IMPROVING LABOUR EFFICIENCY IN THE CROSS DOCK ACTIVITY OF A HOME IMPROVEMENT DISTRIBUTION CENTRE

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ชัชวาล ชุลีเกียรติ : ปรับปรุงประสิทธิภาพแรงงาน ในกิจกรรม โฟลว์ทรู ของศูนย์กระจายสินค้า อุปกรณ์ตกแต่งบ้าน (IMPROVING LABOUR EFFICIENCY IN THE CROSS DOCK ACTIVITY OF A HOME IMPROVEMENT DISTRIBUTION CENTRE) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร.โอฬาร กิตติธีรพรชัย, 88 หน้า.

Crossdocking เป็นหนึ่งในกระบวนการทำงานของศูนย์กระจายสินค้าที่ถูกใช้กันอย่างแพร่หลายในปัจจุบัน เนื่องด้วยความสามารถในการตอบสนอง และลดต้นทุนในที่เกิดจากการดำเนินงานขอศูนย์กระจายสินค้า เพื่อจัดส่ง และบริหารสินค้า ให้ลูกค้าได้อย่างมีประสิทธิภาพ แต่ถึงกระนั้น กระบวนการทำงานของ crossdocking เป็นหนึ่งในกระบวนการที่ใช้แรงงานคนมากที่สุด โดยกระบวนการได้ถูกแบ่งออกดังนี้ จัดหาสินค้า แบ่งและกระจายสินค้า และเตรียมสินค้าเพื่อส่งไปยังลูกค้าที่กำหนด ในกระบวนการทั้งหมดนี้นั้น ส่วนที่มีการใช้แรงงานคนหนาแน่น จะอยู่ที่ส่วนกระจายสินค้า

วิทยานิพนธ์เล่มนี้ได้มีการออกแบบรูปแบบและการเดินของส่วนกระจายสินค้าในกระบวนการ crossdock ของบริษัทค้าปลีก ประเภท วัสดุก่อสร้าง และอุปกรณ์ตกแต่งบ้าน โดยได้นำรูปแบบต่างๆมาทดสอบด้วยการโปรแกรมจำลองคอมพิวเตอร์ จากการศึกษานั้น และได้วัดผลด้วย line per man-hour ปัจจัยในการจำลองได้ศึกษา ระยะทางการเดิน การติดขัดด้วยจำนวนคนในช่อง aisle และเวลาในการกระจายสินค้า

ผลการจำลอง ด้วยคอมพิวเตอร์แสดงให้เห็นว่า รูปแบบA1W2เป็นรูปแบบที่ทำให้เกิดประสิทธิภาพมากที่สุด ด้วยผล 33.89 line per man-hour(เพิ่มขึ้นจากเดิม 23 เปอร์เซน) โดยการวิธีการเดินมีส่วนอย่างมากแก่การปรับปรุงประสิทธิภาพในการกระจายสินค้า รูปแบบการเดินยังไม่มีผลชัดเจน เมื่อเทียบกับการเดินของพนักงาน

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Because of the natural of retail business, logistics and distribution network have become the essential part of business and the core competition of a company. Many modern trade retailers have adopted a cross-docking, a freight consolidation technique pioneered by Wal-Mart, as the best practice for distributing domestic products. Although cross-docking bypasses storage, it requires coordination between incoming and outgoing shipments as well as manual labour to assort small pieces of products into different destination, similar to a flow though activity in the case study distribution centre. As a subsidiary of a large home furnishing and construction material retailer, the distribution centre consolidates incoming shipments from many manufactures and distributes combined shipments to stores on daily basis. As the most labour intensive operation, flow-though activity experienced traffic congestion and low efficiency measured by line per man-hour as workers must unpack, distribute, and sort products into each assigned pigeon hole representing a different store. The analysis of data and work study of operations suggest that the improvement should focus on small- and medium-size products as they account for majority of products. To reduce the congestion, several layouts of assigned stores and direction of traffic flow are proposed and evaluated using a discrete-time events simulation. The evaluation and analysis of interaction reveal that allowing workers to walk back-and-forth could significantly improve productivity and assigning a large-transition store to the rim of distributed aisles could reduce traffic congestion. The suggested layout and traffic direction could improve line per man hour from 28.46 to 33.89.

Department:	Regional Centre for Manufacturing Systems Engineering	Student's Signature	....
		Advisor's Signature	....
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CONTENTS

Page

Page

Page

Table of figures

Table of Tables

1 Introduction

Before focusing on the problem of labour intense in a case study of distribution centre in next chapters, it is important to provide the overview of land scape of modern trade business in Thailand and the strategic necessity of such facility in terms of logistics.

1.1 Outlook of Modern trade market

The modern trade business in Thailand has continuously grown for several years due to the rises of middle class and economic growth in the region. Recent data collected from Bank of Thailand ((BOT) 2017) measured Retail Sales Index as shown in Figure 1-1.

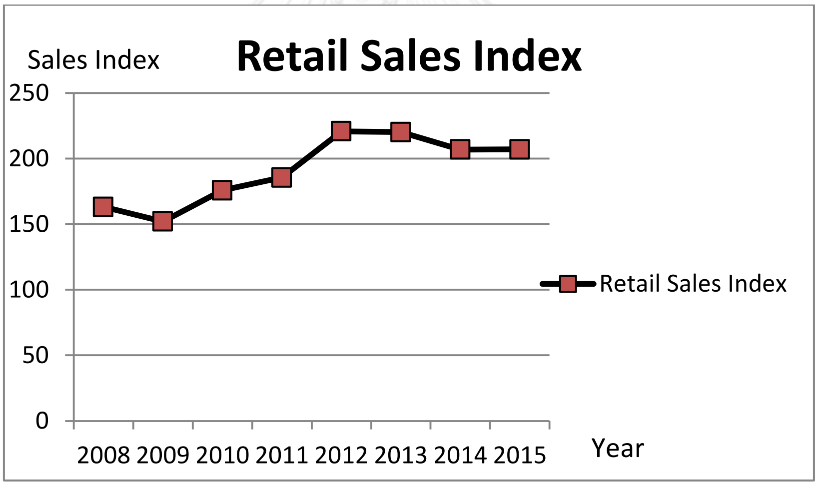


Figure 1-1: Thailand’s retail sales index for the past eight years ((BOT) 2017).

Figure 1-1 reveals the macro perspective of Thailand in terms of Retail Sales Index and implies that the retail business is fundamentally strong and has growth opportunity despite some political events as the index has increased 27 percent for the past eight years. To pin point such growth opportunity, it is important to classify modern trade retail business into four types based on portfolio of products:

- **Convenience stores:** These stores are conveniently located near consumers and offers variety of everyday items such as groceries, snacks and drinks at a suggested retail price. The area of the stores is relatively small and stores only few items of each product. Examples of stores are: Family Mart stores operated by Central Retail Corporation or CRC and Seven-Eleven stores operated by CP-ALL.
- **Hypermarket:** This is a modern trade retailer specialized in fresh food such as meat, dairy products, and bakery. Many stores also offer consumer goods for cleaning and storage. Examples of hypermarket are Gourmet or TOPS operated by CRC and Tesco-Lotus.
- **Cash-and-Carry:** This is a store that is similar to hypermarket but offers products at a discounted price by encouraging customers to pay cash and purchase at large quantities. The best fit for this retailer is Makro.
- **Home furnishing and construction material store:** This is a store for selling furniture, home improvement products, or construction products. Examples of these retailers are Home Product Centre—the largest urban home improvement retailer in Thailand, Home-Work operated by Siam Cement Group or SCG, and Powerbuy operated by CRC.

According to Siam Commercial Bank analysis ((SCB) 2011), these four types of modern trades have been expanding as shown in Figure 1-2.

