WAREHOUSE COST REDUCTION BY IMPROVING THE STORAGE POLICY

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ABSTRACT

The basic aim of enterprise activity is to optimize profitability by increasing revenue and decreasing cost. The result reflects the value for shareholders, customer satisfaction, and employee satisfaction. Supply chain management is an effective system to achieve all this. A warehouse has a significant impact on the supply chain as its cost is a major component of total cost. This study focuses on reducing warehouse cost through optimizing its interior traffic by forklifts.

A revised storage policy, a class-based policy, was chosen and applied to the warehouse operations, especially to improve the way a location is selected for each incoming cargo. The results indicate that applying this storage policy reduces the forklift traffic and distance travelled within the warehouse. It reduces maintenance costs, and direct and indirect manpower costs. It has further possibility for reducing manpower and equipment costs. This improvement uses the existing configuration of the shape and layout of the warehouse, and therefore does not need huge investment during implementation of the new policy.

บทคัดย่อ

เป้าหมายพื้นฐานของธุรกิจ คือ ความสามารถในทำกำไรที่สมเหตุสมผล โดยการเพิ่มรายได้และลดต้นทุน ซึ่งส่งผลสะท้อนออกมาในรูปของมูลค่าแก่ผู้ถือหุ้น ความพึงพอใจของลูกค้าและความพึงพอใจของพนักงาน การจัดการโซ่อุปทานเป็นระบบที่สามารถก่อให้เกิดสิ่งต่างๆที่กล่าวมา คลังสินค้ามีผลกระทบโดยตรงต่อโซ่อุปทาน เพราะเป็นต้นทุนพื้นฐานของต้นทุนโดยรวม งานวิจัยนี้มุ่งเน้นที่การลดต้นทุนคลังสินค้าโดยการบริหารการจราจรภายในอย่างเหมาะสม

การทบทวนนโยบายการจัดเก็บสินค้าโดยแยกตามประเภทได้ถูกนำมาประยุกต์ใช้กับการจัดการคลังสินค้า โดยเฉพาะการปรับปรุงวิธีเลือกสถานที่จัดเก็บสินค้าแต่ละประเภท ผลจากการวิจัยชี้ให้เห็นว่านโยบายการจัดเก็บสินค้าแบบใหม่นี้สามารถลดระยะทางและความคับคั่งของรถยกภายในคลังสินค้าได้ อีกทั้งยังลดการซ่อมบำรุง ต้นทุนแรงงานทั้งทางตรงและทางอ้อม และมีความเป็นไปได้ที่จะสามารถลดต้นทุนแรงงานและเครื่องจักรลงได้อีกในอนาคต การปรับปรุงคลังสินค้าที่เสนอนี้ใช้โครงสร้างและค่าใช้จ่ายที่มีอยู่ในปัจจุบัน ดังนั้นจึงไม่จำเป็นต้องใช้การลงทุนมากในการดำเนินการครั้งนี้

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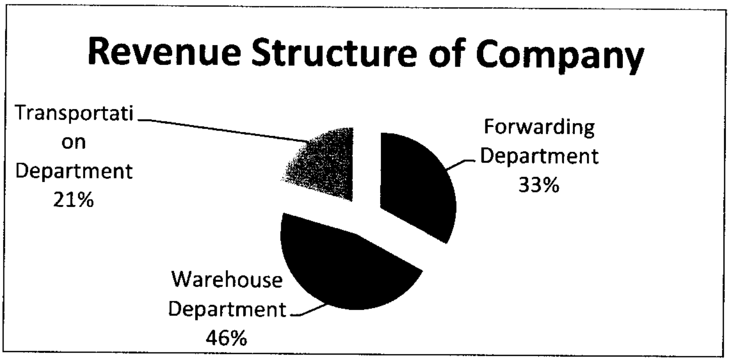
INTRODUCTION

The focus company in this research, called XYZ (a pseudonym), is a third party logistics provider (TPL) in Thailand. Its three major functions are freight forwarding, transportation, and warehousing. XYZ provides these services to various customers such as manufacturers, trading companies, and logistic companies. Thus a wide many various commodities are handled, including plastic resin for the automotive industry, electrical parts for the semiconductor industry, and milk powder for department stores. To succeed in a highly competitive market, XYZ realizes that warehousing service is its core competency and must be enhanced.

XYZ is organized into three operational departments: forwarding, transportation, and warehouse. The forwarding department provides the international freight forwarding service with custom clearance services, mainly to Japan, Indonesia and Vietnam. It handles air and sea exports and imports, and custom clearance at the borders with Laos and Malaysia. The transportation department provides a charter transportation and consolidation service that connects the ports, airports, warehouses and customer locations in the major industrial estates in Thailand. The warehouse department provides storage services, and is organized into two major teams based on the type of customer: single customer and multiple customer teams. There are six warehouses. Five are managed by the single customer team and one by the multiple customer team

XYZ places great importance on collaboration between departments. The forwarding department provides freight forwarding from overseas and import custom clearance, while the transportation department delivers containers from port to warehouse. The warehouse department stores cargo, and finally the transportation department delivers cargo to the end-users by truck. Thus, XYZ provides a one stop service in providing total logistics services to the customer, but it is the Warehousing service which motivates customers to choose XYZ. The revenue sources are shown in Figure 1. The warehouse department contributes most, which indicates its importance.

Figure 1: Revenue Structure, 2013



Source: Company accounts

There are six warehouses. The single customer team handles only one customer per warehouse; and the multiple customer team handles 22 customers per warehouse. The major revenue, 40% of warehouse total, is earned by Warehouse 6 (WH6) which is managed by the multiple customer team. Hence, this study concentrates on WH6.

