

Petersen (1997) examined the warehouse shape factor and found that a deeper warehouse (1 X 2) has a shorter travel distance than a wider warehouse (3 X 1). The figure of '1 X 2' and '3 X l' is the ratio of the depth and width. For instance, '1 X 2' indicates the warehouse which has 100 meters of width and 200 meters of depth. However, Hall (1993) mentioned that a wider warehouse results in better performance. Petersen (1997) explained that this difference originated from the objective of the layout to determine the storage space.

**Figure 2.3: Warehouse Shape**




Source: Author's own

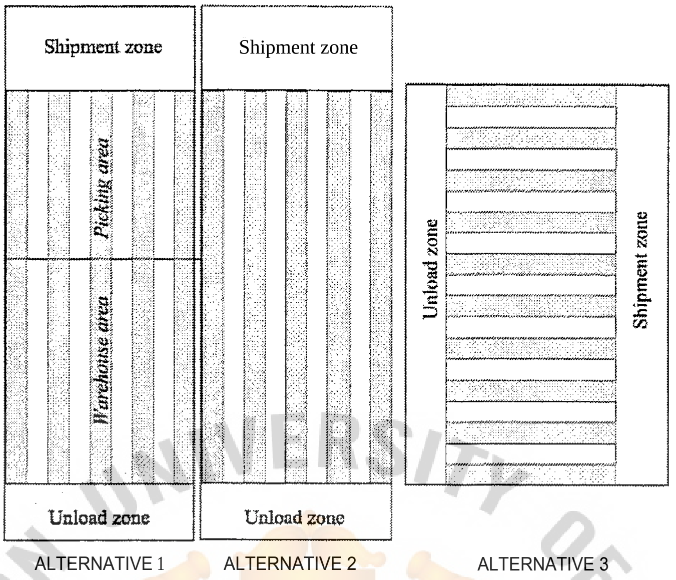
### 2.3.2 Warehouse Layout

The warehouse layout has an eternity of combinations caused by its shape, usage and operating policies, etc. Some theorists argue that best warehouse design and layout is not yet fixed and policy and methodology includes design for all problems which are still under consideration. Designing the best layout for a given case is not easy because of the variety of factors such as racks types, accessibility to the rack, entrance and dock location, etc. (Bartholdi and Hackman, 2005). Over the past 30 years, layout design and product allocation for increasing the space capacity and decreasing the travel distance and material handling cost have been the most argued problems of a warehouse (Van Den Berg, 1999).

Regarding to the aisle inside the warehouse, Petersen (1997) stated that the efficient warehouse may consist of one aisle. And the number of aisles impacts the travel distance significantly (Caron et al., 2000). On the other hand, Hassan (2002) stated that the main aisles crossed by other aisles would improve accessibility, routing flexibility, and travel time and distance in a warehouse.

Huertas, Ramirez, and Salazar (2007) examined the layout comparison which impacts the average picking time that effects labor and equipment as shown in Figure 2.4 and conducted results that give an alternative of three as the most efficient layout in terms of operators' number, forklift number and average picking time. However, it increases the space usage 11 percent. The Figure 2.4 explains the shape of the warehouse with the aisle and the unload zone that will be used for the inbound operation and shipment zones that will be used for the outbound operation.

**Figure 2.4: Example of Warehouse Layout (Alternative 1, 2 and 3)**

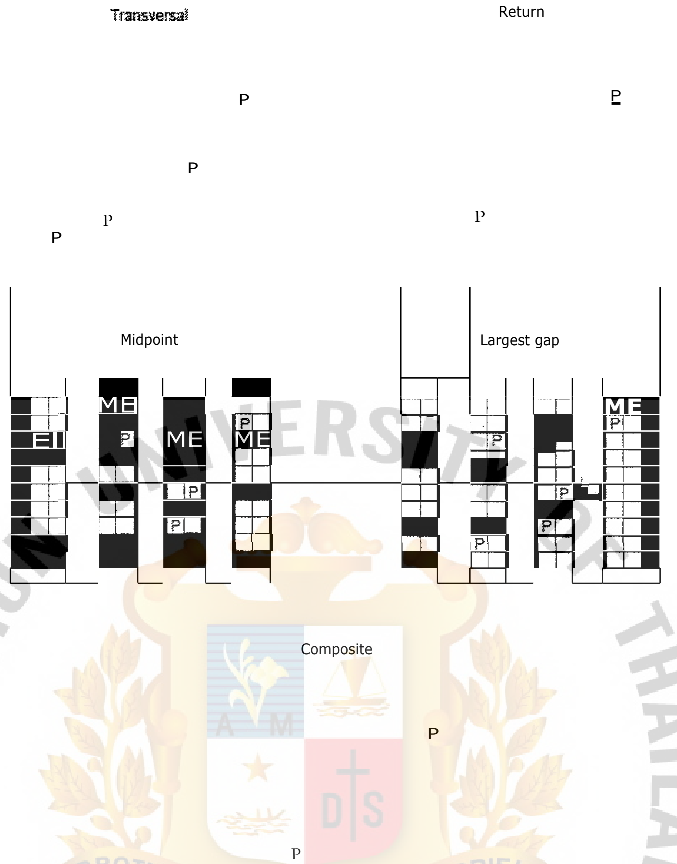



Source: Huertas et al., (2007)

### 2.3.3 Routing policy

Petersen (1997) examined six different routing policies, i.e.,: transversal, return, midpoint, largest gap, composite and optimal as shown in Figure 2.5 and 2.6 and concluded that the optimal routing policy is the most efficient routing policy. The figures show routing by arrows and picking point by 'p'. It presents the routing of picking inside the warehouse. And Petersen (1997) concluded the travel distance is affected by the routing policy and indicates the routing policy is the method of increasing the efficiency in case the picking object is the multiple.

## Figure 2.5: Routing Policy




Source: Petersen (1997)

## Figure 2.6: Optimal routing policy


Source: Petersen (1997)

## 2.4 Cost of Warehouse

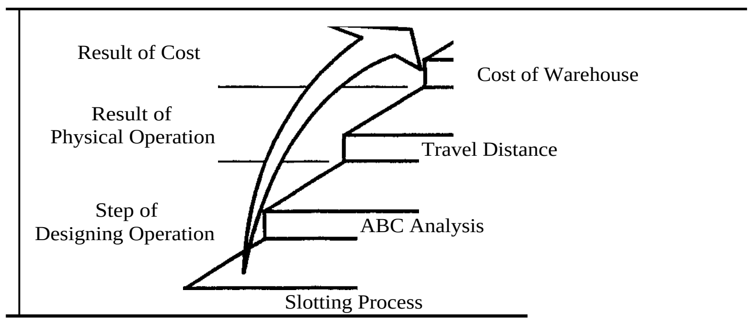
Napolitano (2003) stated that warehouse cost can be categorized into two majorities, i.e., the capital cost and the operating cost. Capital costs are involved in investment such as planning, designing, construction and implementation to start up the new warehouse or when renovating a warehouse. Operating costs are the daily expenses occurred in actual running of a warehouse after start-up. Bartholdi and Hackman (2005) mentioned the total operational costs are impacted on the layout and the operational policies.

Huertas et al. (2007) explained typical operational cost of a warehouse is involved in space utilization, labor, equipment utilization and maintenance, utilities (power, water, etc.) and material. The latter four costs are the variable costs and they are altered by usage levels. Costs of material handling equipment are mostly composed of equipment utilization costs such as purchase, depreciation, leasing, and maintenance cost.

## 2.5 Summary

The described four topics have the association as shown in Figure 2.7. The slotting process and ABC analysis are located as the steps of designing an operation. Travel distance is the result of the physical operations in a warehouse based on the designing operation. Finally, the cost is constructed by the physical operation.

**Figure 2.7: Diagram of Related Literature**




Source: Author's own

The diagram of related literature (Figure 2.7) is backed up by literature's description that total operational costs are impacted by the layout and the operational policies. And the literature also indicates that reducing travel distance concerns both layout design and operating policies. Therefore, the layout design and operating policy impacts both travel distance and cost structure.

# CHAPTER III

# RESEARCH METHODOLOGY

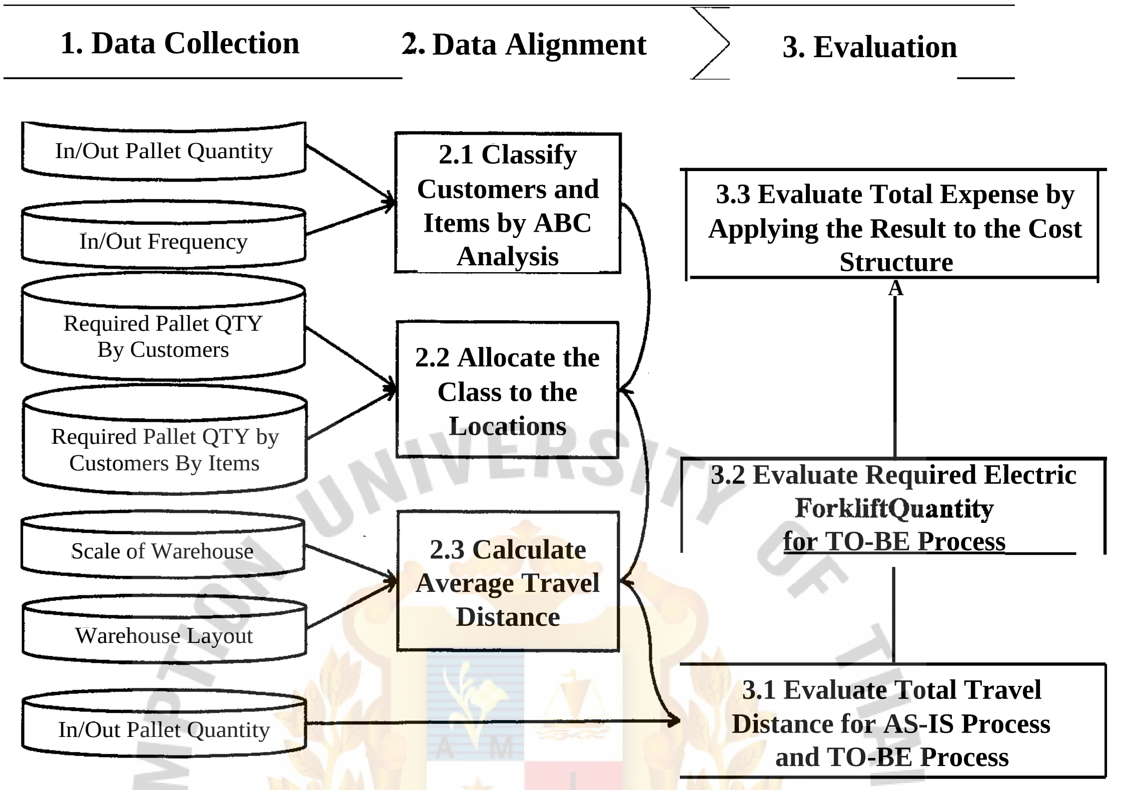
This chapter describes the methodology applied in this study. Firstly, the research method will be explained. And then it explains what are the data points required for this study, AS-IS Process including configuration of the warehouse and cost structure of this company and TO-BE Process including alternatives in order to fulfill the research objectives and methodology of evaluation.

## 3.1 Research Method

This study attempts to evaluate the performance between the random storage policy and class-based storage policy. The performance will be evaluated in the cost effectiveness through measuring the total travel distance for the current process model and alternatives.