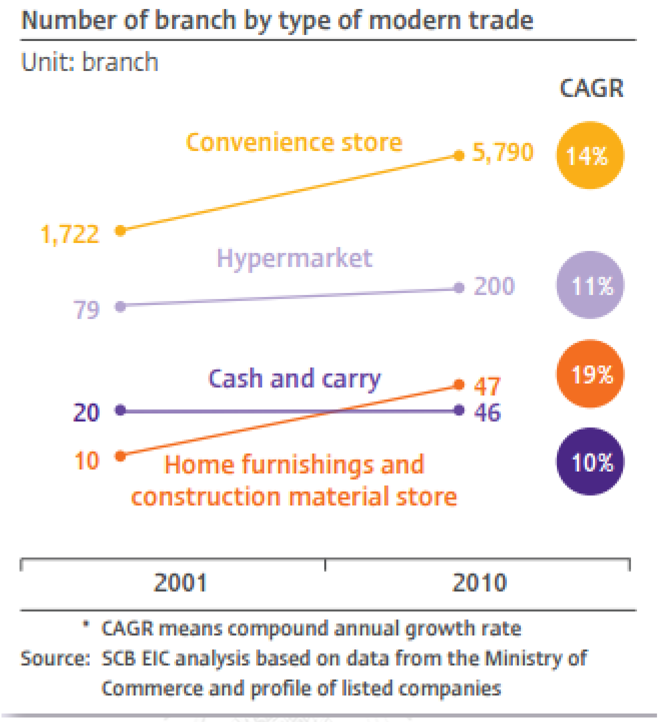


Figure 1-2: Growth of store branches grouped by type of modern trade retailers

Figure 1-2 represents growth in terms of a number of branches from year 2001 to year 2010. Overall, all types of modern trade formats experience growth during this period. In terms of a number of stores, the convenience stores expanded from 1,722 stores in 2001 to 5,790 stores in 2010. In terms of growth rate, the figure, however, reveals interesting fact, specifically the compound annual growth rate (CAGR) of the home furnishings and construction material stores. The high rate of growth is an important indicator as it implies that the industry has high growth potential and, perhaps, is in an introduction stage of its business cycle. To evaluate the previous statement, it is important to understand the business as discussed in the next subsection.

1.2 Home furnishing and construction material store

Home furnishing and construction material store, also known as home improvement retailer, purchase large quantities of products at a discounted price and retail them to consumers or subcontractors. Because of different functions and lifestyle, the retailers usually offer large varieties of products. For example: electronic appliances, furniture, ceramic tiles, and home decorators. Each branch shares similar organization as well as portfolio of products with other branches because the key business strategy is economy of scales. A new store incurs a lesser cost as it is a duplicate of the previous one. Nevertheless, the challenge and the complexity in expanding branches lay in the efficiency of its logistics operations and its distribution channels.

1.2.1 Home Improvement Distribution Channels

Despite an exponential growth of an E-Commerce channel, the home improvement retailer in Thailand, at the mean times, relies heavily on a traditional front store in which customers visit branches. The purchases of customers at a branch trigger information flows of the supply chain, as shown in Figure 1-3.

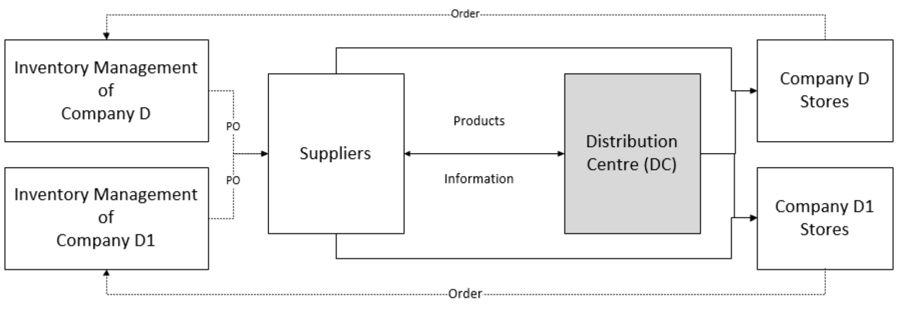


Figure 1-3: Distribution network of the case study distribution centre

Figure 1-3 shows the relationship between a case study distribution centre and its stakeholders. As the customers purchase the products below a predetermined quantity, the information system is automatically signalled orders to Inventory Management whose responsibility includes monitoring and evaluating suppliers. After collecting orders of many branches and manually reviewing ordering quantities, purchasing orders are issued to corresponding suppliers as well as informed a distribution centre so that incoming shipments can be verified and eventually distributed to store branches. Despite double handling of products, the distribution centre increases frequency of shipments and opportunities of cost saving through transportation. Without the distribution centre, shipment consolidation cannot be realized, and each supplier needs to transport its products directly to each branch.

1.2.2 Roles of Distribution network

As an indispensable part of home improvement distribution channel, the distribution centre plays an important role as it allows a company to realize economy of scales and to meet customer's expectation in terms of efficiency and responsiveness. The distribution centre improves the efficiency of supply chain by serving as a temporary destination of suppliers and as a central storage that monitors quantities and qualities. Because of sharing inventory among many branches, the inventory of each product required at each branch can be substantially reduced as the distribution centre replenishes stored products to each branch. This also improves the service level as the variance of lead time can be reduced and the duration of lead time is shortened.

Despite an economic benefit, products stored in a distribution centre incur handling costs and require storage locations. Therefore, many modern trade retailers have adopted a cross-docking, a freight consolidation technique pioneered by Wal-Mart, as the best practice for distributing domestic products. Although cross-docking bypasses storage, it requires the coordination between incoming and outgoing shipments as well as manual labour to small pieces of products into different destinations. Hence, each supplier can combine products for different branches into a single incoming shipment. Once products are unloaded, they are sorted according to destination branches and combined with products from other suppliers. Eventually, products are loaded into an associated truck and shipped to a destination branch. Many practitioners view a cross-dock as a high speed warehouse or a Just-In-Time warehouse as products remain in a distribution centre less than 48 hours.

In addition to coordination and information, cross-docking typically requires many operators and labour intensive as similar to the case study distribution centre.

Cross docking practice needs to handle product in small sizes, for example, piece picking, and carton picking. These smaller units require a higher amount of workforce. Hence to serve different shapes and sizes from a group of products, manual picking is selected to gain efficiency and provide flexibility to cope with different types of products. However, the utilisation of many pickers occupying the picking area creates congestions and queues. Therefore, these blockages reduce the productivity of an operation. An example is shown in Figure 1-4- a case studied company (Company DC), which operates manual order picking.

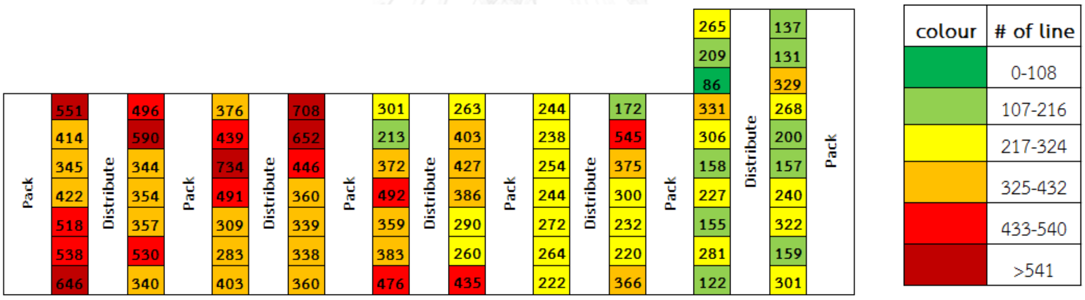


Figure 1-4: Thermal map of a day in distributed area

Figure 1-4, a top view of an order picking area, represents the thermal map of a distributed area in Company DC. Each box in a figure is a store destination for a picker to walk and drop products. Values in boxes represent the number of visits which a picker needs to arrive. Therefore, a higher number of visits result in heavy congestion in that area. The colour is highlighted according to the number of visits to each destination. A poorly managed layout and policies causes blockages in aisles. In this case, it occurs on the left side. The blockage is, now, the major reason of the decrease in efficiency of the pickers in an area. The Company DC expects to have better labour efficiency with a 30 lines per man-hour.

1.2.3 Line per man-hour

In brief, the term “line” is used to represent the workload inside an operation. One line can refer to one work done. Therefore, line can be used as the measurement in term of output done in the operation system. Example of “line” measurement is stated in Chapter 2: Literature Review. In manual operations (especially cross-docking practice), one of the measurements to track the labour performance is by using the number of lines done in the area related to the number of man-hour needed in that area (line per man-hour). Line per man-hour is often used for measuring the labour efficiency in an intense area (distributed area).

1.3 Statement of Problem

Due to the increases of flow through products and limited space, the case study distribution centre has emphasis on the efficiency of flow through operation as it primarily contributes to productivity of the distribution centre. The problem analysis of labour intensity suggests that congestions in the flow through operations can be improved by a new layout of assigned stores and a new direction of traffic flows. This improvement could reduce travelling distance and the distributing time.