Statement of the Problem

The company has a random storage policy for allocating spaces to incoming cargo. This causes problems as high volume from frequent customers' cargo is placed in long distance locations in the warehouse, and low volume from frequent customers' cargo is put in short distance locations. As a result, the total travel distance within the warehouse is great and causes a high level of equipment and manpower costs. Therefore, this research revises the storage policy to reduce the warehouse cost, by using a class-based storage policy and ABC analysis. A comparison of the old and proposed storage policies will be evaluated from the travel distance from the entrance of the warehouse to the location of storage, as will the costs of heavy equipment, maintenance, and manpower. Historical data of cargo volume, frequency and operational costs is collected for the whole of 2013.

There are limitations concerned in the implementation of this research. Its focus is on selected operational processes in a warehouse that has inbound and outbound processes: other external factors are excluded. The reconfiguration of the warehouse shape and layout would require a huge investment, and XYZ adopts strict safety policies. Therefore, this study maintains the current configurations. XYZ uses pallets for simple backtracking to the entrance from the stoage location. Therefore, a batching and routing policy that reduces the travel distance of the picking activity from multiple locations is not applicable.

REVIEW OF RELATED LITERATURE

Four topics are now described: the slotting process, ABC analysis, travel distance, and the warehouse cost. The slotting process and ABC analysis are used in redesigning the warehouse operations. Travel distance and cost are studied to reveal the key factors.

The Slotting Process

'Slotting' is the process of allocating goods to a location (a slot). Frazelle (2002) stated that slotting is the process of optimizing the storage method and location. It has a substantial impact on warehouse activities. Research indicates that more than 85 percent of the items in a warehouse are slotted improperly, leaving much potential for improvement. Hassan (2002) explained how slotting is an important process in the design of a warehouse due to its impact on workload in the operation. It is directly concerned with labor cost, productivity of picking operations, and traffic congestion.

Frazelle (2002) and Petersen, Gerald and Daniel (2004) emphasized the importance of profiling information before slotting is performed. Table 1 presents a profile which indicates the kind of information required. To perform slotting, there are several key questions, and the profiling of operational data has to be analyzed and utilized to find the solution.

Petersen et al. (2004) stated that slotting is the method to determine the order or ranking of the SKUs, and the storage policies which are used to determine how to assign the SKU to the appropriate storage location. The profile components in Table 1 are:
(1) Popularity: the measure of the number of potential times an operator visits the location for a particular item, which is the most frequently used slotting measure in practice (Frazelle, 2002). It is the number of requests for a given SKU (called the number of hits).
(2) Turnover: the total number of an SKU called during a certain period of time. Turnover is the demand for an SKU.

Table 1: Table of Profile Components to Perform Slotting

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

Source: Adapted from Frazelle (2002)

(3) Volume: the request for an SKU multiplied by the cube of the SKU.
(4) Pick density: the ratio of the popularity of an SKU to the cube (volume) of the SKU. This identifies those SKUs which have the highest pick activity for 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 should be located near to the shortest travel distance location.

Petersen et al. (2004) concluded that popularity and COI were the best slotting criteria for reducing the travel distance. Popularity is easier to understand and apply than is COI. Hassan (2002) stated that information of demand of items should be used in making storage assignment decisions. Frazelle (2002) stated that popularity is the number of requests per period and is used with volume to determine an assignment to storage mode and location, resulting in a popularity-volume profile. Popularity is an important measure of the number of potential times of traveling to the location for an item. Most of the workload of warehouse activity is travelling from the entrance to the storage location, from there back to the entrance, and between locations. 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 warehouses adopt the wrong measure of popularity, such as dollar sales, and usage.

Storage Policies

Storage policy is the method of how to assign a warehouse storage location to a cargo (Petersen, 1999). Petersen et al. (2004) presents three types of storage policy that are widely used.
(1) Random storage: The policy most commonly used in warehouses. All incoming cargos are randomly assigned to vacant locations with equal probability. This results in a high utilization of space and reduces congestion in aisles. However, it requires more travel distance and cargo identification.
(2) Volume-based storage: This policy places high volume items in the nearest location to the pick-up and drop-off points. This is effective in reducing travel distance.

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

Hassan (2002) stated that a warehouse should be designed by its objective, such as a distribution center, a manufacturer's warehouse, or a public warehouse. The selection of storage policies to assign cargo locations should be affected by that objective. The storage policy is the most important factor in defining the warehouse operation, as determined by the warehouse objective. A volume-based storage policy assigns each SKU to a specific location. A class-based storage policy classifies the SKUs and the storage zones.

XYZ Company handles over seven hundred SKUs from over twenty customers, and there are more than three thousand storage locations, so it is not realistic that the operator identifies the hundreds of SKUs and allocates the cargo to a unique location for each SKU. Thus, this study examines the class-based storage policy, to consider its operational suitability.

Zoning

The labels 'fast moving area', 'slow moving area' and 'dead stock area' are widely used in warehouses. Frazelle (2002) stated that a fast moving area should be the most accessible warehouse location and used for the most popular items, as defined by three different physical zones: Golden, Silver, and Bronze Zones. The Golden Zone is the closest to the travel aisle and nearest to the waist level of the picker.

Hassan (2002) explained that high demand items should not be stored in only one zone, to reduce traffic congestion. Also, items that are probably ordered together should be allocated neighboring locations to reduce travel distance. Dedicated storage zones should be compatible with randomized storage zones in case some items are required to be moved from their storage zones.