The structure of the research method is shown in Figure 3.1. There are three basic steps, i.e., data collection, data alignment and evaluation. Data alignment will be done based on the collected data in order to do the evaluation.

**Figure 3.1: Research Method**




Source: Author's own

## 3.2 Data Collection

The research methodology requires the historical data of cargo moving and the configuration of the warehouse from XYZ, i.e.,

(a) Historical data of inbound and outbound pallet quantity by customers from January 2013 to December 2013.

(b) Historical data of inbound and outbound frequency by customers from January 2013 to December 2013.

(c) Required pallet quantity per month.

(d) Required pallet quantity by customers by items.

(e) Layout of warehouse with distances.

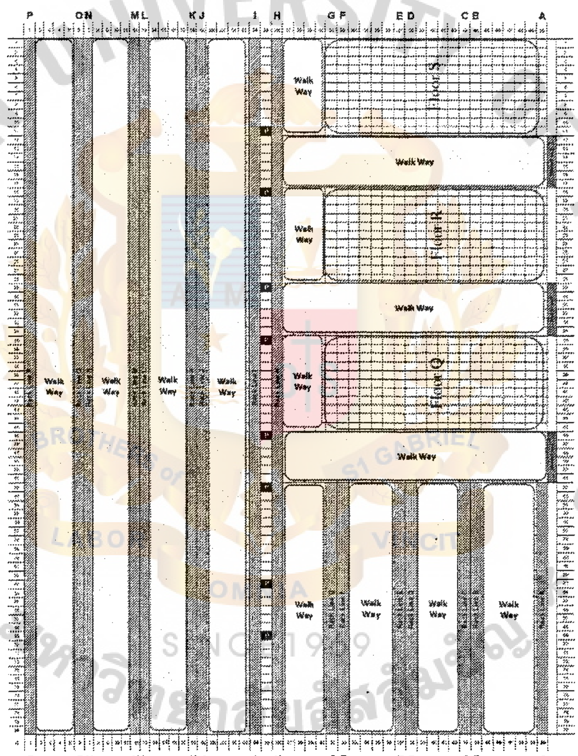
## 3.3 AS-IS Process

### 3.3.1 Configuration of Warehouse, Multiple Customer Team, WH6

3.3.1.1 Warehouse Facility

WH6 has 80 meters of width, 50 meters of depth and a total 4,000 square meters of space with three shutters, and also has a platform that is 80 meters wide and, six meters of deep for a total of 480 square meters with three dock levelers. WH6 has the total of 3,196 pallet position of storage capacity consisting of the selective rack system with 2,416 pallet positions and floor location with 780 pallet positions. The layout is shown in Figure 3.2.

**Figure 3.2: Layout of WH6**






Source: Adopted from company XYZ

3.3.1.2 Equipment

The cargo is moved by forklift on pallets and there is one diesel forklift for external operations and four electric forklifts for internal operation. The electric forklifts are equipped with four additional batteries and battery chargers.

3.3.1.3 Manpower of Warehouse

WH6 has two employees in the back office and ten employees on the worksite of the warehouse that consists of two office staff, one supervisor, five forklift drivers and four checkers. The job scope of each of the title is described as follows. Manpower allocation of the warehouse department is shown in Table 3.1.

(a) Supervisor: Allocate the inbound and outbound cargo to forklift drivers and checkers considering the job volume and each employee's capability.

(b) Forklift Driver: Drive the forklift to unload and load the cargo from the truck or container and move the cargo from the entrance of the warehouse to the location of storage.

(c) Checker: Check the identity of the inbound and outbound cargo and document that shows customer orders to register the location of the cargo co-work with the forklift driver.

(d) Office Staff: Communicate with the customer and expand the inbound and outbound information to the supervisor and register the operational results to the warehouse management system.

**Table 3.1: Manpower Allocation of Warehouse Department**

| Team Name | Office Staff | Supervisor | Forklift Driver | Checker | Total Headcount |
|---|---|---|---|---|---|
| **WH1** | 1 | 0 | 0.5 | 1 | 2.5 |
| **WH2** | 1 | 1 | 1.5 | 2 | 5.5 |
| **WH3** | 1 | **0** | 0.5 | 1 | 2.5 |
| **WH4** | 1 | **0** | 0.5 | 1 | 2.5 |
| **WH5** | 1 | 1 | 2 | 2 | 6 |
| **WH6** | 2 | 1 | 5 | 4 | 12 |
| **Total Headcount** | 7 | 3 | 10 | 11 | 31 |

Source: Adopted from company XYZ

### 3.3.2 Actual Data of Travel Distance

The actual operational data of Company XYZ is shown in Table 3.2. This table indicates WH6 has 23 registered customer and 23 of 13 customers had inbound cargo totaling 1,240 pallets. Measuring the distance from the entrance to location, the travel distance of a single trip was 44,368 meters. After allocating the cargo to the location, a forklift will track back to the entrance. Once the company receives the order of outbound cargo from customers, the cargo will be picked up by same motion of the forklift. Therefore, a single distance from the entrance to a location will be multiplied by four to work out the total travel distance. Eventually, a total travel distance of WH6 on Sept. 2013 was 177,470 meters.

**Table 3.2: Actual In/Outbound Quantity and Travel Distance on Sept. 2013**

| Customer Name | Inbound pallet QTY per Month | Outbound Pallet QTY per Month | Distance from Entrance to Location for Inbound | Multiplied by | Travel Distance |
|---|---|---|---|---|---|
| C1 | 475 | 349 | 18,321 | 4 | 73,283 |
| C2 | 226 | 681 | 8,078 | 4 | 32,312 |
| C3 | 159 | 105 | 4,439 | 4 | 17,756 |
| C4 | 116 | 171 | 4,073 | 4 | 16,293 |
| C5 | 92 | 61 | 2,462 | 4 | 9,847 |
| C6 | 30 | 47 | 1,509 | 4 | 6,034 |
| C7 | 23 | 49 | 1,182 | 4 | 4,728 |
| C8 | - | - | 0 | 4 | - |
| C9 | - | 14 | - | 4 | - |
| C10 | 82 | 46 | 2,793 | 4 | 11,171 |
| C 11 | 4 | 5 | 286 | 4 | 1,142 |
| C12 | 22 | 13 | 626 | 4 | 2,503 |
| C13 | 8 | 6 | 389 | 4 | 1,555 |
| C14 | | - | 0 | 4 | |
| C15 | - | 4 | 0 | 4 | - |
| C16 | 2 | 3 | 141 | 4 | 563 |
| C17 | - | - | 0 | 4 | - |
| C18 | - | - | 0 | 4 | - |
| C19 | 1 | - | 70 | 4 | 282 |
| C20 | - | - | 0 | 4 | |
| C21 | - | - | 0 | 4 | - |
| C22 | - | - | 0 | 4 | - |
| C22 | - | - | 0 | 4 | - |
| TOTAL | 1,240 | 1,554 | 44,368 | | 177,470 |

Source: Adopted from Company XYZ

### 3.3.3 Cost Structure

The allocated cost for WH6 in the fiscal year 2013 was 20,684 Thousand Baht. This cost is constructed of logistical operating expenses and administrative expenses that are shown in Table 3.3. Out of 20,684 Thousand Baht, 5,153 Thousand Baht comes from the logistical operating expenses and 15,531 Thousand Baht comes from the administrative expenses. The logistical operating expenses are tangible cost that can be reduced if activity is reduced, i.e., heavy equipment rental, fuel or electricity for forklifts, maintenance for equipment. Administrative expenses are intangible costs that are allocated based on the employee's head count. Salaries and wages include the allowances for employees, depreciation of assets and all the overhead costs.

**Table 3.3: Current Cost Structure (Unit: Thousand Baht)**

(a) Logistics Operating Expense

| | Heavy Equipment Rental | Fuel or Electricity | Maintenance for Equipment | Expense per Month | Quantity | Monthly Expense | Yearly Expense |
|---|---|---|---|---|---|---|---|
| Diesel Fork Lill | 19 | 3 | 9 | 31 | 1 | 31 | 372 |
| Electric Fork Lift | 27 | 2 | 9 | 38 | | 152 | 1,824 |
| Additional Battery | 35 | - | - | 35 | 4 | 140 | 1,680 |
| Battery Charger | 2 | - | - | 2 | 4 | 8 | 96 |
| Total Expence related with Travel Distance | - | - | - | | - | 331 | 3,972 |
| Other Expense | - | - | - | - | - | 98 | 1,181 |
| | | | | | Total Logistics Expense | 429 | 5,153 |

(b) Administration Expense

| | Expence per Month | Head Count | Monthly Expense | Yearly Expense |
|---|---|---|---|---|
| Office Staff | 108 | 2 | 216 | 2,589 |
| Supervisor | 108 | 1 | 108 | 1,294 |
| Forklift Driver | 108 | 5 | 539 | 6,471 |
| Checker | 108 | 4 | 431 | 5,177 |
| | | Total Administration Expense | 1,294 | 15,531 |

c Total Expense

| | Monthly Expense | Yearly Expense |
|---|---|---|
| Logistics Expense | 429 | 5,153 |
| Administration Expense | 1,294 | 15,531 |
| Total Expense | 1,724 | 20,684 |

Source: Adopted from company XYZ

There are several cost items that are impacted by the travel distance, i.e., 'Electric Fork Lifts', 'Additional Batteries' and 'Battery Chargers' from the logistical operating expenses. This equipment are rented from suppliers and rental fee is paid on a monthly basis. 'Electricity' and 'Maintenance costs' are related costs to this equipment. The costs of 'Forklift drivers' and 'Checkers' are allocated in the administrative expenses. As it was explained, forklift drivers operate the forklift and move the cargo inside the warehouse and checkers register the location of the cargo co-work with forklift drivers. Therefore, seven items are impacted by the quantity of forklifts. The expected scenario of the reduction of travel distance is summarized in Table 3.4. The Scenario is the case that succeeds in reducing one forklift shown in Table 3.5.

**Table 3.4: Expected Results (Unit: Thousand Baht, Per Year)**

| | Current Cost Structure | Scenario | Decreased Percentage |
|---|---|---|---|
| Logistics Operating Expense | 5,153 | 4,253 | 17.47% |
| Administration Expense | 15,531 | 12,943 | 16.67% |
| Total Expense | 20,684 | 17,196 | 16.87% |

Source: Author's own

**Table 3.5: Scenario (Unit: Thousand Baht)**

(a) Logistics Operating [illegible]ense

| | Heavy Equipment Rental | Fuel or Ele | Maintenance for [illegible] | Expense per Month | Quantity | Monthly [illegible]ense | Yearly [illegible]nose |
|---|---|---|---|---|---|---|---|
| Diesel Fork Litt | 19 | 3 | 9 | 31 | 1 | 31 | 372 |
| Electric Fork Lift | 27 | 2 | 9 | 38 | 3 | 114 | 1,368 |
| Additional Battery | 35 | - | - | 35 | 3 | 105 | 1,260 |
| Battery Charger | 2 | | - | 2 | 3 | 6 | 72 |
| Total Expence related with Travel Distance | - | - | - | - | - | 256 | 3,072 |
| Other Expense | - | - | - | | - | 98 | 1,181 |
| | | | | | Total Logistics Expense | 354 | 4,253 |

(b) Administration Expense

| | Expence per Month | Head Count | Monthly Expense | Yearly Expense |
|---|---|---|---|---|
| Orme Staff | 108 | 2 | 216 | 2,589 |
| Supervisor | 108 | 1 | 108 | 1,294 |
| Forklift Driver | 108 | 4 | 431 | 5,177 |
| Checker | 108 | 3 | 324 | 3,883 |
| | | Total Administration Expense | 1,079 | 12,943 |

( c) Total Expense

| | Monthly Expense | Yearly Expense |
|---|---|---|
| Logistics Expense | 354 | 4,253 |
| Administration Expense | 1,079 | 12,943 |
| Total Expense | 1,433 | 17,196 |

Source: Author's own

### 3.3.4 Storage Policy

XYZ applies a random storage policy for incoming cargo which is randomly assigned to vacant locations with an equal probability.