This thesis studies one of distribution centres of the home improvement retailers- named Company DC. The studies show that the distributing area in the cross-docking operation needs to be improved. By using data collected of four months, the study cased company (Company DC) has a 28.46 line per man-hour. Details of company background are described in Chapter 3: Cased Studied Company. With collected data and observations, it shows the congestions and long lead-time in distributing process. Improvements can be done by re-designing the layout and policies in the distributed area.

According to the policies, Company DC’s direction is aimed to increase the volume of Flow Through products due to cost saving (compared with the storage type products). Moreover, based on the characteristics of the FT (S&M), it has more room to improve and is preferable in the Company DC's perspective. Hence, this thesis focuses on the Flow through activity, emphasized only on small and medium size products, in the DC in order to cope with the company's trend and future plans. The problem will be discussed more in Chapter 4: problem analysis.

1.4 Objective:

Re-design the layout and operations of the flow through activities in the case study distribution centre to improve line/man-hour as a labour efficiency measurement.

1.5 Scope

This newly designed operation is focused on the re-design of the layouts in the cross-docking area, which includes the design for receiving articles area, picking process, and packing process until pallets are pending in the shipping area. However, the inventory management and ordering system cannot be controlled, this is because the Company DC is receiving policies to serve for a holding company. Therefore, controlling received product or scheduling is not possible in this case.

Moreover, the scope excludes the shipping area because the transportation process is planned in waves for cost saving by the full truck load policies. Therefore, the measurement of this proposal will be tracked until the pallet is ready to be transferred into the transporting area.

This proposal is focused on the improvement of productivity in the flow through process of the studied distribution centre, where each article is different in dimensions and weight. However, the improvements and research studies are tested by computer simulation. Therefore, it should be assumed that the measurement of activities in one line will be equal in each article. Hence, the measurement of this proposal will be the improvement of productivity in line/man-hour.

Even though the scenarios in computer simulation runs with certain cases, this thesis is focused on concluding the result into one solution for applying and implementing changes for future distributing areas.

Moreover, studying the improvement will be done by using the concepts from theories and literatures, no new equipment or material handling will be newly introduced. This means excluding introduction of new material handling, employees, IT system, receiving and transporting policies.

1.6 Expected outcome

The current line per man-hour is 28.46. The new proposed layout should increase the labour efficiency.

1.7 Methodology

Table 1-1:Framework and proposed methodology

	Step	Tools Used	Thesis methodology
1	Definin system requirements	Checkilist, literatures	Identify objectives, refer to literatures and books
2	Define and obtain data	Flow charts, data	DC's flowchart process, and data
3	Analyse data	database model, flowchart	warehouse profiling(line/order, thermal map, and boxplot)
4	Establish unit loads to be used	Sureeys from existing operations, simulations	Made assumptions and collect data for simulations
5	Determine operating procedures	Use framework to understand high level procedures	collect data in the fields and cross check with work instruction
6	Consider possivle equipment types	Analytic and simulation and method	Set up scenario for simulations
7	Calculate equipment capacities	Historic performance measure, analytic on simulations	-
8	Define services and ancillary operat	** not necessary	-
9	Prepare possible layouts	CAD layout, warehouse relationship chart	Drawn proposed layout and chart refer to the layouts
#	Evaluate and assess	Simulation software	Validate and run simulations
#	Identify prefered design	No specific process	Summary all proposed design and find the best practice.

Table 1-1 is the framework from (Baker and Canessa 2009), the first two columns show steps and tools used in many literatures and researches. On the right column is the adapted methodology of the author for this thesis. The procedure is adjusted to be approachable within the scope and limitation of the topic.

2 Literature Review

2.1 Concepts of Flow Through in DC

In the supply chain network, Flow through or, also known as Cross docking operation, can be considered as one of the practices to improve the productivity of warehouse by using transferring products directly from receiving area to shipping area with a minimal transit time and storage procedure in the process (Frazelle 2001). With the practice of flow through strategy, it could benefit distribution centre in many ways. For example, retail organizations consider flow through to be one of the core competencies of the organization for cost reduction and enhance customer satisfaction (Bartholdi and Gue 2004). In addition, another advantage of cross-docking practice is to control the inventory size by maintaining the fluctuation, which can lead to prevent bull-whip effect (Daganzo 2005). However, it is a trade-off between inventories in a distribution centre and inventory in the store(Waller, Cassady et al. 2006). The concept of flow through can be illustrated in Figure 2-1.

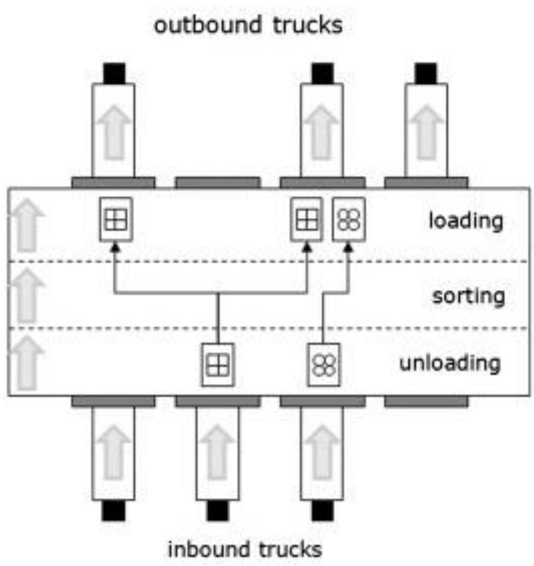


Figure 2-1: Concept of Flow Through operation (Boysen and Fliedner 2010).

Figure 2-1 represents the concept flow of Flow Through. Many literatures may have minor differences from this figure, however the basic operations consist of three main procedures: receiving, sorting (some literature may state order picking), and shipping (Agustina, Lee et al. 2014). First, it begins with products are arrived at the inbound docks, where products are received (physically, and digitally registered). Then products are unpacked and sorted by destinations. Lastly, products are shipped out of a distribution centre (Boysen and Fliedner 2010). More details of the cross-docking practice and concerns can be found in (Napolitano 2000).

In addition, the above figure demonstrates the line activity in DC's operation. On incoming pallet in the unloading area can be divided into one or more lines, depends on the store destination. For example, a circle product has one line because it is directly transferred to shipping area. In contrast, the square is divided into two lines in an operation due to difference in store destination.

The entire cross-docking activities are typically completed within 48 hours after presence of an incoming shipment at a DC. The inbound and outbound are studied by (Yu and Egbelu 2008), who use MIP model and suggested a heuristic method to control the inbound and outbound transportation. An extended research is conducted by (Chen and Song 2009), with the use of multiple incoming trucks and suggested several heuristics to manage the scheduling instead. Beside freight consolidation, the practice requires minimal footprint as a little or no storage area is needed and significantly increases shipping frequency as well as truck utilization. Despite a short transit time compared with a conventional warehouse, cross-docking typically demands reliable and constant steams of information.

2.2 Order picking in flow through practice.

Even through flow through brings organizations to gain advantages, the practice are challenging in many ways as well. The area, which is the most challenging, is in the order picking area. The orders picking activity is identified as retrieve and deliver a product to another destination. For flow through practice, an area is provided for sorting activity to be used. Each area can represent different destination for the shipping area. Many company and academic literatures are focusing on order picking area because of failure in this section might lead to high operational cost, and poor productivity (De Koster, Le-Duc et al. 2007).

Currently, order picking methods can be categorised into two main methods: human operations or machines. This thesis focus on the human employing methods since it is related purely on the cased study company. The details are as follows:

- Pick by order or Discrete Order picking: This is the most basic type of order picking policies. One picker picks one order line at a time. Since, the operations are in shifts, pickers are allowed to pick any product at any time. Advantages from this method are: it is easy to understand and implement with paper based or handheld devices. However, this method has the least efficiency.
- Batch picking: Similar to discrete picking, but a picker picks a batch of products instead. This allows multiple products to be picked and transported into the same destination at the same time. An advantage of this is to reduce travel distance.
- Zone picking: This method divides the warehouse area into sections and arranges pickers in each area. A picker only responsible only in his/her zone(s). Advantage of zone picking is to avoid confusion.