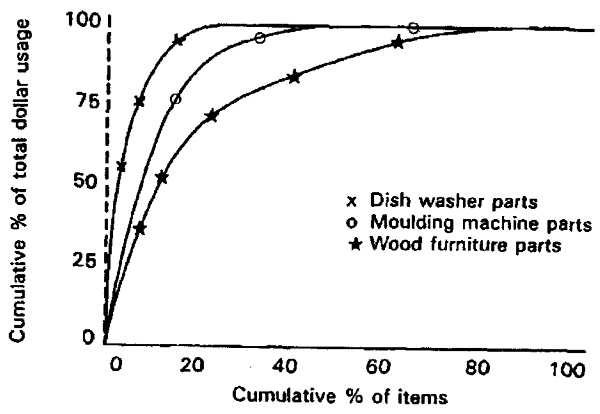
ABC Analysis

ABC analysis is an analytical method for inventory management that categorizes inventory into three classes, A, B and C (Flores & Whybark, 1986). This is often called Pareto analysis or the rule of 80/20. Thus, 20 percent of the items occupy 80 percent of the workload in a warehouse. ABC analysis is a technique of ranking and classifying the importance of large quantities of objects.

Flores and Whybark (1986) found that ABC analysis is the most commonly used method for inventory management. Items are categorized as A, B and C based on cost or usage. This study examined the relationship between dollar usage (cost-volume) of an item and item quantity, for three companies as shown in Figure 2 below. This distribution is sometimes called the ABC curve, Pareto distribution, or popularity distribution. It helps management to define alternative strategies to handle important items with priority. ABC analysis shows what is important to management. The curves identify those minority items with a high dollar usage.

Flores and Whybark (1986) described how the cutoffs for each of class A, B and C must be set by management. Some firms use the Pareto rule for this. That is, the number of A items should represent 20 percent of the total. Management must decide the criteria by considering the order of priority and the firm's limitations.

Figure 2: Dollar Usage Curves for Inventory Items



Source: Flores and Whybark (1986)

Frazelle (2002) defined the most popular items of Family A to be in the most accessible warehouse locations (Class A zone, called the golden zone).:
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)

Travel Distance

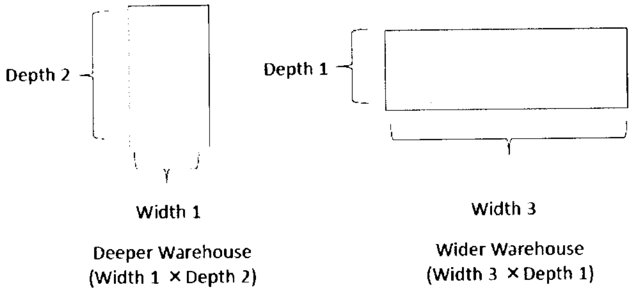
Travel distance is the distance from the warehouse entrance to the storage location, and from there back to the entrance. It is affected by the layout design and the operating policy (Caron, Marchet & Perego, 2000). The distance consists of the movement though horizontal and vertical distance by the picker or forklift. Transportation inside the warehouse is the most time consuming movement (Bartholdi & Hackman, 2005). Reducing the travel distance increases productivity of the picking operation. The literatures indicates that travel distance is impacted by several factors, which affect each other because if the layout design is changed the same operating policy cannot be used to achieve the same results.

Warehouse Shape and Layout

Petersen (1997) examined the warehouse shape factor and found that a deeper warehouse (1 $\times$2) has a shorter travel distance than a wider warehouse (3 $\times$ 1). The figures '1 $\times$2' and '3 $\times$ 1' are the ratios of depth and width. For instance, '1 $\times$2' indicates that a warehouse 100 meters wide and 200 meters deep. However, Hall (1993) said that a wider warehouse has better performance. Petersen (1997) explained that this difference originated from the objective of using layout to determine the storage space.

A warehouse layout has almost infinite combinations caused by its shape, usage and operating policies. Some researchers argue that best warehouse design and layout is not yet precisely determined, and that 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 rack types, accessibility to the rack, and entrance and dock location (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).

Figure 3: Warehouse Shape

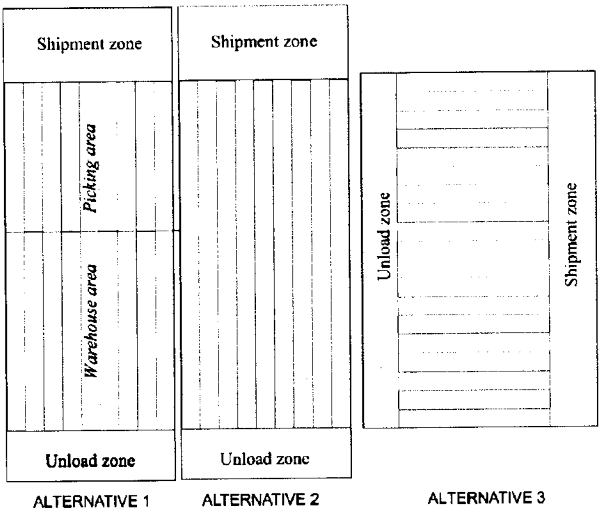


Source: Author

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

Huertas, Ramírez, and Salazar (2007) examined the layout comparison which impacts the average picking time and which affects labor and equipment (shown in Figure 4 below) and revealed results that give three alternatives as the most efficient layouts in terms of operator numbers, forklift numbers and average picking time. It increases the space usage by 11 percent. Figure 4 shows the shape of a warehouse with aisles and unload zones used for inbound operation, and shipment zones used for outbound operation.