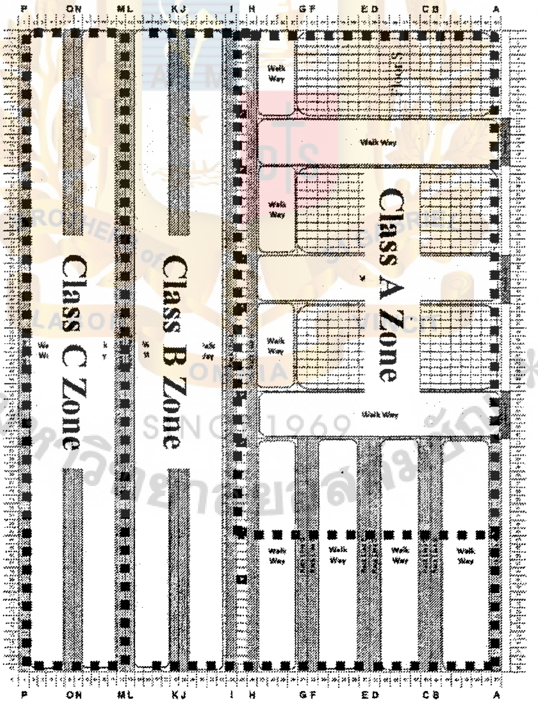
### 3.4 TO-BE Process

As mentioned in the research objectives, this study attempts to reduce the cost of warehouse using a class-based storage policy and ABC analysis. The Alternative 1 attempts to apply it to the customers' classification and it is applied to the twenty three customers. The Alternative 2 attempts to apply it to the items of customer class A and B. It means customer class A and B have sub-classes based on the items.

#### 3.4.1 Alternative 1

The Alternative 1 applies a class-based storage policy base on the customers and the warehouse will be separated into zone A, B and C as shown in Figure 3.3. The customers and locations will be classified to zone A, B, and C.

**Figure 3.3: Zoning Plan of Alternative 1**

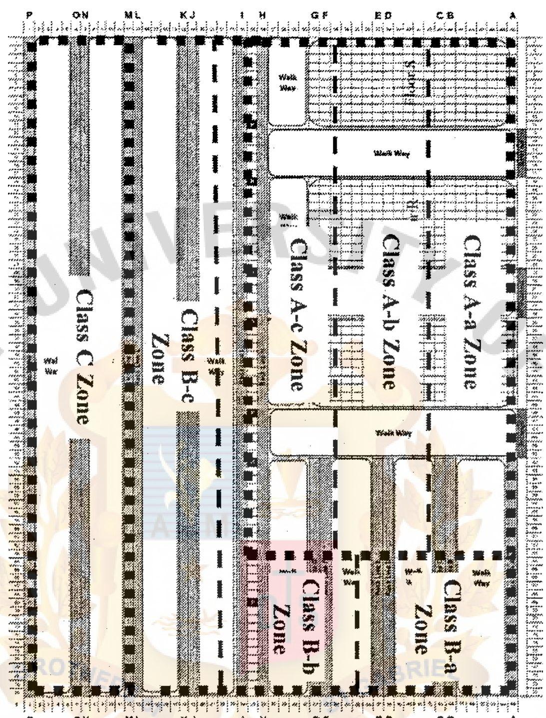



Source: Author's own

#### 3.4.2 Alternative 2

The Alternative 2 applies a class-based storage policy based on the customers similar to Alternative 1, but the items of customer class A and B will be applied to ABC analysis again and set the sub-class for the item of class A and B. The warehouse will be separated to zone A, B and C, and zone A and B will be classified sub-classes. Therefore, Alternative 2 holds the class A-a, A-b, A-c, B-a, B-b, B-c and C as shown in Figure 3.4.

**Figure 3.4: Zoning Plan of Alternative 2**




Source: Author's own

**3.5 Methodology of Evaluation**

The methodology of evaluation works out the 'Required electric forklift quantity for Alternative 1 and 2' through the process of measuring total travel distance. The figure of the 'Required electric forklift quantity for alternative land 2' will be applied to the cost structure of the current operation model. Eventually, it evaluates the cost effectiveness of alternatives. The evaluating structure is shown in Table 3.6.

**Table 3.6: Evaluating Structure of Total Travel Distance**

| | Applied Storage Policy | Classification by Item | Input | output |
|---|---|---|---|---|
| AS IS Process | Random Storage | Not applied | Volume×Average Distance | Total Travel Distance |
| Alternative 1 | Class-based Storage | Not applied | Volume×Average Distance | Total Travel Distance |
| Alternative 2 | Class-based Storage | Applied | Volume×Average Distance | Total Travel Distance |

Source: Author's own

Microsoft Office Excel 2010 is used for all the calculation and evaluation. Abbreviations stand for as following.

T1: Total travel distance of AS-IS process

T2: Total travel distance of alternative 1

T3: Total travel distance of alternative 2

$V_T$: Volume (Inbound pallet quantity)

$V_A$: Pallet quantity of customer class A

$V_B$: Pallet quantity of customer class **B**

$V_C$: Pallet quantity of customer class C

$V_{Aa}$: Pallet quantity of customer class A of sub-class a

$V_{Ab}$: Pallet quantity of customer class A of sub-class b

$V_{Ac}$: Pallet quantity of customer class A of sub-class c

$V_{Ba}$: Pallet quantity of customer class B of sub-class a

$V_{Bb}$: Pallet quantity of customer class B of sub-class b

$V_{Bc}$: Pallet quantity of customer class B of sub-class c

$A_A$: Average distance of zone class A

$A_B$: Average distance of zone class B

$A_C$: Average distance of zone class C

$A_{Aa}$: Average distance of zone class A of sub-class a

$\bar{A}_{Ab}$: Average distance of zone class A of sub-class b

$A_{Ac}$: Average distance of zone class A of sub-class c

$A_{Ba}$: Average distance of zone class B of sub-class a

$\bar{A}_{Bb}$: Average distance of zone class B of sub-class b

$\bar{A}_{Bc}$: Average distance of zone class B of sub-class c

$F$ : Travel distance per electric forklift

$R_2$ : Required electric forklift quantity of alternative 1

$R_3$ : Required electric forklift quantity of alternative 2

### 3.5.1 Classify customers and items by ABC analysis and allocate the class to the locations

This evaluation starts from data alignment using ABC analysis to the customers. Customers are allocated to the three classes that are either A, B and C by volume index. And Items of Customer class A and B are applied the ABC analysis again and sub-classified by it. Therefore, the class will exist totally of nine classes, i.e., A, B, C, A-a, A-b, A-c, B-a, B-b and B-c.

WH6 has 3,196 pallet locations and the locations will be classified to each class following the ratio of 'Required pallet quantity per month' to fulfill the storage demand for the warehouse space. The practical method will be explained as follows:

(a) Apply the method of ABC analysis to customers by volume index and classify the customers by three classes and calculate the volume per class ($V_A$, $V_B$ and $V_C$).

(c) Define the space allocation for zone class A, B and C using the data of 'Required pallet quantity per month' and results in the classing of customers.

(d) Apply the method of ABC analysis to items of class A's customers by volume index and sub-classify the items by three classes and calculate the volume per sub-class ($V_{Aa}$, $V_{Ab}$ and $V_{AC}$).

(e) Define the space allocation for sub-class of zone A customers using the data of `Required pallet quantity per month' and the results of sub-classifing of the items.

(f) Apply the method of ABC analysis to items of class B's customer by volume index and sub-classify the items by three classes and calculate the volume per sub-class ($V_{Ba}$, $V_{Bb}$ and $V_{Bc}$).

(g) Define the space allocation for the sub-class of zone B customers using the data of `Required pallet quantity per month' and the results of sub-classifying the items.

### 3.5.2 Calculate Average Travel Distance

(a) Calculate the average distance of each zone of A-a ($A_{Aa}$), A-b ($A_{Ab}$) and A-c ($\bar{A}_{Ac}$).

(b) Calculate the average distance of zone A ($A_A$) by calculating the average distance among zone A-a ($\bar{A}_{Aa}$), A-b ($A_{Ab}$) and A-c ($\bar{A}_{Ac}$).

(c) Calculate the average distance of each zone of B-a $\bar{A}_{Ba}$), B-b ($A_{Bb}$) and B-c ($A_B$ ).

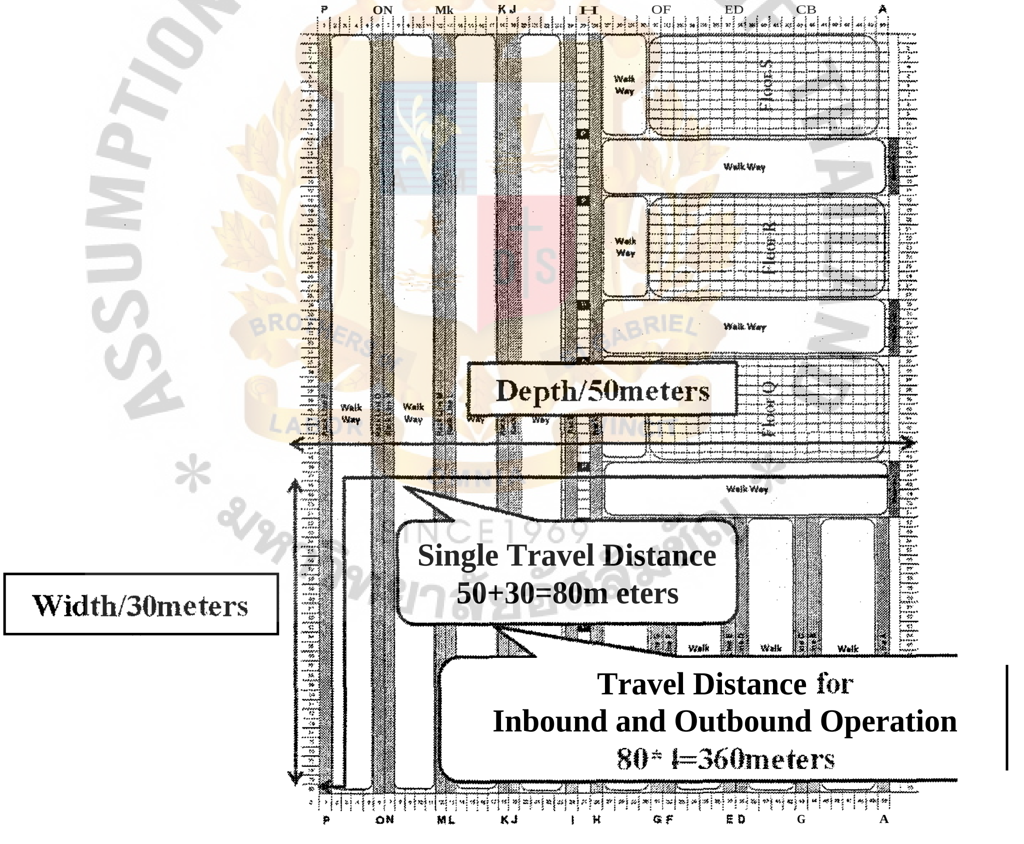
(d) Calculate the average distance of zone B ($A_B$) by calculating the average distance among zone B-a ($\bar{A}_{Ba}$), B-b ($\bar{A}_{Bb}$) and B-c ($\bar{A}_{Bc}$).