(De Koster, Le-Duc et al. 2007)listed the details of order picking activities in Figure 2-2.

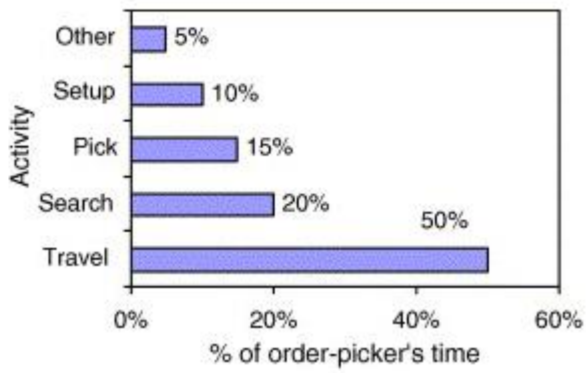


Figure 2-2: Average time usage of a picker in order picking operation.

Figure 2-2 represents the distribution of time in an average percent used by a picker in an order picking activity. With this data, mostly the best way to improve the efficiency of manual order picking activity is by reducing the time for travelling (50%). Time travelling is created by travelling distance and congestions. (Frazelle 2001) suggests a pick location and picker should be located near each other to reduce travelling distance. Literatures have shown that the way to improve travel time is by improving the layout and policies to suit with the operation and flow of each individual distribution centre

2.3 Labour intensity

In a manual warehouse system, an order picking area is the most labour intensive area. This is because it requires labours or pickers to contribute work and transfer products. Researches in cross docking field usually focus on the reduction of labour cost. For example: (Bartholdi III and Gue 2000). This is because order picking activity of cross docking practice is the most labour consumption. However, from the differences in operations and unique product characteristics, there is no one single solution but a concept to approach for the best practices. These concepts have to be adopted into the distribution centre. Mostly the concerning topic are layouts and walking policies of the flow through operations.

In addition, according to (Pan and Wu 2012) the travel activity should be identified as one of the non-value added activity or, in another term, waste. This is because it consumes labour time and cost for an organization.

2.4 Layouts and operations designing

The efficiency of order picking area depends on the layout and policies settings in the distribution centre. Layout is the main effect on travel distance of a picker. A larger footprint area means the increase in travel distance. Hence, the productivity of manual picking is decreased (Thomas and Meller 2015). The relationship of cross-dock layout and incoming docks is studied and suggested by (Bartholdi and Gue 2004).

For the layout of sorting area, the concept can be relied on and adjust from the routing policies of storage operation. Since, the procedure is similar to a storage activity in terms of travelling distance concerns and effects on the designs, in term of physical flow; storing product into the storage rack is similar to placement in the sorting area of flow through.

(Vis and Roodbergen 2011), have proven that the policies and methods for storage area can be adapted and implemented into the flow through operation as well. They suggested that a fixed layout is suitable in the period of time, if layout and product does not change. However, if dealing with fluctuation of demand, the category-based is more recommended. Category based is a layout of location and products are grouped to adapt with changes. However, a picker might deal with confusion of locating stores from this method.

According to (Pan, Wu et al. 2014), they simulate different types of walking policies with different layout for storage operations. The highest yields, which they have proposed is across pick-column (AP) policy. Travelling distance is the measurement in this literature. The policy arranges the highest frequency item in the lowest and nearest location, which allows a picker to pick easily. Then arrange the next highest frequency to the next location and so on. The simulations are based on three different types of routing policies. The results are shown in Figure 2-3.

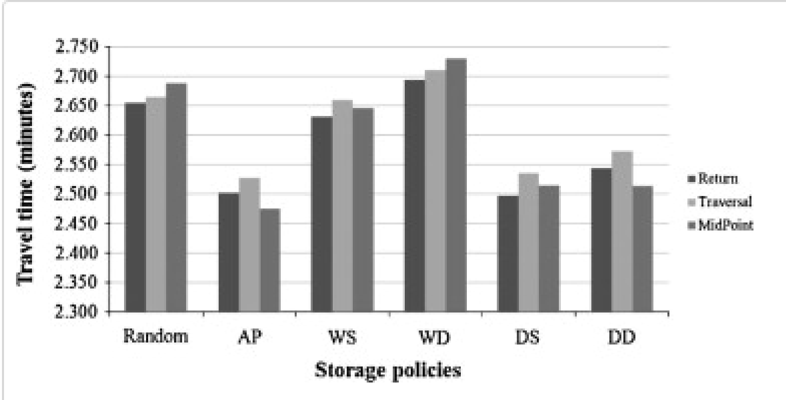


Figure 2-3: Results using different type of layout by (Pan, Wu et al. 2014).

Figure 2-3 shows that AP in all three types of walking policies are the most effective storage by measuring the travel distance. The three walking policies are returning policy, traversal policy, and mid-point policy.

The main point of three walking policies related to the thesis is that it can represents different types of walking policies that also similar to walking in the sorting area. The concept of adapting the AP storage policies with sorting area of flow through is explained in Chapter 6.

Literature from (De Koster, Le-Duc et al. 2007), have reviewed six different types of routing methods.(see Figure 2-4)

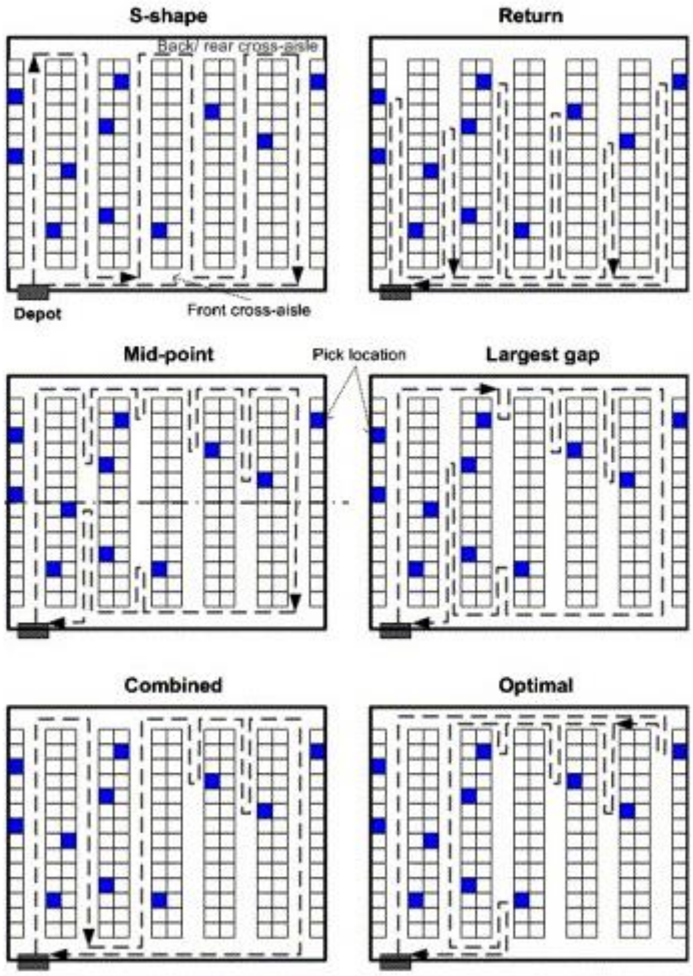


Figure 2-4: Different routing methods for storage warehouse (De Koster, Le-Duc et al. 2007).

Figure 2-4 illustrated the different methods of routing that can be implemented for the distribution centre. S-shape routing is one of the most conventional methods. If a product needs to visit any position in that aisle, a picker needs to walk the whole aisle. The other five routing types are the concepts of how to reduce the travelling distance. It can be by visit that position and return to the fixed area(Return), walk regarding the mid-point to always walk in the short distance(Mid-point), considering largest gap in walking (largest gap), combine or optimal is where the decision is more complex and needed picker to decide for himself. The limitation of these different types of routing concept is that the SKUs need to be a few in each walk or else each different type of routing would not be benefit much to a picker. Moreover, to optimize the travel distance, the high frequency in visiting stores should locate near the front of an aisle.

2.5 Effect of congestions

Congestions happen when many pickers are blocked in the same aisle. Congestion can slow a picker inside the warehouse. The reduction in travel distance can results in lower in congestion, which leads to lowering the overall efficiency inside the warehouse activity. Research from (Pan and Wu 2012), demonstrated how the congestion and throughput are related. Although congestion and performances are related, but the function between these two are different in each distribution centre due to the unique characteristics of each DC. Therefore, the function of congestion and speed has to be based on assumptions or from collected data of cased study distribution centre.