Figure 4: Examples of Warehouse Layout (Alternatives 1, 2 and 3)

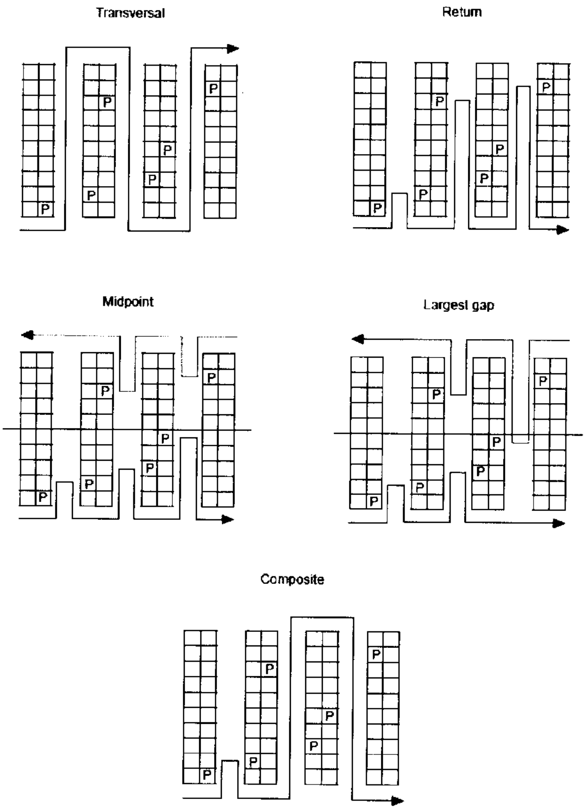


Source: Huertas et al. (2007)

Routing policy

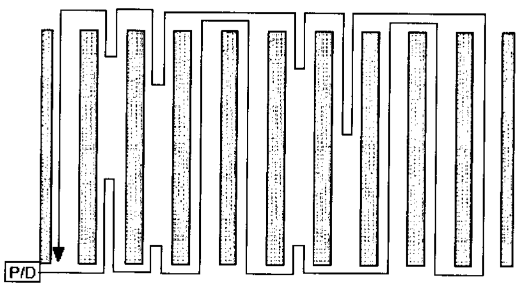
Petersen (1997) examined six different routing policies: transversal, return, midpoint, largest gap, composite, and optimal (in Figures 5 and 6) and concluded that the optimal routing policy is that which is most efficient. The Figures show routing by arrows, and picking point by 'p', i.e. the routing of picking inside the warehouse. Petersen (1997) concluded that travel distance is affected by the routing policy, which indicates that routing policy is the method for increasing efficiency in picking multiple objects.

Figure 5: Routing Policy



Source: Petersen (1997)

Figure 6: Optimal routing policy



Source: Petersen (1997)

Warehouse Cost

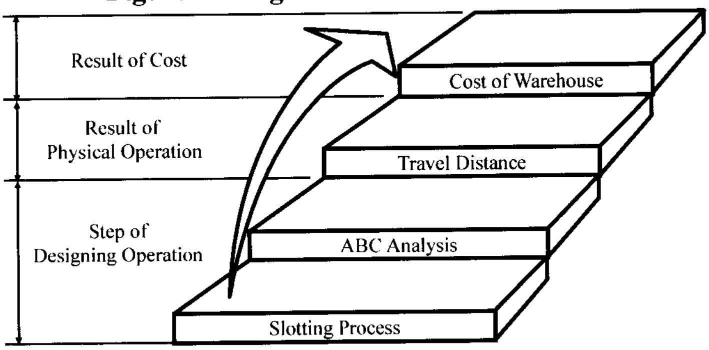
Napolitano (2003) categorized two types of warehouse cost: capital cost and operating cost. Capital costs are involved in investment such as planning, designing, construction and implementation to start up a new warehouse or when renovating one. Operating costs are the daily expenses incurred in the actual running of a warehouse. Bartholdi and Hackman (2005) stated that total operational costs are affected by layout and operational policies.

Huertas et al. (2007) explained that the 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 affected by usage levels. Costs of material handling equipment are mostly equipment utilization costs such as purchase, depreciation, leasing, and maintenance.

Summary

The four topics reviewed are shown in Figure 7 below. The slotting process and ABC analysis are steps in designing an operation. Travel distance is the result of the physical operations in a warehouse based on the designed operations. Finally, the cost is determined by the physical operations.