(e) Calculate the average distance by zone C ($A_C$).

### 3.5.3 Evaluate Total Travel Distance for AS-IS Process and TO-BE Process

Travel distance is evaluated based on the inbound pallet quantity and average travel distance. Inbound pallet quantity is multiplied by the average travel distance. The average travel distance is multiplied by four because the cargo to storage starts to move from entrance to the storage location for inbound cargo and after the forklift allocates the cargo, it goes back to the entrance. And in case outbound cargo, the forklift starts to move from entrance to the storage location and after the forklift picks the cargo, it goes back to the entrance. Thus, the average travel distance is multiplied by four for evaluating travel distance for inbound and outbound operation. Figure 3.5 presents an example in case the cargo is allocated to 80 meters' distance location. The single travel distance is calculated by the combination of depth and width and single travel distance is multiplied by four. Hence, total travel distance for inbound and outbound will be measured. To verify the method of calculation by average distance, actual travel distance shown in Table 3.2 will be compared with this methodology in chapter 4.

**Figure 3.5: Example of Evaluating Travel Distance**




Source: Author's own

In addition, the company adopts a random storage policy and the incoming cargo is allocated to the empty locations with equal probability in the current operation. To compare with the alternatives in same condition, the total volume will be distributed to each zone class with an equal probability, i.e., total volume will be multiplied to 0.3333 based on three classes of A,B and C.

(a) Evaluate the total travel distance of AS-IS Process ($T_1$) by using the following formula:

$$T_1 = (((V_T \text{ x } 0.3333) \text{ x } AA) + ((VT \text{ x } 0.3333) \text{ x } \bar{A}_B) + ((VT \text{ x } 0.3333) \text{ x } A_c)) \text{ x } 4$$

(b) Evaluate the total travel distance of alternative 1($T_2$) by using the following formula:

$$T_2 - ((VA \; X \; \bar{A}_A) \quad (V_B \; X \; AB) + (V_C \; X \; A_C)) \text{ x } 4$$

(c) Evaluate the total travel distance of alternative 2( $T_3$ ) by using the following formula:

$$T3 = ((V_{Aa} \; X \; A_{Au}) \quad (V_{Ab} \;^{x}\; A_{Ab}) \quad (V_{Ac} \; X \; \bar{A}_{Ac}))$$
$$((V_{Ba} \; X \; A_{Ba}) \quad (V_{Bb} \; X \; A_{Bb}) \quad ('_{Bc} \; X \; \bar{A}_{Bc})) + (V_C \;^{x}\; Ac)) \text{ x } 4$$

**3.5.4 Evaluate Required Electric Forklift Quantity for TO-BE Process**

The total expense of alternative 1 and alternative 2 will be evaluated by following the process:

(a) The value of $T_1$ will be divided by four, i.e. quantity of electric forklifts as shown in Table 3.3. And evaluate the travel distance per electric forklift *(F).* In case the value of $T_1$ is 1,000,000 meters, the travel distance per electric forklift is 250,000 meters.

That is:

$$F = T_1 \; = 4$$

(b) The value of $T2$ and $T3$ will be divided by travel distance per electric forklift. And evaluate the required electric forklift quantity ( $R2$ and $R_3$) by alternatives. In case the value of $T2$ is 750,000 meters, it is divided by the travel distance per electric forklift of 250,000 meters and the required electric forklift quantity will be three. That is:

$$R2 = T2 \div F$$

$$R3 = T3 \div F$$

### 3.5.5 Evaluate Total Expense by Applying the Result to the Cost Structure

The logistical operating expense and administrative expense will be simulated by the alternative 1 and alternative 2. The quantity of electric forklifts, additional battery and batteries chargers will be deducted from the logistical operating expense followed by the required electric forklift quantity. The head count of forklift drivers and checkers will be deducted from administrative expenses followed by the required forklift quantity. And then the total expenses will be calculated.

## 3.6 Summary

The total travel distance and total expenses are the key measurements of this study. Reduction of the total travel distance should impact to the required forklift quantity and head count of forklift drivers and checkers. The simulation results will be compared and analyzed by AS-IS Flow, Alternative1 and Alternative 2.

The proposed alternatives are expected to improve operational efficiency in the warehouse via reducing the travel distance and the company should benefit from applying the slotting process and ABC analysis as the research objectives pursue. The next chapter will discuss the analysis and compare the result of the proposed model.

# CHAPTER IV

# PRESENTATION AND CRITICAL DISCUSSION OF RESULTS

In this chapter, the results of the evaluation are presented. It conducts the total expense of the TO-BE Process through the data alignment and evaluation. The results of the TO-BE Process will be analyzed and compared with the AS-IS Process.

## 4.1 Data Alignment

The following data is collected from XYZ and it is shown in Appendix 1, 2 and 3.

(a) Historical data of inbound and outbound pallet quantity by customers from January 2013 to December 2013(Appendix 1).

(b) Historical data of inbound and outbound frequency by customers from January 2013 to December 2013(Appendix 1). The frequency is the operating days throughout the year.

(c) Required pallet quantity per month (Appendix 2).

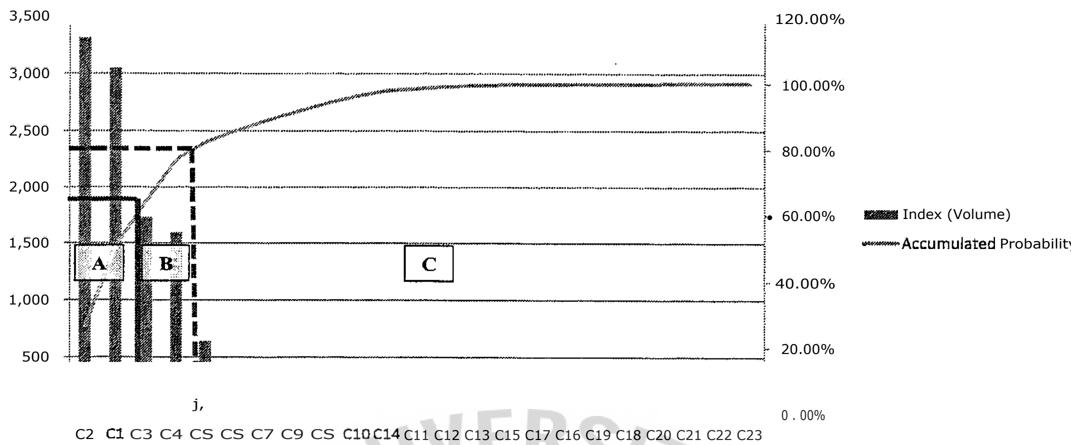
(d) Required pallet quantity by customers by items (Appendix 2).

(e) Layout of warehouse with distance (Appendix 3).

### 4.1.1 Result of Classification of Customers and Location

(a) The results of the ABC analysis to customers are shown in Appendix 4 and Figure 4.1. 23 customers are classified into three classes. Two customers are classified into Class A, two customers are classified into Class B and rest 19 customers are classified into Class C.

**Figure 4.1: Result of ABC Analysis to Customers (Pareto Chart)**




Source: Author's own

(b) The results of allocated locations for customer Class A, B and C are shown in Table 4.1 and the basic calculation of working out the allocated locations is shown in Appendix 5. The ratio of 'required pallet quantity per month' per class occupied is expanded to the actual location quantity.

**Table 4.1: Result of Definition of Allocated Location**

| | Required Pallet QTY Per Month | Allocation Ratio | Allocated Location |
|---|---|---|---|
| Class A | 1,591 | 51% | 1,620 |
| Class B | 832 | 27% | 847 |
| Class C | 716 | 23% | 729 |
| Total | 3,138 | 100% | 3,1% |

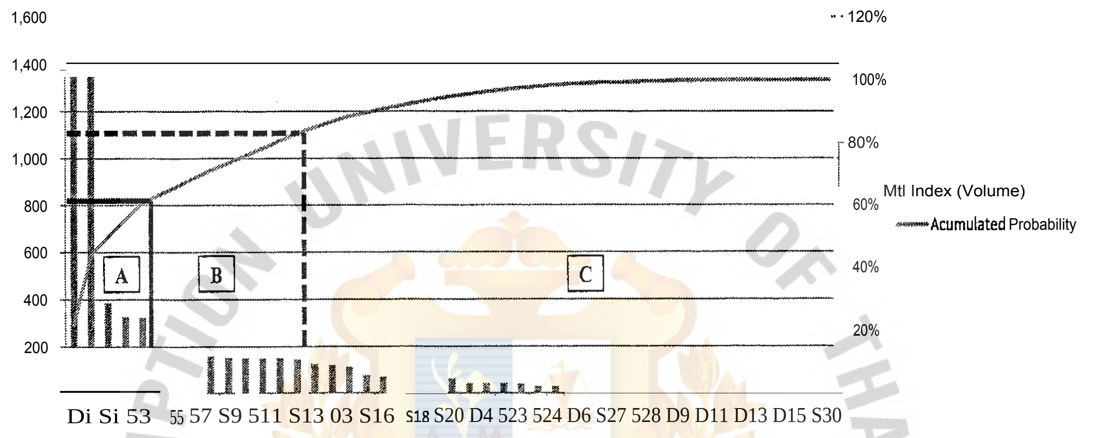
| | Required Pallet QTY Per Month | Allocation Ratio | Allocated Location |
|---|---|---|---|
| Class A-a | 963 | 61% | 980 |
| Class A-b | 319 | 20% | 324 |
| Class A-c | 310 | 19% | 315 |
| Total | 1,591 | 100% | 1,620 |

| | Required Pallet QTY Per Month | Allocation Ratio | Allocated Location |
|---|---|---|---|
| Class B-a | 519 | 62% | 529 |
| Class B-b | 177 | 21% | 180 |
| Class B-c | 136 | 16% | 138 |
| Total | 832 | 100% | 847 |

Source: Author's own

(c) The results of the ABC analysis to items of Class A customers are shown in Appendix 6 and Figure 4.2. 45 items are classified to three of sub-classes. Five items are classified into Class A-a, eight items are classified into Class A-b and rest 32 items are classified into Class A-c.

Figure 4.2: Result of ABC Analysis to Items of Class A (**Pareto** Chart)

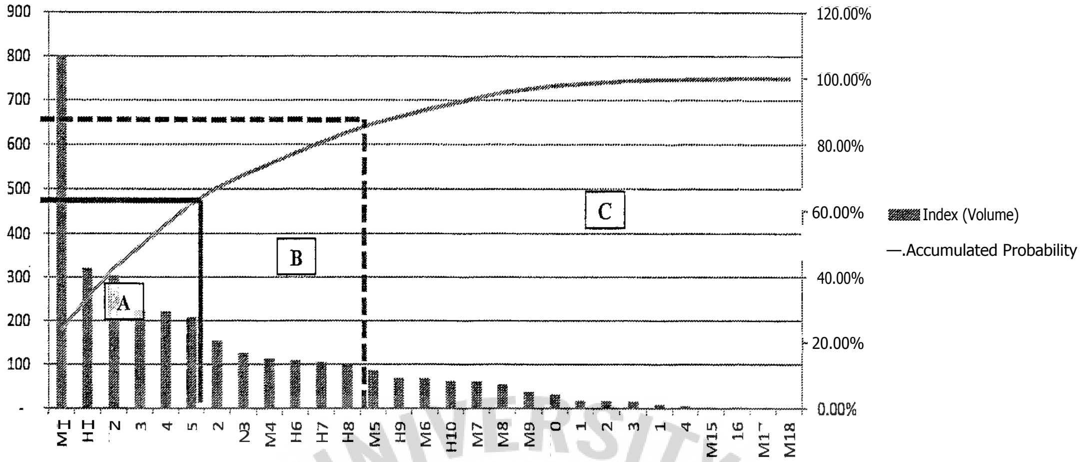



Source: Author's own

(d) The results of allocated locations for Class A-a, A-b and A-c is shown is Table 4.1 and the basic calculation of working out the allocated locations is shown in Appendix 7.