Another type of congestion take place due to many different products needs to go into same store at the same time. Queue happens because the store can be occupied by one picker at a time. This is called staging queue. It creates a queue in an aisle. Research from (Gue and Kang 2001), shows that the performances and delays cause by single and doubling staging area are different. Single staging is more preferable. In addition, an increase in number for short queues is recommended than a fewer in number of long queue.

Results from (Pan and Wu 2012), the congestion in their study conditions are shown in Figure 2-5.

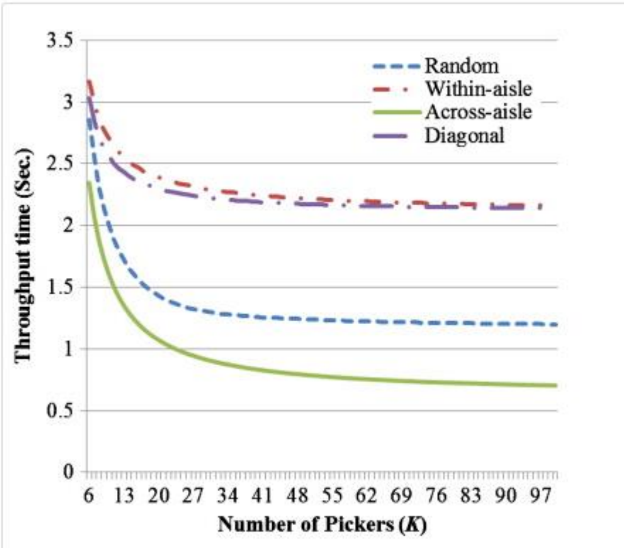


Figure 2-5: Average throughput of different walking policies varied with congestion in an aisle (Pan and Wu 2012).

Figure 2-5 represents the change of throughput in seconds related by the number of pickers in an aisle. The reduction in productivity is caused by an increment of congestion in an aisle. The literature explained the scenario of pickers exceeding the capacity of an aisle, which excessive pickers need to wait outside an aisle for an available space. The maximum setting of this simulation is 30 pickers. This is why after 30 pickers the throughput tends to go toward one value.

2.6 Computer Simulation

In Practical, implementation is the best way to see the whole process especially the new introduced operations. It is also helps operator to see and learn through the implementation. This is because the operators and managers and see the whole picture. However, implementation consumes times and resources. Which some cases, the cost of failure might not be acceptable for the experimental implementation. Therefore, in certain cases, partially implementation or a scale down experiment can be done, instead, to reduce the cost and risk to failure.

Computer simulation is another alternative to generate similar environment and condition then measure the differences between the new concept and the actual operations. This is the suitable solution for this academic work, due to the conditions and historical data that can be controlled and we can measure the differences between them. Even through, the computer simulation takes time for collecting data to generate the simulation, but the time and resources needed are much shorter than the implement ones.

Besides of collecting data, some assumptions have to be made to allow gaps between simulation and actual operation. These assumptions are the key to see the conditions and limitations between actual and theoretical ones. Literature from (Pan and Wu 2012) have use computer simulation to study the throughput or order picking system. These are their assumptions:

- Each item is independent to each other
- All information is fixed
- Picker efficiency is constant (walking time, and picking time)

Information which the computer simulation data is related are picking time, walking time, speed of the picker, number of aisles, racks, and speed of pickers.

2.6.1 ANOVA test

The one-way analysis of variance (ANOVA) is used to determine the similarity of two data sets, in term of statistically significant differences. Fundamentally, the null hypothesis is shown below:

$$H_0: \mu_1 = \mu_2 = \mu_3 = \cdots = \mu_k$$

Given the significant level to be one value, if P-value is below the given value, the null hypothesis is rejected. This significant value can be different in each test. For example, the significant value is 0.05 or 0.025.

3 Case Study Company

3.1 Organization Overview

The case study company or Company DC is one subsidiaries of Company D that has organisation structure, as shown in Figure 3-1.

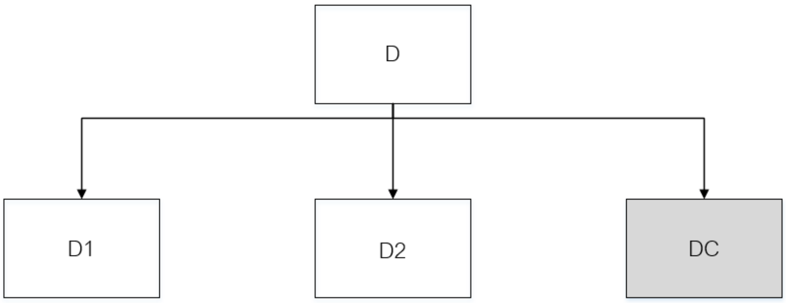


Figure 3-1: Organization structure of the holding group

In Figure 3-1, Company D is a holding company that consists of three subsidiaries. Particularly Company D1, Company D2, as Company DC as another format retailer, a facility manager, and a logistics provider, respectively.

3.1.1 Company D

The main business of Company D is in retail business of home improvement products through stores and e-commerce. Despite the sale of private labels, Company D does not manufacture product. It, rather, has purchased large quantities of merchandises and asked its suppliers to put its own private labels. At the time of writing, Company D has more than 70 stores located in major cities of Thailand as well as stores located aboard. The target customers are home owners who want to improve or renovate their house or garden.

3.1.2 Company D1

As a subsidiary of Company D, Company D1 retails constructions and house improvement products with different store format targeted contractors and builders. At the time of writing, less than ten outlets of Company D1 are operated across Thailand. Despite the different segment in the market, Company D and Company D1 share some common products that also service by Company DC.

3.1.3 Company D2

Because of available space for rental at outlets of Company D and Company D1, Company D2 has served as a third party company responsible for managing available space and providing facilities to attract more customers.

3.1.4 Company DC

Company DC, the last company and the focus of this document, is a logistic provider company operating a distribution centre for both Company D and Company D1. It receives products from suppliers, consolidates, and distributes to each store. Company DC also serve as a gateway for returning products from stores back to suppliers on behalf of Company D and Company D1. Before the operational detail of Company DC, it is important to understand information flow between this holding group, as shown in in Figure 3-2.

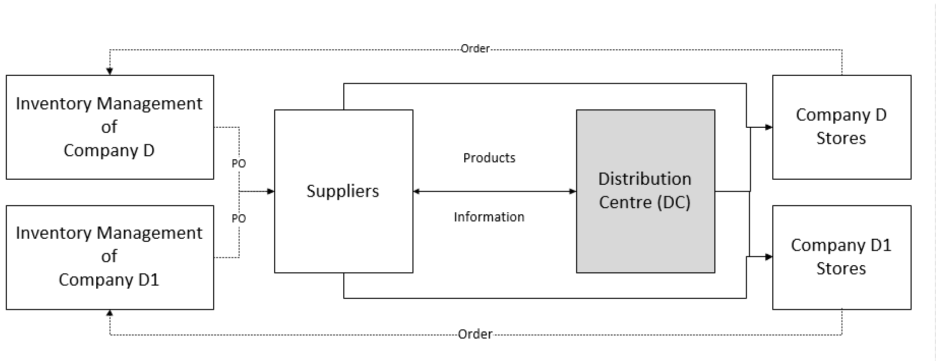


Figure 3-2: Schemetic diagram of information flow

Figure 3-2 represents the inflow and outflow product (in black) and information (in dotted) throughout the Company DC as a distribution centre. The flow starts when customers pay for regular shelf products or order special items at a store. The computer system tracks quantity and send information to the Inventory Management of respected retailers. Once, any product reaches its designed minimal level or triggers a special order. IM consolidates those orders from every store and submits a purchasing order (PO) to corresponding suppliers as well as Company DC.