Figure 7: Diagram of Related Literature



Source: Author

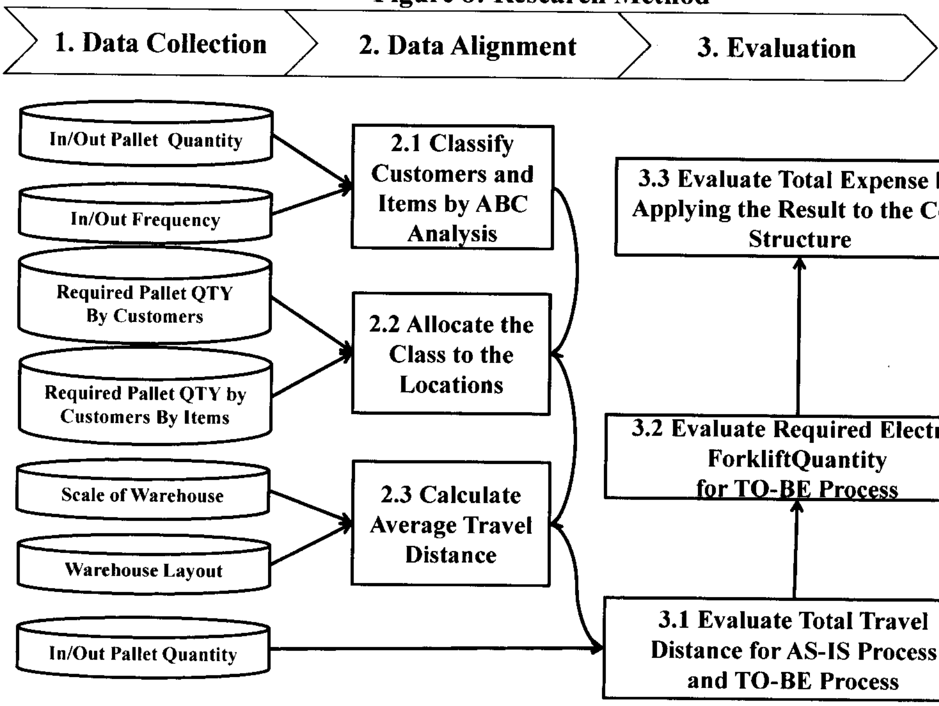
Figure 7 is supported by the literature's findings that total operational costs are affected by layout and operational policies, and that reducing travel distance concerns both layout design and operating policies. Therefore, layout design and operating policy impacts both travel distance and cost structure.

RESEARCH METHODOLOGY

Research Method

The structure of the research method is shown in Figure 8 below. There are three basic steps: data collection, data alignment, and evaluation.

Figure 8: Research Method



Source: Author

The 2013 historical data of cargo movement and the configuration of the warehouse, is collected, including data of inbound and outbound pallet quantity by customers, and data of inbound and outbound frequency by customers. It also includes the required pallet quantity per month and by customer items. The layout of the warehouse and its distances are also included.

The AS-IS Process

First, the existing operations and layout have to be ascertained, and are now described.

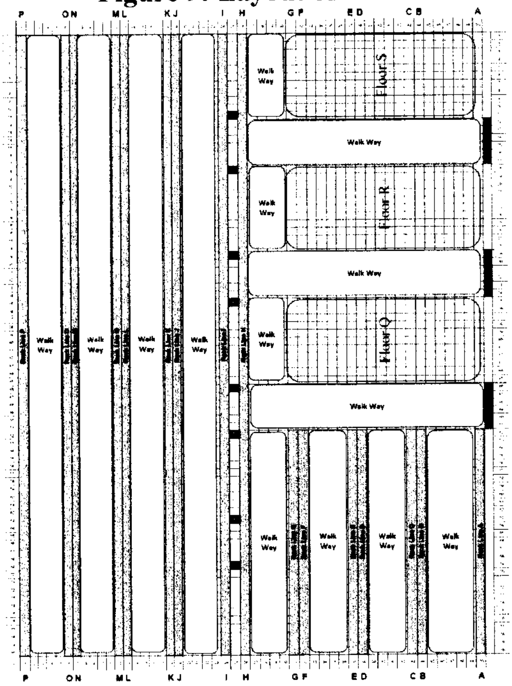
Configuration and Operation of Warehouse WH6

WH6 is 80 meters wide and 50 meters deep, a total 4,000 square meters of space. It also has a platform 80 meters wide by 6 meters deep. WH6 has a total of 3,196 pallet positions, consisting of a rack system with 2,416 pallet positions and floor locations with 780 pallet positions. The layout is shown in Figure 9.

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

WH6 has two employees in the back office and ten employees in the warehouse. The Supervisor allocates the inbound and outbound cargo to forklift drivers and checkers. Forklift Drivers unload cargo from the truck or container and move it from the warehouse entrance to its randomly allocated storage location. Checkers verify the identity of the inbound and outbound cargo and the document that shows customer orders, to register the location of the cargo with the forklift driver. Office Staff communicate with the customer, send information to the supervisor, and register the operational results in the warehouse management system.

Figure 9: Layout of WH6



Source: Adapted from company XYZ

Actual Data of Travel Distance and Cost Structure

The actual operational data of Company XYZ shows that 12 customers had inbound cargo totaling 1,240 pallets. Once the company receives a customer's order, the cargo will be picked up by a forklift. After delivering the cargo to a location, the forklift returns to the entrance.

The allocated cost for WH6 in the fiscal year 2013 consisted of logistical operating expenses and administrative expenses. The logistical operating expenses are variable, and reduced if activity is reduced. Administrative expenses are fixed costs based on the number of employees.

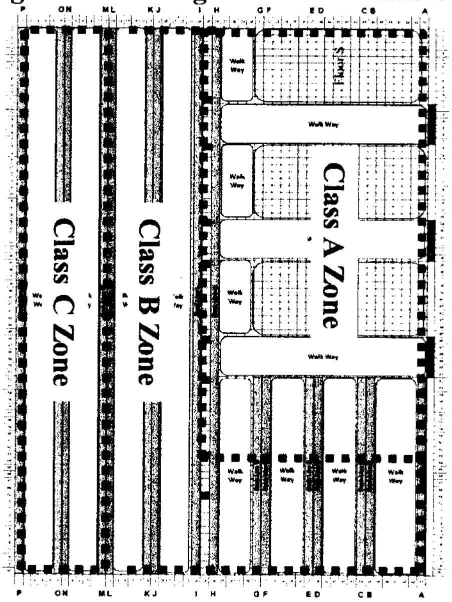
Several cost items are affected by the travel distance, e.g. Electric Forklifts, and Additional Batteries and Battery Chargers. This equipment is rented from suppliers. Electricity and Maintenance costs are linked to this equipment. The costs of Forklift drivers and Checkers are within administrative expenses. The expectation is that one forklift (and its associated costs) can be dispensed with under a new system.