(e) The results of the ABC analysis for items of Class B customers are shown in Appendix 8 and Figure 4.3. 29 items are classified to three of sub-classes. Six items are classified into Class B-a, six items are classified into Class B-b and rest 17 items are classified into Class B-c.

**Figure 4.3: Result of ABC Analysis to Items of Class B (Pareto Chart)**




Source: Author's own

(f) The results of the allocated locations for Class B-a, B-b and B-c are shown in Table 4.1 and the basic calculation of working out the allocated locations is shown in Appendix 9.

In addition to the ABC analysis and allocating locations, volume (Inbound pallet quantity per year) per classes are shown in Table 4.2 and the basic data of volume per customers and items are shown in Appendix 10.

**Table 4.2: Summary of Inbound Pallet Quantity per Year by Class**

| Equation and Meaning | Class | Inbound Pallet QTY Per Year |
|---|---|---|
| :Pallet quantity of customer class A | Class A | 6,362 |
| : Pallet quantity of customer class B | Class B | 3,327 |
| :Pallet quantity of customer class C | Class C | 2,862 |
| | Total | 12,551 |
| :Pallet quantity of customer class A of sub-class a | Class A-a | 3,850 |
| :Pallet quantity of customer class A of sub-class b | Class A-b | 1,123 |
| :Pallet quantity of customer class A of sub-class c | Class A-c | 1,389 |
| | Total | 6,362 |
| $V_{Ba}$ : Pallet quantity of customer class B of sub-class a | Class B-a | 2,076 |
| :Pallet quantity of customer class B of sub-class b | Class B-b | 707 |
| $V_{B}$ : Pallet quantity of customer class B of sub-class c | Class B-c | 544 |
| | Total | 3,327 |

Source: Author's own

### 4.1.2 Result of Calculation of Average Travel Distance

The average distance of zone A *(AA)*, B *(AB)*, C $(A_c)$, A-a $(\bar{A}_{Aa})$, $(\bar{A}_{Ab})$, A-c $(A_{Ac})$, B¯a $(A_{Ba})$, B-b $(\bar{A}_{Bb})$ and B-c $(A_{Bc})$ are shown in Table 4.3.

**Table 4.3: Summary of Distance**

| Equation and Meaning | | Class | Number of Entries | Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| | | | Location | Meter | Meter | Meter |
| $A_A$ | : Average distance of zone class A | Class A | 1,620 | 29.67 | 6.1 | 53 |
| $A_B$ | : Average distance of zone class B | Class B | 847 | 45.57 | 30 | 60.4 |
| $A_C$ | : *Average* distance of zone class C | Class C | 729 | 55.71 | 42 | 72.4 |

| Equation and Meaning | | Class | Number of Entries | Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| | | | Location | Meter | Meter | Meter |
| $\bar{A}_{Aa}$ | : Average distance of zone class A of sub-class a | Class A-a | 980 | 20.57 | 6.1 | 36 |
| $\bar{A}_{Ab}$ | : Average distance of zone class A of sub-class b | Class A-b | 325 | 34.10 | 15.4 | 51.6 |
| $\bar{A}_{Ac}$ | : Average distance of zone class A of sub-class c | Class A-c | 315 | 34.35 | 24 | 53 |

| Equation and Meaning | | Class | Number of Entries | Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| | | | Location | Meter | Meter | Meter |
| $\bar{A}_{Ba}$ | : Average distance of zone class B of sub-class a | Class B-a | 529 | 42.61 | 30 | 59.4 |
| km, | : Average distance of zone class B of sub-class b | Class B-b | 180 | 44.50 | 37 | 55.4 |
| $A_{Bc}$ | : Average distance of zone class B of sub-class c | Class B-c | 138 | 49.59 | 42 | 60.4 |

Source: Author's own

### 4.1.3 Comparison of Actual Travel Distance and Average Travel Distance

As described in Chapter 3.5.2, the actual travel distance and travel distance calculated by average distance are compared. The results are shown in Table 4.4 and the basic data of the average travel distance is shown in Appendix 11. The difference is 7.64%.

**Table 4.4: Difference of Travel Distance between Actual and Average**

| **Actual** Travel Distance (Meter) | Travel Distance by Ave rage Distance (Meter) | Difference |
|---|---|---|
| 177,470 | 192,155 | 7.64% |

Source: Author's own

## 4.2 Evaluate the Travel Distance

(a) The results of the evaluation of the total travel distance of AS-IS Process ($T_1$) is shown in Table 4.5. Total travel distance of AS-IS Process is 2,191,114.65 meters per year.

**Table 4.5: Total Travel Distance of AS-IS Process** ($T_1$)

| Zone of the Class | Total Volume Per Year | Allocation Ratio | Inbound Pallet QTY Per Year | Average Distance | Trip Frequency | Trawl Distance |
|---|---|---|---|---|---|---|
| Class A | 12,551 | 33.33% | 4,183 | 29.67 | 4 | 496,511.63 |
| Class B | 12,551 | 33.33% | 4,183 | 45.57 | 4 | 762,490.36 |
| Class C | 12,551 | 33.33% | 4,183 | 55.71 | 4 | 932,112.65 |
| | | **Total Pallet QTY** | 12,550 | | **Total Travel Distance** | **2,191,114.65** |

Source: Author's own

(b) The results of the evaluation of the total travel distance of alternative 1($T_2$) is shown in Table 4.6. Total travel distance of alternative 1 is 1,999,240.36 meters per year. 191,847.29 meters of travel distance is decreased from AS-IS Process.

**Table 4.6: Total Travel Distance of Alternative 1($T_2$)**

| Class | Inbound Pallet QTY Per Year | Average Distance | Trip Frequency | Travel Distance |
|---|---|---|---|---|
| Class A | 6,362 | 29.67 | 4 | 755,108.66 |
| Class B | 3,327 | 45.57 | 4 | 606,420.00 |
| Class C | 2,862 | 55.71 | 4 | 637,711.70 |
| Total Pallet QTY | 12,551 | | **Total Trawl Distance** | **1,999,240.36** |

Source: Author's own

(c) The results of the evaluation of the total travel distance of alternative 2($T_3$) is shown in Table 4.7. Total travel distance of alternative 2 is 1,886,112.55 meters per year. 305,002.10 meters of travel distance is decreased from AS-IS Process.

**Table 4.7: Total Travel Distance of Alternative 2($T_3$)**

| Class | Inbound Pallet QTY Per Year | Average Distance | Trip Frequency | Travel Distance |
|---|---|---|---|---|
| Class A-a | 3,850 | 20.57 | 4 | 316,762.29 |
| Class A -b | 1,123 | 34.10 | 4 | 153,181.35 |
| Class A -c | 1,389 | 34.35 | 4 | 190,837.14 |
| | | | **Summary of Class A** | **660,780.77** |
| Class B-a | 2,076 | 42.61 | 4 | 353,863.42 |
| Class B-b | 707 | 44.50 | 4 | 125,852.28 |
| Class B-c | 544 | 49.59 | 4 | 107,904.37 |
| | | | **Summary of Class B** | **587,620.08** |
| Class C | 2,862 | 55.71 | 4 | 637,711.70 |
| **Total Pallet QTY** | 12,551 | | **Total Travel Distance** | **1,886,112.55** |

Source: Author's own

## 4.3 Evaluate the Required Electric Forklift Quantity for TO-BE Process

(a) The results of the evaluation of the travel distance per electric forklift *(F)* is shown as follows:

$$547{,}778.66\ (F) = 2{,}191{,}114.65 \quad 4$$

(b) The results of the evaluation of the required electric forklift quantity for alternative 1 ($R_2$) and alternative 2 ($R_3$) is shown as follows:

$$3.65\ (R2) = 1{,}999{,}249.36 \quad 547{,}778.66$$

$$3.44\ (R3) = 1{,}886{,}112.55 \div 547{,}778.66$$

## 4.4 Evaluate the Total Expense by Applying the Result to the Cost Structure

The results of R2 and R3 are applied to the cost structure that is related with the forklift quantity as shown in Table 4.8 and 4.9.

## Table 4.8: Result of the Total Expense for Alternative 1

(a) Logistics Operating ense

| | Heavy Equipment Rental | Fuel or Electric' | Maintenance for · ui ment | Expense per Month | Quantity | Monthly ense | Yearly tense |
|---|---|---|---|---|---|---|---|
| Diesel Fork Lift | 19 | | | 31 | | 31 | 372 |
| Electric Fork Lift | 27 | | | 38 | 3.65 | 13830 | 1,664 |
| Additional Battery | 35 | | | 35 | 3.65 | 127.75 | 1,533 |
| Battery Charger | 2 | - | - | 2 | 3.65 | 7.30 | 88 |
| Total Expence re ted with Travel Distance | - | - | - | | | 305 | 3,657 |
| Other Expense | - | | - | | - | 98 | 1,181 |
| | | | | | Total Logistics Expense | 403 | 4.838 |

(b) Administration ense

| | Expence per Month | Head Count | Monthly Expense | Yearly Expense |
|---|---|---|---|---|
| Office Staff | 108 | 2 | 216 | 2,589 |
| Supervisor | 108 | 1 | 108 | 1,294 |
| Forklift Driver | 108 | 4.65 | 502 | 6,018 |
| Checker | 108 | 3.65 | 394 | 4,724 |
| | | Total Administration Expense | 1,219 | 14,625 |

( c) Total Expense

| | Monthly Expense | Yearly Expense |
|---|---|---|
| Logistics ense | 403 | 4,838 |
| Administration Expense | 1,219 | 14,625 |
| Total Expense | 1,622 | 19,463 |

Source: Author's own

## Table 4.9: Result of the Total Expense for Alternative 2

(a) Logistics Operating Expense

| | Heavy Equipment Rental | Fuel or Electricity | Maintenance for Equipment | Expense per Month | Quantity | Monthly Expense | Yearly Expense |
|---|---|---|---|---|---|---|---|
| Diesel Fork Lilt | 19 | 3 | 9 | 31 | 1 | 31 | 372 |
| Electric Fork Lilt | 27 | 2 | 9 | 38 | 3.44 | 130.72 | 1,569 |
| Additional Battery | 35 | - | - | 35 | 3.44 | 120.40 | 1,445 |
| Battery Charger | 2 | - | - | 2 | 3.44 | 6.88 | 83 |
| Total Expence related with Travel Distance | - | - | - | - | - | 289 | 3,468 |
| Other Expense | - | - | - | - | | 98 | 1,181 |
| | | | | | Total Logistics Expense | 387 | 4,649 |

(b) Administration Expense

| | Expence per Month | Head Count | Monthly Expense | Yearly Expense |
|---|---|---|---|---|
| Office Staff | 108 | 2 | 216 | 2,589 |
| Supervisor | 108 | 1 | 108 | 1,294 |
| Forklift Driver | 108 | 4.44 | 479 | 5,746 |
| Checker | 108 | 3.44 | 371 | 4,452 |
| | | Total Administration Expense | 1,173 | 14,081 |

c Total Expense

| | Monthly Expense | Yearly Expense |
|---|---|---|
| Logistics Expense | 387 | 4, 649 |
| Administration Expense | 1,173 | 14,081 |
| Total Expense | 1,560 | 18,730 |

Source: Author's own

### 4.5 Summary

The results indicate the improved storage policy decreased the cost of warehouse by 5.9 percent, 1,221 Thousands Baht per year in alternative 1 and 9.4 percent, 1,954 Thousands Baht per year in alternative 2. The results are shown in Table 4.8.