To deliver products, suppliers make shipping appointments at Company DC. This triggers Company DC to reserve unloading docks and schedule crew for inspection and receiving product. At the appointed date and time, products are inspected, packed, consolidated, wrapped, transported to each corresponding store via trucks owned by external transportation companies. This transportation practice not only allow Company DC to focus on its core mission, but also benefits bottom line as it allows for back-haul to further reduce transportation cost and balance transportation flow. Transportation trucks may be varied depending on number of pallets, route, destination, and regulation. For example, 18-wheel trucks are not allowed for an inner Bangkok during weekday. To balance between incoming shipments and outgoing shipments as well as maximise docks, Company DC operate a 24 hours with three shipping waves: 08:00, 16:00, and 00:00 every day. Each wave is strictly controlled to ensure precise delivery time at stores. In addition to a regular delivery to stores of Company D and Company D1, Company DC also provides warehousing storage service for home delivery unit that ships a huge products, for example refrigerators or furniture. At the time of writing, this service accounts approximately 10 percent of the total shipping volume.

Because the relationship between IM and company DC is paramount to operation and central to this thesis, it is important to highlight and explain the collaboration and conflict of these two parties in detail.

3.1.5 Relationship between IM and Company DC

As an internal department of Company D and Company D1, IMs manage and issue PO to suppliers on their behalf. Because of the fluctuation of demand and large number of SKUs, numbers of POs are typically varied throughout the year. Furthermore, both companies have actively pursued strategic purchasing, a decision to purchasing large quantities of product because of financial and marketing benefits. For example, a supplier may offer longer credit terms when purchasing expensive home appliances in large quantities that both companies can undercut their competitors in terms of price and promotion. In addition to strategic decision, the surge in inventory is also derived from the nature of business, such as seasonality of home improvement products, long transportation lead time, and frequent promotion. These factors affect inventories at stores as well as stock items at Company DC.

Despite such relationship, Company DC is a logistic service provider and has no control over total volumes and product types. In the Company DC view, it treated IM as customer and response as requested. Company DC can, however, negotiate receiving schedule with suppliers. To some extent, Company DC offers a fixed schedule and a dock some suppliers who delivery products on time and comply with its policy. Nevertheless, some local ceramic suppliers request a large receiving area more than eight hours to inspect and re-palletise.

3.1.6 Expectation of Company D to Company DC

As its main customer and main shareholder, Company D translates its expectation into Key Performance Indicators (KPIs) such as on-time delivery, ship accuracy, lead time, and inventory turnover to ensure end to end service and to maintain the customer satisfactions.

The trend of e-Commerce and multi-channel distribution put another pressure to Company DC to pool the excess inventory at a warehouse as central location. From the pressure form such channel Company DC must reduce lead time and improve delivery precision.

Having reviewed business relationship and roles of Company DC, the detail operation is the focused of following sub-section.

3.2 Background of Company DC.

Located 70.0 kilometres north of Bangkok, Company DC has served as a consolidation point for domestic freight and a warehousing facility for imported freight since 2004. Its location provides a quick access to suburban Bangkok stores as well as of stores located in major cities across Thailand as incoming trucks can delivery without zone restriction and outgoing trucks can detour the congested Bangkok metropolitan, as shown in Figure 3-3.

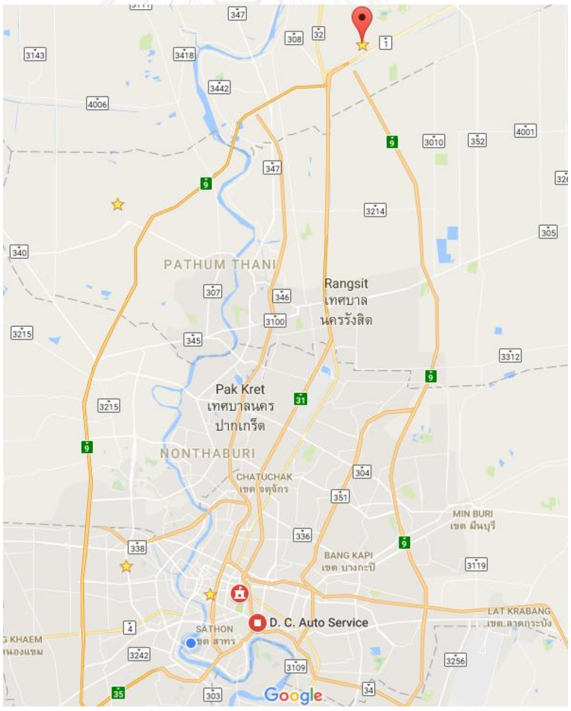


Figure 3-3: Location of Company DC(pinned in the map) from the central of Bangkok

At the time of writing, Company DC manages approximately 90 percent of products by total value. Examples of such products are bathroom, sanitary ware, kitchen and home appliances, electronics, furniture, and decorative goods. The reminding 10 percent is by passed and shipped directly from domestic suppliers to stores. In terms of SKUs, Company DC currently handles approximate 60,000 SKUs, which composed of 40,000 SKUs of regular products and 20,000 SKUs seasonal products. Company DC divides products based on operation into two main groups:.

- Put-Away product or Stock items
- Flow-Through products or Cross-docking items

3.2.1 Put-Away Products

Put-Away products are merchandises stored at Company DC because of their long lead time and/or economy of scale. Althrough this group accounts for 40 percent of total shipped, it requires a large plot of storage space. Majority of put-away products are imported items such as ceramic tiles and kitchenware, large and bulky item such as furniture and refrigerators, and home appliance such as televisions.

3.2.2 Flow-Through Product:

Flow-Through products are merchandises that Company D decides not to stock at Company DC, but orders regularly in smaller quantity. Because of opposite characteristics, majority of flow-through products are domestic items that have a short lead time and are available to deliver as soon as IM orders. Currently, flow-through products account for 60 percent of total value, and Company DC handles this group manually. As a result, the group is further divided into two types based on physical dimension of products

- Small-and-Medium size flow through products or FT(S&M) such as screwdrivers

- Large size flow through products or FT(L) such as windows frame and folding tables

In the past, Company DC separated and sorted small size products and medium size products separately. However, its managers decided to combine the operation because of small shipping volume and congesting in packing area. The combination also reduced number of pickers and sorters required. The statics summarised condition of products is available in Table 3-1.

Table 3-1: Details of each type of products.

	SKUs	Lines per month	Examples of products	Sample pictures
FT(S&M)	27,654	448,152	Screws, Showers, Door knobs, Small decorations, Electric Drills, Light bulbs.	
FT(L)	11,530	127,378	Paints, doors, windows frame, Folding tables, Metal sheets.	
Put Away	21,723	350,366	Televisions, Ceramics, Refrigerators, Electronics, etc.	
Total	60,907	925,896		

Table 3-1 provides important statistic of each product group, particularly number of SKUs and lines per month. The majority of lines per order derive from FT(S&M) because they are regularly sold. This fact supports our interests in its layout and its operation of FT(S&M).

3.3 Layout and Material Equipment of Company DC

Company DC started its operation from a single building, namely DC 1, and continue to expand by constructing additional building. At the time of writing, Company DC comprises of six building with approximately 136,500 sq.m of area, as shown in Figure 3-4.

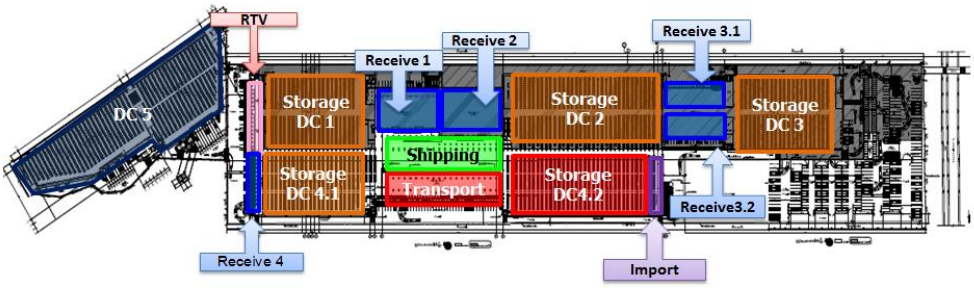


Figure 3-4 Layout of Company DC

With exception of newly constructed DC 5, other buildings are connected with one other with similar, if not identical, construction structure. These connected buildings allow smooth traffic and operation as well as sharing docks and material handling equipment. DC 5 is constructed in isolation of other buildings because of different land plot. It is divided into different areas based on their function, particularly

- Receiving Area
- Storage Area
- Shipping and Transportation Area
- Return-to-Vendor Area

3.3.1 Receiving Area

Althrough Company DC has many receiving docks, products are specified to each receiving dock to minimise traveling distance and reduce congestion. For example, Receive 3.1 area and Receive 3.2 area are designed to receive product that are stored in DC 3. It should be noted that Receive 2 area is designed for both put-away product that are stored in DC 2 as well as flow-through products operating nearby because both products may be delivered by the same suppliers. Receiving crews can distinguish each type by tag number corresponding to PO.