The TO-BE Process

Alternative 1 applies the class-based policy to the 22 customer classifications. Alternative 2 applies the policy to the items of customer class A and B, and these have sub-classes based on the items.

Alternative 1 separates the warehouse into zones A, B and C as shown in Figure 10. Customer classifications determine their allocated storage locations in these zones.

Figure 10: Zoning Plan of Alternative 1

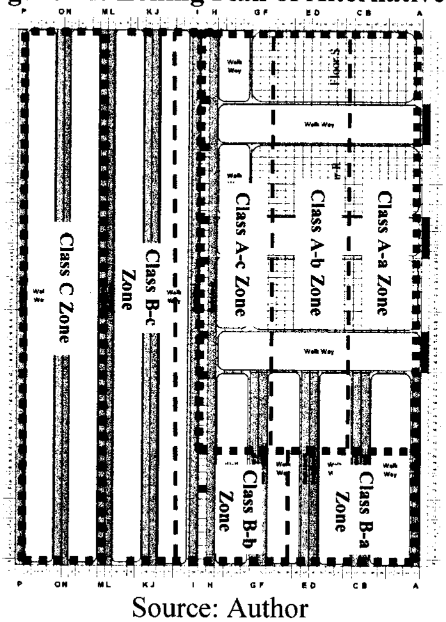


Source: Author

Alternative 2

Alternative 2 is similar to Alternative 1, but the items in customer classes A and B will be subjected to ABC analysis again to identify sub-classes. Therefore, Alternative 2 contains classes A-a, A-b, A-c, B-a, B-b, B-c and C, as shown in Figure 11.

Figure 11: Zoning Plan of Alternative 2



Source: Author

Method of Evaluation

The evaluation calculates the 'Required electric forklift quantity' for Alternatives 1 and 2 by measuring total travel distance. This 'Required electric forklift quantity' will then 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 2.

Table 2: 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

Microsoft Office Excel 2010 is used for all the calculation and evaluation. Abbreviations used in the formulae below are:

T_1: Total travel distance of AS-IS process
T_2: Total travel distance of alternative 1
T_3: 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
$\bar{A}_A$: Average distance of zone class A
$\bar{A}_B$: Average distance of zone class B
$\bar{A}_C$: Average distance of zone class C
$\bar{A}_{Aa}$: Average distance of zone class A of sub-class a
$\bar{A}_{Ab}$: Average distance of zone class A of sub-class b
$\bar{A}_{Ac}$: Average distance of zone class A of sub-class c
$\bar{A}_{Ba}$: 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

Classify customers and items by ABC analysis and allocate class to location

This evaluation starts from data alignment using ABC analysis of the customers. Customers are allocated to the three classes that are either A, B and C by volume. ABC analysis is again applied to achieve sub-classifications, resulting in a total of nine classes -: A, B, C, A-a, A-b, A-c, B-a, B-b and B-c.

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

(a) Apply ABC analysis to customers by volume index, 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 the results from the classifying of customers.
(d) Apply ABC analysis to items of class A's customers by volume index, 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 from sub-classifying the items.
(f) Apply ABC analysis to items of class B's customer by volume index, 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.

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

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

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

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

(e) Calculate the average distance by zone C ($\bar{A}_C$).

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. Figure 12 presents an example where cargo is allocated a location of 80 meters distance. The single travel distance is calculated by the combination of depth and width. Total travel distance for inbound and outbound will be measured. To verify the method of calculation by average distance, actual travel distance will be compared using this method.

The company's existing random storage policy allocates incoming cargo to empty locations with equal probability. To compare with the alternatives in the same condition, the total volume will be distributed to each zone class with an equal probability, i.e., total volume will be multiplied by 0.3333 based on the three classes of A, B, C.

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

$$T_1 = (((V_T \times 0.3333) \times \bar{A}_A) + ((V_T \times 0.3333) \times \bar{A}_B) + ((V_T \times 0.3333) \times \bar{A}_C)) \times 4$$

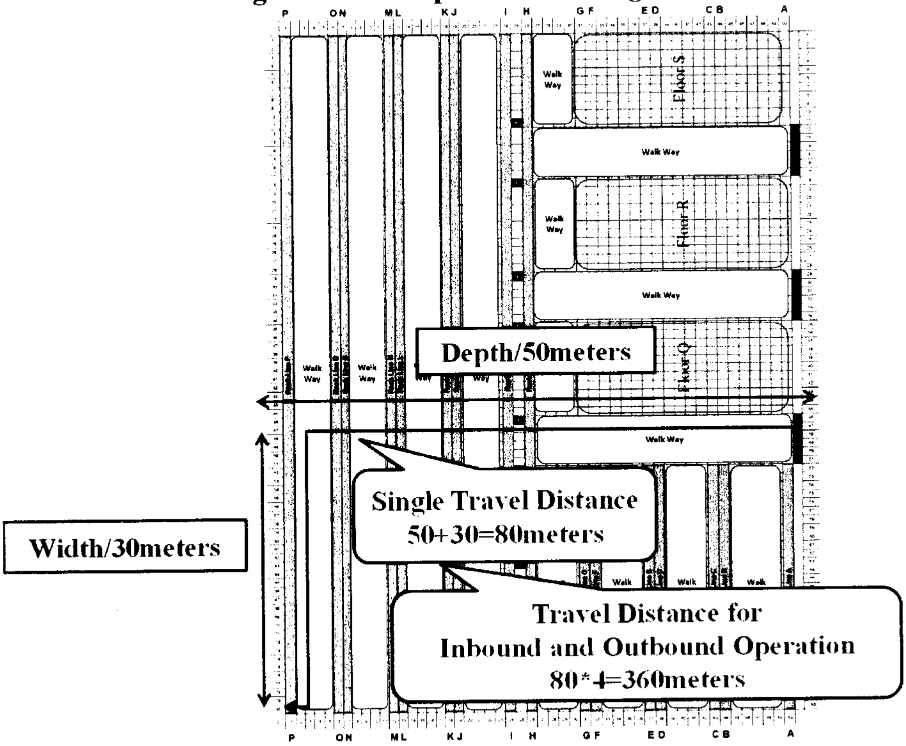
(b) Evaluate the total travel distance of alternative 1(T_2) by using this formula:

$$T_2 = ((V_A \times \bar{A}_A) + (V_B \times \bar{A}_B) + (V_C \times \bar{A}_C)) \times 4$$

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

$$T_3 = \left((V_{Aa} \times \bar{A}_{Aa}) + (V_{Ab} \times \bar{A}_{Ab}) + (V_{Ac} \times \bar{A}_{Ac})\right) + \left((V_{Ba} \times \bar{A}_{Ba}) + (V_{Bb} \times \bar{A}_{Bb}) + (V_{Bc} \times \bar{A}_{Bc})\right) + (V_C \times \bar{A}_C)) \times 4$$

Figure 12: Example of Evaluating Travel Distance



Source: Author

Evaluate Required Electric Forklift Quantity for the TO-BE Process

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

(a) The value of T_1 will be divided by four, i.e. quantity of electric forklifts, and evaluate the travel distance per electric forklift (*F*). If the value of T_1 is 1,000,000 meters, the travel distance per electric forklift is 250,000 meters.
That is:

$$F = T_1 \div 4$$

(b) The value of T_2 and T_3 will be divided by travel distance per electric forklift. Evaluate the required electric forklift quantity (R_2 and R_3) by alternatives. If the value of T_2 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:

$$R_2 = T_2 \div F$$
$$R_3 = T_3 \div F$$

Evaluate Total Expense by Applying the Result to the Cost Structure

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

Summary

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

DISCUSSION OF RESULTS

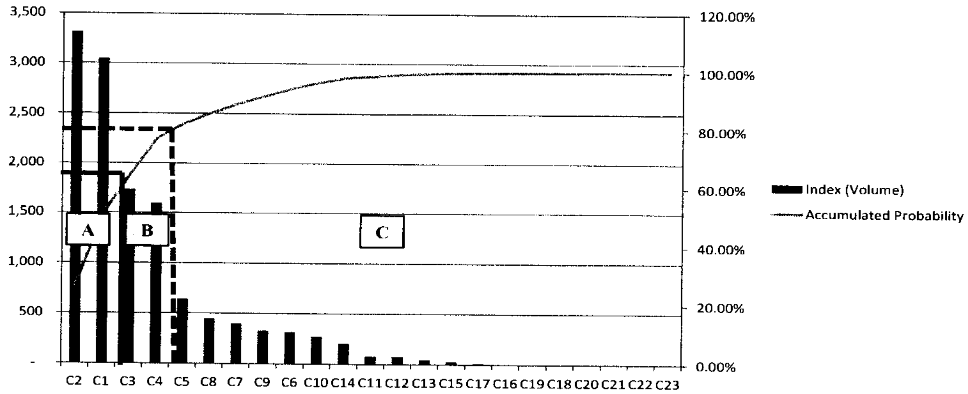
The evaluation of results is now presented. It examines the total expense of the TO-BE Process through data alignment and evaluation. The results of the TO-BE Process will be analyzed and compared with the AS-IS Process, for customers, pallets, cargo items, quantities, frequency, layout and distances.

Results of Classification of Customers and Location

(a) The result of the ABC analysis of customers is shown in Figure 13.

(b) The results of allocated locations for customer Class A, B and C are shown. The ratio of 'required pallet quantity per month per class occupied is applied to the actual location quantity.

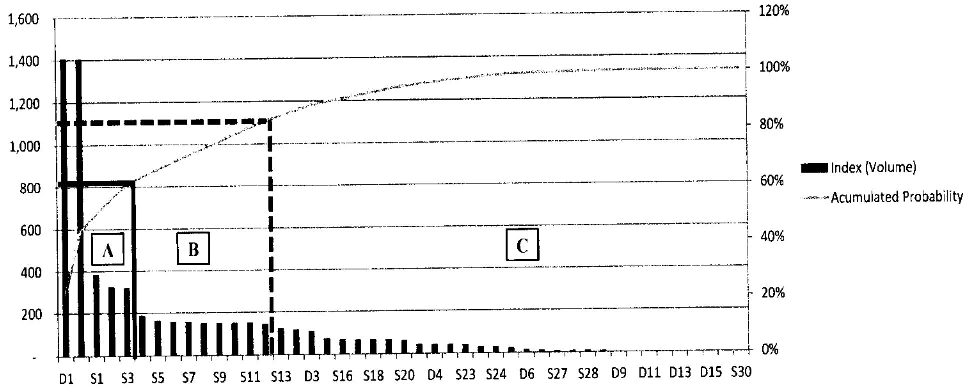
Figure 13: Result of ABC Analysis to Customers (Pareto Chart)



Source: Author

(c) The results of the ABC analysis to items of Class A customers are shown in Figure 14. The items are divided into three sub-classes.