**Table 4.10: The Result of Evaluation (Unit: Thousand Baht)**

| | Yearly Expense | | |
|---|---|---|---|
| | Logistics Expense | Administation Expense | Total Expense |
| AS-IS Process | **5,153** | **15,531** | **20,684** |
| Alternative 1 | **4,838** | **14,625** | **19,463** |
| Alternative 2 | **4,649** | **14,081** | **18,730** |

| | Decreased Amount | | |
|---|---|---|---|
| | Logistics Expense | Administation Expense | Total Expense |
| Alternative 1 | **315** | **906** | **1,221** |
| Alternative 2 | **504** | **1,450** | **1,954** |

| | Improved Percentage | | |
|---|---|---|---|
| | Logistics Expense | Administation Expense | Total Expense |
| Alternative 1 | **6.1%** | **5.8%** | **5.9%** |
| Alternative 2 | **9.8%** | **9.3%** | **9.4%** |

Source: Author's own

# CHAPTER V

# SUMMARY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the four sections that are the conclusions and summary of the findings, theoretical implications, managerial implications and lastly the limitations and recommendations for future research.

## 5.1 Conclusions and Summary of the Findings

This study applies a class-based storage policy to the warehouse operating by a random storage policy. And it was examined by two methods, i.e., classifying customers by ABC analysis (Alternative 1) and classifying the items of Class A and B customer's and assigning the sub-class for it (Alternative 2). The positive results were obtained from both alternatives.

The answer of the core-question; "How the storage policy impacts the cost of the warehouse?" is that "An improved storage policy reduces the travel distance and it finally affects the cost of the warehouse positively". Applying a suitable storage policy reduces the traffic inside the warehouse and it has the possibility of reducing the manpower and equipment.

In addition to reducing the manpower and equipment, the reduction of the travel distance shortens the operating hours as well. XYZ limits the maximum speed of forklifts inside the warehouse at 5km per hour. The distance decreased in alternative 1 could be converted to 38.37 hours of forklift operating hours and in alternative 2 could be converted to 61 hours of forklift operating hours.

The ABC analysis is applicable for improving the storage policy. Generally speaking, ABC analysis is the method to optimize the procurement and management of the inventory level. This study attempted to apply the classifying of customers and, items and the results were applied to allocating locations in the warehouse. And this study also attempted to apply the 'ABC of ABC' that classifies the items of Class A and B customers and assigns the sub-class and obtained positive results. The results indicated that detail classifications contribute to shortening the travel distance.

This study found an equal relationship between volume and frequency that operates by pallet units for inbound and outbound cargo. XYZ operates by pallet units using a forklift by simple backtracking for moving the cargo. The volume has an equal meaning of frequency in this operation. On the other hand, the case of inbound cargo by pallet and outbound cargo by carton, the frequency of outbound cargo has a direct impact on the travel distance in terms of multiplying and depends on the customer's call of the cargo. In this case, a routing policy that defines the shortest picking route has much more significance to enhance the most efficient picking operation.

### 5.2 Theoretical Implications

This study makes contributions to the cost reduction of the warehouse as proposed by previous research findings and studies in the application of storage policy. The transportation inside the warehouse is the most time consuming motion and the findings indicate the application of storage policy reduces its motion. Also, the results indicate that the application of storage policy affects the cost structure of XYZ Company. The series of results and findings advocates both the theory, i.e., total operational costs are impacted by the layout and the operational policies (Bartholdi & Hackman, 2005) and reducing travel distance is concerned with both layout design and operating policies (Caron et al., 2000).

### 5.3 Managerial Implications

The application of a proper storage policy reduces the asset level and maintenance cost including the direct and indirect manpower related to the warehouse operation and management. The results indicate the possibility of reduction of equipment and manpower without changing configuration and layout that require a huge investment.

This is the significant point of improving the storage policy for the warehouse operation. The reduction of the equipment and manpower is easy to affect operational quality even it is reducible. The management of XYZ should pay attention to protect safety regulations in the warehouse operation and secure operational accuracy to maintain the customer satisfaction.

The scale of the W116 is 4,000 square meters and four forklifts are equipped in it. Even the results cannot achieve the reduction of one forklift, the management of XYZ should improve the storage policy in the other warehouse in addition to WH6 and try to reduce the total forklift quantity as a whole company. Furthermore, the larger warehouses were affected in a greater figure of cost. The management of the warehouse should realize the importance of applying a suitable storage policy.

This study focused on reducing costs of the warehouse through improving the storage policy and examining it by using the historical data of the XYZ. XYZ could further use the results and findings in their current operations in order to enhance the company's cost structure and operational efficiency. Even though the results indicate detailed classification contributes to shortening the travel distance, management of the warehouse should consider the difference of a storage policy between the volume-based storage policy and the class-based storage policy. The much detailed classification enforces the warehouse operator complexity. Class-based storage policy has an advantage in applying the wide area to the multiple customers and items. This advantage should be utilized in the practical operation. And it is obvious that the complexity beyond the operator skill and current operation results negatively. The alternative 1 could obtain the positive results and firstly XYZ should select the Class A customer and start the segregation of Class A customers and other customers. The application of Class A for XYZ means a conversion about the storage policy from a random storage policy to the class-based storage policy. There is a great significance in switching policies.

A proper implementation plan is required to secure the operational quality for conversion of a storage policy. The action plan is suggested from two perspectives, i.e., training for operator and implementation in actual operation. Table 5.1 presents the suggested implementation plan.

**Table 5.1: Suggested Implementation Plan**

| |
|---|
| a) Training for Operators |
| a-1: Storage Policy |
| a-2: Objective of Conversion of Storage Policy |
| a-3: Difference between the Random Storage Policy and Class-Based Storage Policy |
| a-4: Sharing Results after the Implementation |
| b) Implementation in Actual Operation |
| b-1: ABC Analysis and Ranking the Customers and Items |
| b-2: Conversion of Storage Policy |
| b-3: Operating by Class A and Others |
| b-4: Operating by Class A, B and C |
| b-5: Operating by Class A, B, C and Sub-Class |

Source: Author's own

The training for operator should be started from the question of "What is the 'Storage Policy'?" for smooth implementation in physical operation. Generally speaking, the operator of a warehouse that operated by the random storage policy shall not aware the existing of a storage policy. Starting from promoting the awareness of a storage policy, the objective of conversion of a storage policy and the difference between current storage policy and newly applied storage policy should be trained. Sharing results after the implementation support and encourage the operator to work by the newly applied storage policy.

On the occasion of the implementation of class-based storage policy, the ranking by the ABC analysis should be worked out. The ranking clarifies the most important customers in terms of increasing the efficiency in operation. As a first step of implementation of physical operation, the warehouse should be operated by the two classes, i.e., Class A customers and other customers. A simple segregation would be workable in the physical operation. The operation by two classes has significance in the conversion of the storage policies and also supports operator's comprehension of different storage policy. After the observation of operation by two classes, more complex model should be implemented step-by-step. Management of the warehouse should try to fuse the theory of a storage policy and the practice at the worksite in the warehouse.

Warehouse management system (WMS) is widely used in the logistics industry and XYZ also uses basic function of WMS in registering the operational result to the WMS such as inbound and outbound activity and stock information in current operation. Even though it requires investment in upgrading system from the basic function, adding the function of identifying class of items and allocating the appropriate location for inbound cargo from WMS to the operator would help to reduce the complexity of operation and workload of operator.

XYZ needed to improve on their operational efficiency towards the eventual objective of enterprise activity which is optimizing profitability in order to achieve the higher domain in the logistics industry and to win the severe completion in the industry.

### 5.4 Limitations and Recommendations for Future Research

In this study, the configuration of the warehouse shape and layout was fixed by one model, that is, the current shape and layout of XYZ. The modification of the configuration requires a huge investment and it is concerned with the safety policy of the company. Therefore, the results were adapted from the application of a different storage policy to the unique layout of the warehouse. The future study could use a different storage policy to the several layouts of a warehouse in order to find the best level of travel distance for the warehouse.

The relationship between volume and frequency and operational difference is described previously. The routing policy is one of the important elements to impact the travel distance even if the case of XYZ is not applicable. Needless to say, the combination of a storage policy, warehouse configuration and a routing policy are infinite. The researcher and the management of the warehouse should pay keen attention to research and define it in order to achieve the best of best results.

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# APPENDICES

## APPENDIX 1

Historical Data of XYZ (a) and (b)

(a) Historical data of inbound and outbound pallet quantity by customers from January 2013 to December 2013.

(b) Historical data of inbound and outbound frequency by customers from January 2013 to December 2013.

| Customer Name | Inbound Pallet QTY per Year | Outbound Pallet QTY per Year | Total Pallet Qty per Year | Inbound Frequency | Outbound Frequence | Total Frequency |
|---|---|---|---|---|---|---|
| C1 | 3,046 | 3,214 | 6,260 | 66 | 274 | 340 |
| C2 | 3,316 | 3,088 | 6,404 | 64 | 176 | 240 |
| C3 | 1,732 | 1,798 | 3,530 | 75 | 214 | 289 |
| C4 | 1,595 | 1,612 | 3,207 | 44 | 205 | 249 |
| C5 | 641 | 864 | 1,505 | 41 | 107 | 148 |
| C6 | 313 | 465 | 778 | 63 | 128 | 191 |
| C7 | 394 | 501 | 895 | 15 | 46 | 61 |
| C8 | 446 | 640 | 1,086 | 10 | 33 | 43 |
| C9 | 328 | 343 | 671 | 7 | 54 | 61 |
| C10 | 272 | 278 | 550 | 22 | 34 | 56 |
| C11 | 79 | 113 | 192 | 23 | 33 | 56 |
| C12 | 77 | 112 | 189 | 5 | 36 | 41 |
| C13 | 47 | 82 | 129 | 8 | 44 | 52 |
| C14 | 204 | 173 | 377 | 5 | 12 | 17 |
| C15 | 28 | 62 | 90 | 7 | 12 | 19 |
| C16 | 6 | 22 | 28 | 3 | 20 | 23 |
| C17 | 16 | 20 | 36 | 5 | 6 | 11 |
| C18 | 4 | 25 | 29 | 1 | 12 | 13 |
| C19 | 5 | 13 | 18 | 3 | 11 | 14 |
| C20 | 2 | 4 | 6 | 2 | 3 | 5 |
| C21 | - | 7 | 7 | - | 2 | 2 |
| C22 | - | - |  | - | - | - |
| C23 | - | - | - | - | - | - |
|  | 12,551 | 13,435 | 25,986 | 469 | 1,462 | 1,931 |

# APPENDIX 2

Historical Data of XYZ (c) and (d)