3.3.2 Storage Area

In a distribution centre, one of important area is a storage area as it is designed to keep products safe and secure as well as accounts for majority of area. In Company DC, the storage area are divided based on products and named after their buildings, as shown in Table 3-2.

Table 3-2: Details of storage area

Storage Code	Area (sq. m.)	Pallet Position	Examples of Product
DC.1	19,260	17,000	Refrigerator, Television, Electronics.
DC.2	25,380	25,000	Small part of bathroom sanitary, microwaves
DC.3	20,070	17,000	Import bathroom sanitary, office equipment
DC 4.1	23,488	13,000	Air condition, refrigerators.
DC 4.2	26,934	14,000	Local Ceramics
DC 5	21,560	28,000	Import Ceramics

In Table 3-2, all of these storage areas are equipped with single deep pallet rack that allows easy access to any available positions. Because of different products, the profile of each storage area is also difference. For example DC 1 and DC 4.1 are designed to keep home application, including tall refrigerators. As a result, the first level of these racks is 2.0 meters in height, whereas the first level in other storage area is 1.6 meters in height.

3.3.3 Shipping and Transport Area

After picking activity, all products are transported to the shipping and transport area. The connected buildings allow the sharing of shipping and transport area with one another, while DC 5 building has its own two isolated docks for ceramic tiles. Products are re-palletised to a specific height at the shipping area and must remain in the transport area until corresponding trucks departed the docks.

3.3.4 Return to Vendor (RTV) Area

Because returning is unavoidable in a modern retail business, Company DC dedicates an area near DC 1 for returning products. RTV products include damaged goods and repositioning products.

3.3.5 Material Handling Equipment.

Material handling equipment plays important role to transport and identify product, especially in a manual operating distribution centre similar to Company DC. This equipment is controlled by maintenance department and listed in Table 3-3.

Table 3-3: Lists of material handling equipment available in Company DC

Name	Quantity	Function	Image of the equipment
Reach Truck	61	For high location storage.	
Power pallet truck	96	Allocate pallet in every part of DC	
Hand Pallet	35	Distribution and pick face area.	
Fork Lift	8	Loading and unloading ceramics	
Handheld RF terminal	150	In Picking process.	

These areas and equipment are interacted together through an activity as described in the next section.

3.4 Overall Activities in Company DC

Overall activities in Company DC starts when a supplier receives a timeslot and ends when a pallet leaves an outgoing dock, as shown in Figure 3-5.

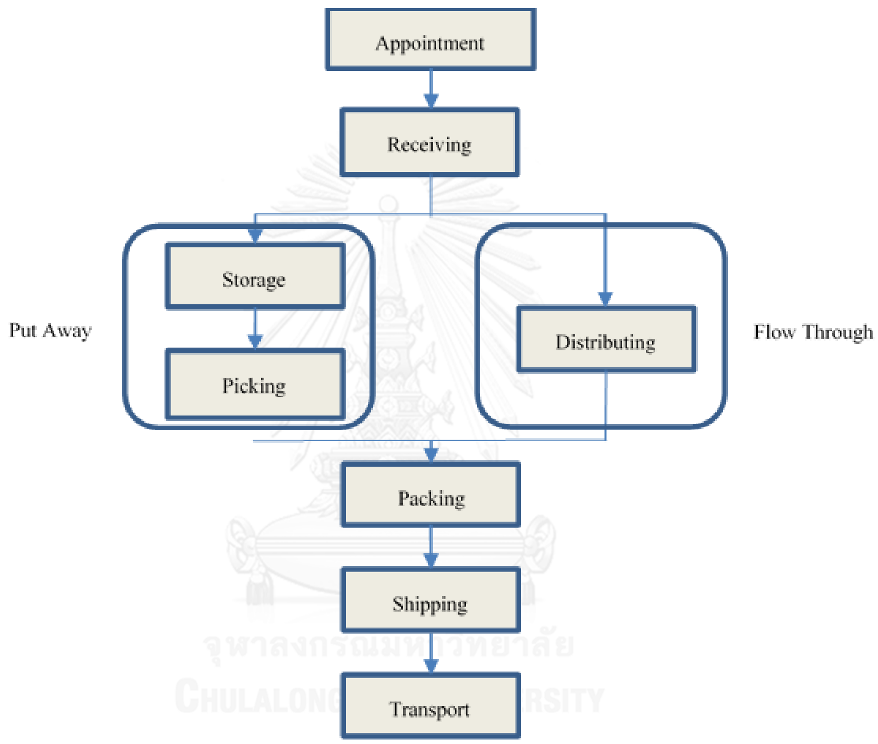


Figure 3-5: Main process flow inside the Company DC

In Figure 3-5, put away products and flow-through products share thr similar activities until receiving and after packing. The difference in activities occurs because flow-through products must be distributed after receiving, but put away products must be stored until retrieved orders arrives. These similar activities are described below:

:

- **Appointment** is an activity in which starts at the retail stores. As mentioned earlier, Company D and Company DC purchase products and hire Company DC to process, store, consolidate, and transport their products. Once purchasing orders are released for IM to suppliers, Company DC also receives copies of such orders and uses them as reference when corresponding suppliers make appointment date and time for delivery.
- **Receiving** is an activity that is occurred when a supplier arrives to Company DC. Once a truck arrives at the gate of Company DC, a driver must submit the delivery form and show the PO order. The truck is then inspected in the front area before entering the DC. This is for controlling the inbound and outbound of Company DC. To minimise travelling distance, Company DC, in general, specifics unloading docks of each product family. Supplier is responsible for unloading products and placing on pallets. After palletising, a receiving team of Company DC process physical counting quantity and visual; inspecting quality.
- **Flow through/ Put Away** are activities that correspond to flow-through products and put-way products, respectively. They are different greatly and, thus, deserve detail discussion in next sections.
- **Packing** is an activity that combines products from many storage and zone together according to final destination. Some small products may be placed

into plastic totes, other fragile products may put into a special wooden container to protect during transportation. Nevertheless, a combined shipping pallet must be wrapped with plastic film so that each pallet reaches a specific height suitable for loading into trucks as well as for maintaining the shape during transportation. During the typical packing activity, flow-through products are consolidated with other flow-through product, whereas put-away products are palletized separately because the packing staging areas are difference as well as the practice help to avoid confusion. The wrapped pallets are, then, moved the shipping process.

- **Shipping** is an act of waiting and accumulating wrapped pallets for shipping. It is a critical policy of Company DC that an outgoing truck must be full truck load because the company incurs transportation cost. During this process, flow-through products and put-away products that share same destination are accumulated at the shipping staging area next to the dock corresponding to a store. The shipping schedule is divided into three waves based on regions of stores.
- **Transporting** is an activity that Company DC outsources to logistics providers but has direct responsibility both financially and physically. Transportation trucks may be varied depending on pallets and available equipment at the final destination as well as regulation.

Company DC employs more 1,000 people of full time worker and part time workers and operates three shifts a day: 06:00-15:00, 14:00-23:00, and 22:00-07:00.