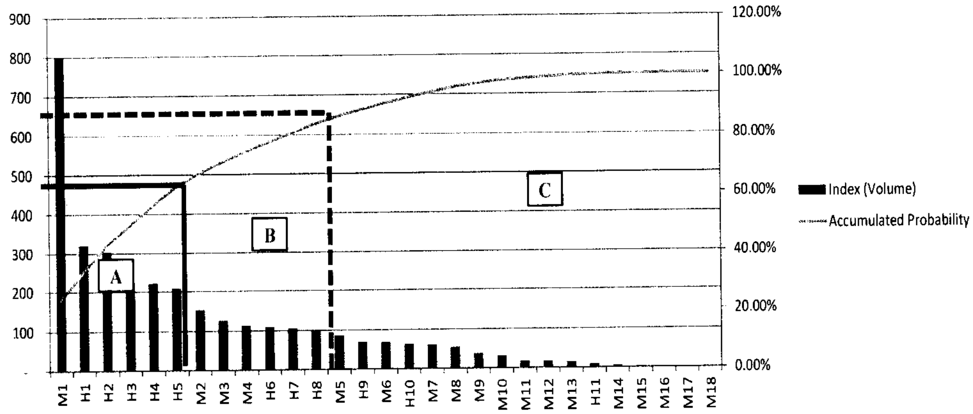
Figure 14: Result of ABC Analysis to Items of Class A (Pareto Chart)



Source: Author

(d) The results of the ABC analysis for items of Class B customers are shown in Figure 15, in three sub-classes.

Figure 15: Result of ABC Analysis to Items of Class B (Pareto Chart)



Source: Author

The average distances of zone A ($\bar{A}_A$), B ($\bar{A}_B$), C ($\bar{A}_C$), A-a ($\bar{A}_{Aa}$), A-b ($\bar{A}_{Ab}$), A-c ($\bar{A}_{Ac}$), B-a ($\bar{A}_{Ba}$), B-b ($\bar{A}_{Bb}$) and B-c ($\bar{A}_{Bc}$) are then calculated.

The actual travel distance and travel distance, calculated by average distance, are compared. The results are shown in Table 4 below. The difference is 7.64%. Subsequent Tables contain more results

Table 3: Difference of Travel Distance between Actual and Average

Actual Travel Distance (Meter)	Travel Distance by Average Distance (Meter)	Difference
177,470	192,155	7.64%

Source: Author

Table 4: 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	Travel 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

Table 5: 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 Travel Distance**	**1,999,240.36**

Source: Author

Table 6: 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

Evaluate the Required Electric Forklift Quantity for TO-BE Process

The results of the evaluation of the travel distance per electric forklift (F) are:

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

The results of the evaluation of the required electric forklift quantity for alternative 1 (R_2) and alternative 2 (R_3) are:

$$3.65\ (R_2) = 1{,}999{,}249.36 \div 547{,}778.66$$
$$3.44\ (R_3) = 1{,}886{,}112.55 \div 547{,}778.66$$

The results indicate that the improved storage policy reduced the cost of the warehouse by 12.2 %, per year in alternative 1, and by 15.7 % per year in alternative 2 (as shown below).

Table 7: 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**	**13,331**	**18,169**
Alternative 2	**4,649**	**12,787**	**17,436**

	Decreased Amount		
	Logistics Expense	Administation Expense	Total Expense
Alternative 1	**315**	**2,200**	**2,515**
Alternative 2	**504**	**2,744**	**3,248**

	Improved Percentage		
	Logistics Expense	Administation Expense	Total Expense
Alternative 1	**6.1%**	**14.2%**	**12.2%**
Alternative 2	**9.8%**	**17.7%**	**15.7%**

Source: Author

CONCLUSION

The results show that an improved storage policy reduces the travel distance and positively affects the warehouse, by reducing the traffic inside the warehouse, and with the possibility of reducing manpower and equipment.

The reduced travel distance shortens the operating hours. XYZ Company limits the maximum speed of forklifts inside the warehouse at 5km per hour, for safety. The distance reduced in alternative 1 could be converted to 38.37 hours of forklift operating hours and in alternative 2 could be converted to 61 hours.

Generally speaking, ABC analysis is a method to optimize the procurement and management of the inventory level. This study classified customers and items, and also applied the 'ABC of ABC' to assign sub-classes. This obtained positive results which indicated that detailed classifications can contribute to shortening the travel distance.

This study found an equal relationship between volume and frequency in the operation of pallet units for inbound and outbound cargo. However, for outbound cargo by carton, the frequency has a direct multiplying impact on the travel distance. In this case, a routing policy that defines the shortest picking route has much more significance in producing the most efficient picking operation.

The findings indicate that applying a new storage policy reduces movement, and affects the cost structure of XYZ. The findings support the literature theory, that total operational costs are impacted by the layout and operational policies (Bartholdi & Hackman, 2005) and that reducing the travel distance is connected to both layout design and operating policies (Caron et al., 2000). The application of a proper storage policy reduces the required asset level and maintenance cost, including direct and indirect manpower. There is the possibility of reducing equipment and manpower without needing the huge investment involved in changing the layout configuration.

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. Modification of the configuration would need huge investment and would affect the company's safety policy. Therefore, the results came from the application of a different storage policy to the original layout of the warehouse. Future study could use a different storage policy for the several layouts of a warehouse.

Routing policy is an important element affecting travel distance even if in this study of XYZ it is not applicable. The combinations of storage policy, warehouse configuration and routing policy are almost infinite. Therefore the management of the warehouse should pay keen attention to ongoing research and assess its usefulness.

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