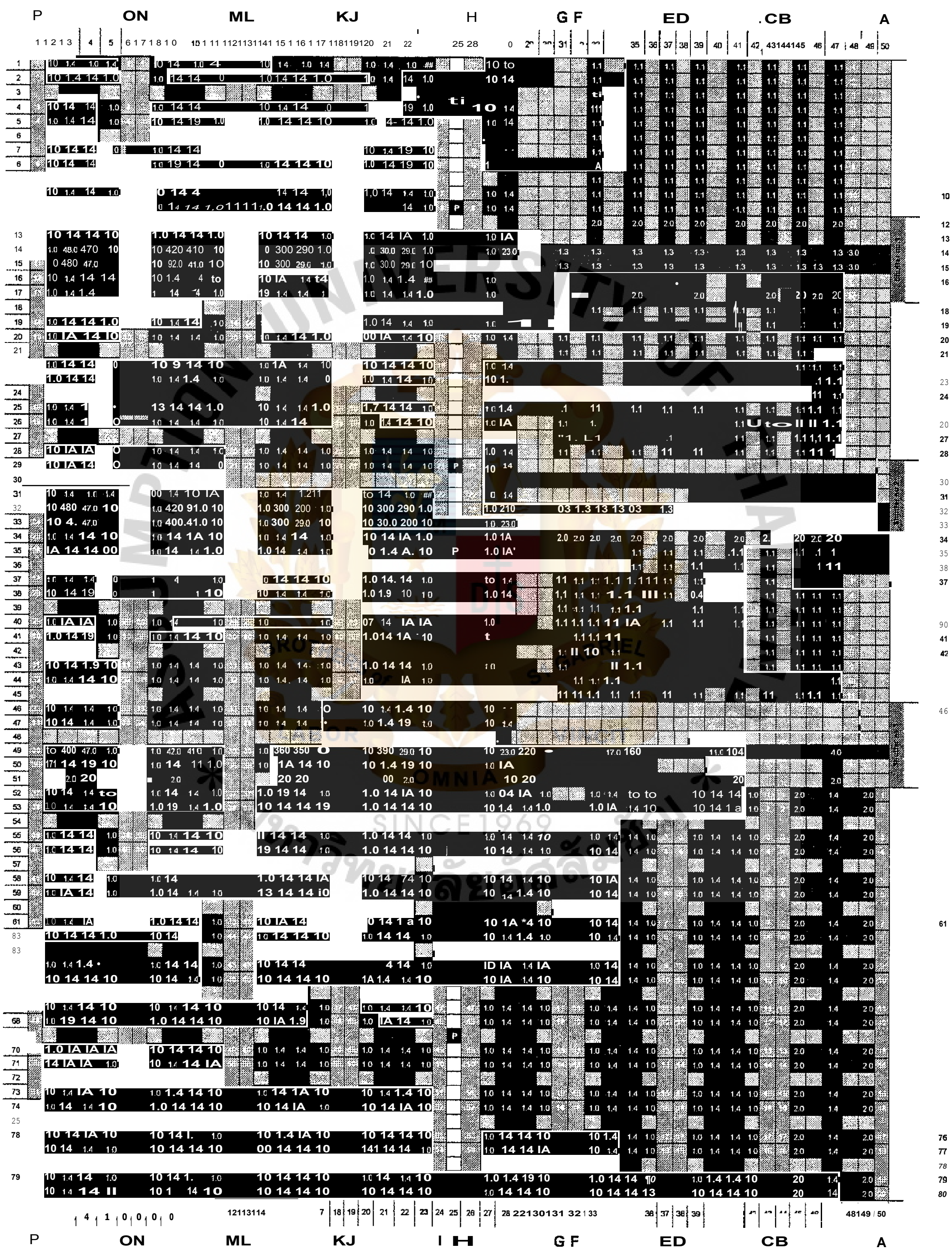
(c) Required Pallet Quantity per Month

(d) Required Pallet Quantity by Customers by Items

| Customer Number | Required Pallet QTY Per Month | Item Name of Class A | Required Pallet QTY Per Month | Item Name of Class B | Required Pallet QTY Per Month |
|---|---|---|---|---|---|
| C1 | 762 | D1 | 352 | M1 | 200 |
| C2 | 829 | D2 | 352 | H1 | 80 |
| C3 | 433 | S1 | 97 | H2 | 76 |
| C4 | 399 | S2 | 82 | H3 | 56 |
| C5 | 160 | S3 | 81 | H4 | 55 |
| C6 | 78 | S4 | 47 | H5 | 52 |
| C7 | 99 | S5 | 41 | M2 | 39 |
| C8 | 112 | S6 | 40 | M3 | 32 |
| C9 | 82 | S7 | 40 | M4 | 28 |
| C10 | 68 | S8 | 38 | H6 | 27 |
| C11 | 20 | S9 | 38 | H7 | 26 |
| C12 | 19 | S10 | 38 | H8 | 25 |
| C13 | 12 | S11 | 38 | M5 | 22 |
| C14 | 51 | S12 | 37 | H9 | 17 |
| C15 | 7 | S13 | 31 | M6 | 17 |
| C16 | 2 | S14 | 30 | H10 | 16 |
| C17 | 4 | D3 | 28 | M7 | 15 |
| C18 | 1 | S15 | 19 | M8 | 14 |
| C19 | 1 | S16 | 17 | M9 | 10 |
| C20 | 1 | S17 | 17 | M10 | 8 |
| C21 | - | S18 | 17 | M11 | 5 |
| C22 | - | S19 | 17 | M12 | 4 |
| C23 | - | S20 | 16 | M13 | 4 |
| TOTAL | 3,138 | S21 | 11 | H11 | 2 |
| | | D4 | 10 | M14 | 2 |
| | | S22 | 10 | M15 | 1 |
| | | S23 | 10 | M16 | 1 |
| | | D5 | 8 | M17 | 0 |
| | | S24 | 8 | M18 | 0 |
| | | S25 | 6 | TOTAL | 832 |
| | | D6 | 4 | | |
| | | S26 | 3 | | |
| | | S27 | 3 | | |
| | | D7 | 2 | | |
| | | S28 | 2 | | |
| | | D8 | 2 | | |
| | | D9 | 1 | | |
| | | D10 | 1 | | |
| | | D11 | 1 | | |
| | | D12 | 1 | | |
| | | D13 | 1 | | |
| | | D14 | 1 | | |
| | | D15 | 0 | | |
| | | S29 | 0 | | |
| | | S30 | 0 | | |
| | | TOTAL | 1,591 | | |

# APPENDIX 3

## Layout of Warehouse with Distances



# APPENDIX 4

Result of ABC Analysis to Customers (Table)

| Customer Name | Index (Volume) | Accumulated Probability | Class |
|---|---|---|---|
| C2 | 3,316 | 26.42% | A |
| C1 | 3,046 | 50.69% | A |
| C3 | 1,732 | 64.49% | B |
| C4 | 1,595 | 77.20% | B |
| C5 | 641 | 82.30% | C |
| C8 | 446 | 85.86% | C |
| C7 | 394 | 89.00% | C |
| C9 | 328 | 91.61% | C |
| C6 | 313 | 94.10% | C |
| C10 | 272 | 96.27% | C |
| C14 | 204 | 97.90% | C |
| CI 1 | 79 | 98.53% | C |
| C12 | 77 | 99.14% | C |
| C13 | 47 | 99.51% | C |
| C15 | 28 | 99.74% | C |
| C17 | 16 | 99.86% | C |
| C16 | 6 | 99.91% | C |
| C19 | 5 | 99.95% | C |
| C18 | 4 | 99.98% | C |
| C20 | 2 | 100.00% | C |
| C21 | - | 100.00% | C |
| C22 | | 100.00% | C |
| C23 | - | 100.00% | C |
| - | 12,551 | | |

# APPENDIX 5

Allocated Location by Customer

| Customer Number | Class | Required Pallet QTY Per Month | Allocation Ratio | Allocated Location |
|---|---|---|---|---|
| C1 | A | 762 | 24.27% | 776 |
| C2 | A | 829 | 26.42% | 844 |
| C3 | B | 433 | 13.80% | 441 |
| C4 | B | 399 | 12.71% | 406 |
| C5 | C | 160 | 5.11% | 163 |
| C6 | C | 78 | 2.49% | 80 |
| C7 | C | 99 | 3.14% | 100 |
| C8 | C | 112 | 3.55% | 114 |
| C9 | C | 82 | 2.61% | 84 |
| C10 | C | 68 | 2.17% | 69 |
| C11 | C | 20 | 0.63% | 20 |
| C12 | C | 19 | 0.61% | 20 |
| C13 | C | 12 | 0.37% | 12 |
| C14 | C | 51 | 1.63% | 52 |
| C15 | C | 7 | 0.22% | 7 |
| C16 | C | 2 | 0.05% | 2 |
| C17 | C | 4 | 0.13% | 4 |
| C18 | C | 1 | 0.03% | 1 |
| C19 | C | 1 | 0.04% | 1 |
| C20 | C | 1 | 0.02% | 1 |
| C21 | C | - | 0.00% | - |
| C22 | C | - | 0.00% | - |
| C23 | C | - | 0.00% | - |
| TOTAL | | 3,138 | 100.00% | 3,196 |

# APPENDIX 6

Result of ABC Analysis to Items of Class A (Table)

| Item Name | Index (Volume) | Acumulated Probability | Class |
|---|---|---|---|
| Dl | 1,408 | 22% | A-a |
| D2 | 1,406 | 44% | A-a |
| Si | 386 | 50% | A-a |
| S2 | 327 | 55% | A-a |
| S3 | 323 | 61% | A-a |
| S4 | 189 | 63% | A-b |
| S5 | 164 | 66% | A-b |
| S6 | 159 | 69% | A-b |
| S7 | 158 | 71% | A-b |
| S8 | 151 | 73% | A-b |
| S9 | 151 | 76% | A-b |
| S10 | 151 | 78% | A-b |
| S11 | 151 | 81% | A-b |
| S12 | 146 | 83% | A-c |
| S13 | 124 | 85% | A-c |
| S14 | 118 | 87% | A-c |
| D3 | 111 | 88% | A-c |
| S15 | 76 | 90% | A-c |
| S16 | 69 | 91% | A-c |
| S17 | 67 | 92% | A-c |
| S18 | 67 | 93% | A-c |
| S19 | 67 | 94% | A-c |
| S20 | 62 | 95% | A-c |
| S21 | 43 | 95% | A-c |
| D4 | 41 | 96% | A -c |
| S22 | 41 | 97% | A-c |
| S23 | 40 | 97% | A-c |
| D5 | 30 | 98% | A-c |
| S24 | 30 | 98% | A-c |
| S25 | 24 | 99% | A-c |
| D6 | 16 | 99% | A-c |
| S26 | 11 | 99% | A-c |
| S27 | 10 | 99% | A-c |
| D7 | 9 | 99% | A-c |
| S28 | 9 | 100% | A-c |
| D8 | 8 | 100% | A-c |
| D9 | 4 | 100% | A-c |
| D10 | 3 | 100% | A-c |
| D11 | 3 | 100% | A-c |
| D12 | 2 | 100% | A-c |
| D13 | 2 | 100% | A-c |
| D14 | 2 | 100% | A-c |
| D15 | 1 | 100% | A-c |
| S29 | 1 | 100% | A-c |
| S30 | 1 | 100% | A-c |

# APPENDIX 7

Allocated Location by Item of Class A Customer

| Item Name | Class | Required Pallet QTY Per Month | Allocation Ratio | Allocated Location |
|---|---|---|---|---|
| D1 | A-a | 352 | 22.13% | 359 |
| D2 | A-a | 352 | 22.10% | 358 |
| Si | A-a | 97 | 6.07% | 98 |
| S2 | A-a | 82 | 5.14% | 83 |
| S3 | A-a | 81 | 5.08% | 82 |
| S4 | A-b | 47 | 2.97% | 48 |
| S5 | A-b | 41 | 2.58% | 42 |
| S6 | A-b | 40 | 2.50% | 40 |
| S7 | A-b | 40 | 2.48% | 40 |
| S8 | A-b | 38 | 2.37% | 38 |
| S9 | A-b | 38 | 2.37% | 38 |
| S10 | A-b | 38 | 2.37% | 38 |
| S11 | A-b | 38 | 2.37% | 38 |
| S12 | A-c | 37 | 2.29% | 37 |
| S13 | A-c | 31 | 1.95% | 32 |
| S14 | A-c | 30 | 1.85% | 30 |
| D3 | A-c | 28 | 1.74% | 28 |
| S15 | A-c | 19 | 1.19% | 19 |
| S16 | A-c | 17 | 1.08% | 18 |
| S17 | A-c | 17 | 1.05% | 17 |
| S18 | A-c | 17 | 1.05% | 17 |
| S19 | A-c | 17 | 1.05% | 17 |
| S20 | A-c | 16 | 0.97% | 16 |
| S21 | A-c | 11 | 0.68% | 11 |
| D4 | A-c | 10 | 0.64% | 10 |
| S22 | A-c | 10 | 0.64% | 10 |
| S23 | A-c | 10 | 0.63% | 10 |
| D5 | A-c | 8 | 0.47% | 8 |
| S24 | A-c | 8 | 0.47% | 8 |
| S25 | A-c | 6 | 0.38% | 6 |
| D6 | A-c | 4 | 0.25% | 4 |
| S26 | A-c | 3 | 0.17% | 3 |
| S27 | A-c | 3 | 0.16% | 3 |
| D7 | A-c | 2 | 0.14% | 2 |
| S28 | A-c | 2 | 0.14% | 2 |
| D8 | A-c | 2 | 0.13% | 2 |
| D9 | A-c | 1 | 0.06% | 1 |
| D10 | A-c | 1 | 0.05% | 1 |
| D11 | A-c | 1 | 0.05% | 1 |
| D12 | A-c | 1 | 0.03% | 1 |
| D13 | A-c | 1 | 0.03% | 1 |
| D14 | A-c | 1 | 0.03% | 1 |
| D15 | A-c | 0 | 0.02% | 0 |
| S29 | A-c | 0 | 0.02% | 0 |
| S30 | A-c | 0 | 0.02% | 0 |
| Total | | 1,591 | 100.00% | 1,620 |

# APPENDIX 8

Result of ABC Analysis to Items of Class B (Table)

| Item Name | Index (Volume) | Accumulated Probability | Class |
|---|---|---|---|
| **M1** | 798 | 23.99% | B-a |
| H1 | 321 | 33.63% | B-a |
| H2 | 304 | 42.77% | B-a |
| H3 | 224 | 49.50% | B-a |
| H4 | 221 | 56.15% | B-a |
| H5 | 208 | 62.40% | B-a |
| M2 | 154 | 67.03% | B-b |
| M3 | 126 | 70.81% | B-b |
| M4 | 113 | 74.21% | B-b |
| H6 | 109 | 77.49% | B-b |
| H7 | 105 | 80.64% | B-b |
| H8 | 100 | 83.65% | B-b |
| M5 | 86 | 86.23% | B-c |
| H9 | 69 | 88.31% | B-c |
| M6 | 68 | 90.35% | B-c |
| H10 | 62 | 92.22% | B-c |
| M7 | 61 | 94.05% | B-c |
| M8 | 54 | 95.67% | B-c |
| M9 | 38 | 96.81% | B-c |
| M10 | 32 | 97.78% | B-c |
| M11 | 18 | 98.32% | B-c |
| M12 | 17 | 98.83% | B-c |
| M13 | 16 | 99.31% | B-c |
| H11 | 9 | 99.58% | B-c |
| M14 | 6 | 99.76% | B-c |
| M15 | 3 | 99.85% | B-c |
| M16 | 3 | 99.94% | B-c |
| M17 | 1 | 99.97% | B-c |
| M18 | 1 | 100.00% | B-c |

# APPENDIX 9

Allocated Location by Item of Class B Customer

| Item Name | Class | Required Pallet QTY Per Month | Allocation Ratio | Allocated Location |
|---|---|---|---|---|
| **M1** | B-a | 200 | 23.99% | 203 |
| H1 | B-a | 80 | 9.65% | 82 |
| H2 | B-a | 76 | 9.14% | 77 |
| H3 | B-a | 56 | 6.73% | 57 |
| H4 | B-a | 55 | 6.64% | 56 |
| H5 | B-a | 52 | 6.25% | 53 |
| M2 | B-b | 39 | 4.63% | 39 |
| M3 | B-b | 32 | 3.79% | 32 |
| M4 | B-b | 28 | 3.40% | 29 |
| H6 | B-b | 27 | 3.28% | 28 |
| H7 | B-b | 26 | 3.16% | 27 |
| H8 | B-b | 25 | 3.01% | 25 |
| M5 | B-c | 22 | 2.58% | 22 |
| H9 | B-c | 17 | 2.07% | 18 |
| M6 | B-c | 17 | 2.04% | 17 |
| H10 | B-c | 16 | 1.86% | 16 |
| M7 | B-c | 15 | 1.83% | 16 |
| M8 | B-c | 14 | 1.62% | 14 |
| M9 | B-c | 10 | 1.14% | 10 |
| M10 | B-c | 8 | 0.96% | 8 |
| M11 | B-c | 5 | 0.54% | 5 |
| M12 | B-c | 4 | 0.51% | 4 |
| M13 | B-c | 4 | 0.48% | 4 |
| H11 | B-c | 2 | 0.27% | 2 |
| M14 | B-c | 2 | 0.18% | 2 |
| M15 | B-c | 1 | 0.09% | 1 |
| M16 | B-c | 1 | 0.09% | 1 |
| M17 | B-c | 0 | 0.03% | 0 |
| M18 | B-c | 0 | 0.03% | 0 |
| TOTAL | | 832 | 100.00% | 847 |

# APPENDIX 10

## Inbound Volume and Class by Customers and Items

| Class | Customer Name | Inbound Pallet QTY per Year | Class | Item Name | Inbound Pallet QTY per Year | Class | Item Name | Inbound Pallet QTY per Year |
|---|---|---|---|---|---|---|---|---|
| A | C1 | 3,046 | A-a | Dl | 1,408 | B-a | M1 | 798 |
| A | C2 | 3,316 | A-a | D2 | 1,406 | B-a | H1 | 321 |
| B | C3 | 1,732 | A-a | S I | 386 | B-a | H2 | 304 |
| B | C4 | 1,595 | A-a | S2 | 327 | B-a | H3 | 224 |
| C | C5 | 641 | A-a | S3 | 323 | B-a | H4 | 221 |
| C | C6 | 313 | A-b | S4 | 189 | B-a | H5 | 208 |
| C | C7 | 394 | A-b | S5 | 164 | B-b | M2 | 154 |
| C | CS | 446 | A -b | S6 | 159 | B-b | M3 | 126 |
| C | C9 | 328 | A-b | S7 | 158 | B-b | M4 | 113 |
| C | C10 | 272 | A -b | S8 | 151 | B-b | H6 | 109 |
| C | Cu | 79 | A -b | S9 | 151 | B-b | H7 | 105 |
| C | C12 | 77 | A-b | S10 | 151 | B-b | H8 | 100 |
| C | C13 | 47 | A -b | S11 | 151 | B-c | M5 | 86 |
| C | C14 | 204 | A-c | S12 | 146 | B-c | H9 | 69 |
| C | C15 | 28 | A-c | S13 | 124 | B-c | M6 | 68 |
| C | C16 | 6 | A-c | S14 | 118 | B-c | H10 | 62 |
| C | C17 | 16 | A-c | D3 | 111 | B-c | M7 | 61 |
| C | C18 | 4 | A-c | S15 | 76 | B-c | M8 | 54 |
| C | C19 | 5 | A-c | S16 | 69 | B-c | M9 | 38 |
| C | C20 | 2 | A-c | S17 | 67 | B-c | M10 | 32 |
| C | C21 | - | A-c | S18 | 67 | B-c | M11 | 18 |
| C | C22 | - | A-c | S19 | 67 | B-c | M12 | 17 |
| C | C23 | - | A-c | S20 | 62 | B-c | M13 | 16 |
| | TOTAL | 12,551 | A-c | S21 | 43 | B-c | HI I | 9 |
| | | | A-c | D4 | 41 | B-c | M14 | 6 |
| | | | A-c | S22 | 41 | B-c | M15 | 3 |
| | | | A-c | S23 | 40 | B-c | M16 | 3 |
| | | | A-c | D5 | 30 | B-c | M17 | 1 |
| | | | A-c | S24 | 30 | B-c | M18 | 1 |
| | | | A-c | S25 | 24 | | TOTAL | 3,327 |
| | | | A-c | D6 | 16 | | | |
| | | | A-c | S26 | 11 | | | |
| | | | A-c | S27 | 10 | | | |
| | | | A-c | D7 | 9 | | | |
| | | | A-c | S28 | 9 | | | |
| | | | A-c | D8 | 8 | | | |
| | | | A-c | D9 | 4 | | | |
| | | | A-c | D10 | 3 | | | |
| | | | A-c | D11 | 3 | | | |
| | | | A-c | D12 | 2 | | | |
| | | | A -c | D13 | 2 | | | |
| | | | A-c | D14 | 2 | | | |
| | | | A-c | D15 | 1 | | | |
| | | | A-c | S29 | 1 | | | |
| | | | A-c | S30 | 1 | | | |
| | | | | TOTAL | 6,362 | | | |

APPENDIX 11

Travel Distance Calculated by Average Distance on Sept. 2013

| Customer Name | Class | Inbound Pallet QTY per Month (Sept) | Average Distance | Multiplied by | Travel Distance by Average Distance (Meter) |
|---|---|---|---|---|---|
| C1 | A | 475 | 29.67 | 4 | 56,378 |
| C2 | A | 226 | 29.67 | 4 | 26,824 |
| C3 | B | 159 | 45.57 | 4 | 28,981 |
| C4 | B | 116 | 45.57 | 4 | 21,144 |
| C5 | C | 92 | 55.71 | 4 | 20,499 |
| C6 | C | 30 | 55.71 | 4 | 6,685 |
| C7 | C | 23 | 55.71 | 4 | 5,125 |
| C8 | C | - | 55.71 | 4 | - |
| C9 | C | - | 55.71 | 4 | - |
| C10 | C | 82 | 55.71 | 4 | 18,273 |
| C11 | C | 4 | 55.71 | 4 | 891 |
| C12 | C | 22 | 55.71 | 4 | 4,902 |
| C13 | C | 8 | 55.71 | 4 | 1,783 |
| C14 | C | - | 55.71 | 4 | - |
| C15 | C | - | 55.71 | 4 | - |
| C16 | C | 2 | 55.71 | 4 | 446 |
| C17 | C | - | 55.71 | 4 | - |
| C18 | C | - | 55.71 | 4 | - |
| C19 | C | 1 | 55.71 | 4 | 223 |
| C20 | C | - | 55.71 | 4 | - |
| C21 | C | - | 55.71 | 4 | - |
| C22 | C | - | 55.71 | 4 | - |
| C22 | C | - | 55.71 | 4 | - |
| TOTAL | | 1,240 | | | 192,155 |