3.5 Put-Away Procedure.

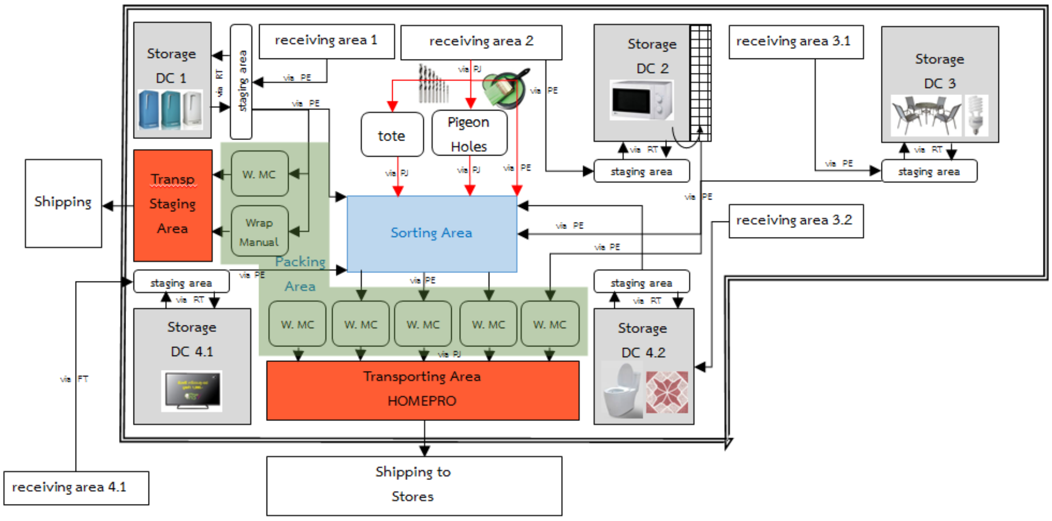


Figure 3-6: Layout and procedure of put-away products in Company DC

From the Figure 3-6, shows a brief overall layout as well as corresponding products in the main connected DC colored areas. In the figure, it represents different operations and functions in the DC, whereas arrows show the movement of the physical products. The red area represents the transporting area, where palletized products are staged before shipping. The blue area represents the storage area. The white areas are the buffer area reserved for placed pallets on DC floor before storage to positions.

The figure also shownท two transportation area with used for particular destination regardless storage type. However, “Shipping to DS” is a special transportation area reserved for shipments directly to customer’s houses, while other shipments are transported to the transporting area in the bottom part of the building. This separation helps to simplified operations and avoids mistakes.

The black arrows represent the movement of Put Away products that are retreated from rack storage and accumulated before manually wrapped by wrapping machine (W.MC). On the other hand, Flow through product flows is represented by the red arrow and explained in the next section.

3.6 Flow-Through Procedure

Flow through procedure is at the forefront of their DC and also the main focus of this thesis. Therefore, it is worth to elaborate the procedure in details, as shown in Figure 3-7.

3.6.1 Process flow chart

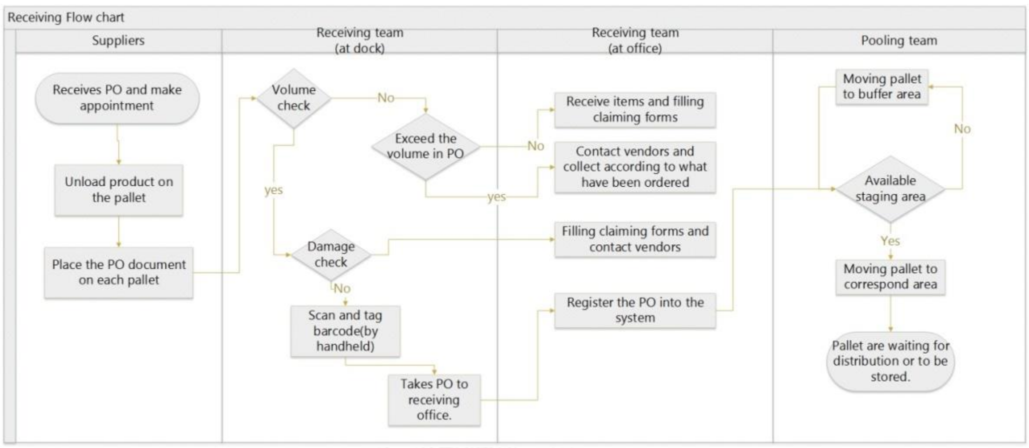


Figure 3-7: Receiving procedure of flow-through products

Figure 3-7 separate receiving operations by title of employee whom are responsible in receiving area.

Having parked at the receiving dock, a supplier people unloads products and places on a pallet. Usually there are two or more suppliers in a truck to help in unloading. Product will, then, be unloaded according to the PO number, which is a purchasing order from the Inventory management team. The PO is then put on top of each pallet and waits for inspection by receiving team.

Once all the receiving team check quality and quantity of products, products are unloaded to avoid confusion and make mistakes. If there is no issue, the team scans a tag to confirm for quantity and triggers next operation. However, if the quality and/or quantity are in correct, the administrative is required to file claims and inform suppliers.

Later on, the pooling team with power electric equipment will clear the receiving area by using power electric truck to transport those pallets to the buffer area.

3.6.2 Operation and Distributed area

As stated in section above, the flow through products are grouped by operation into FT (S&M) and FT (L). Because of its incoming volume, the focus of this thesis is on the operation and distribution of FT(S&M). Current layout with process flow is drawn in the Figure 3-8.

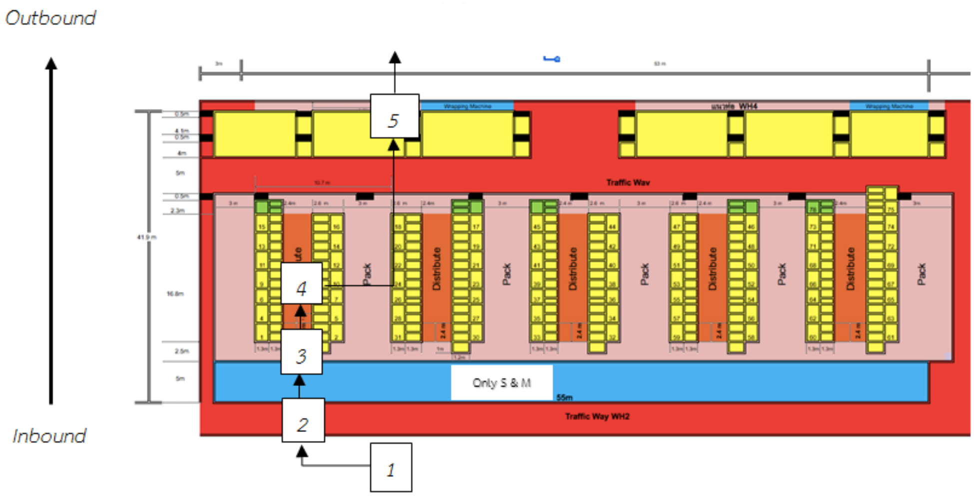


Figure 3-8 Layout of flow-through area

Figure 3-8 is the layout of current distributed area that consists of of 41.9 metres wide and 56 metres long. Red area, it is in the Receive 2 area. The columns of yellow boxes represent the pigeon holes. Red area with labelled is an area for pickers to walk and place item into pigeon holes. The pack area is an area for packing and allocated packed pallet to the wrapping machine.

Area 1

Area 1 or Receiving area is where the flow through products are unloaded from a supplier truck. Once it is received through the receiving procedures, pallets will then transported to Area 2.

Area 2

Area 2 or Flow Through buffer area is for all FT products (S&M, L sizes) to be waited. This is because, in peak time, the distribution area is run out of free space; this is why it requires buffer area. All flow through pallets wait in this area until there is a space in the area 3. A pallet is allocated into Area 3 by power electric (PE). The reason for this area to be used is because in certain time, there is not enough man power to distribute the merchandizes into the pigeon hole. In order to prevent the blockage issue in front of the receiving dock, all merchandizes need to be transported elsewhere.

Area 3

Area 3 is a waiting area for a pallet ready to be distributed match with an available picker. In this area, a pallet is scanned for the information in each pallet by a handheld given to each picker. With this handheld, a picker is able to identify and collect data of the picked product. This handheld shows quantity and consolidates store's destination for all articles placed on that pallet.

Area 4

Area 4 or the From the FT layout figure, the small boxes represent stores. Each store is a pigeon hole with the same dimension, where it is use to separate the destination of FT product. The main purpose of pigeon hole is to temporary staging products for consolidating them into a pallet with desirable height and stable platform.

In the DC, each box is separated by the metal partition and labelled the name of the store. The arrangement of each store is based on the date, which that store is officially open. For example, the store1 is opened before store 2 and 4. For store that has been closed, the pigeon hole will be eliminated like store 3. The picking process is done by a team of employee in each shift. Since there are many stores and many SKU's, the picker needs to walk around every aisle. In other word, this process is done manually. For example, product A is ordered from store 1, store 41, and store 50. Employees need to walk to each store. Once finished, they have to walk to the distribution area to pick a new product to delivery to each store again.

When picker arrives, he need to scan articles belong to that store and drop items into the pigeon hole. Then picker will scan the store barcode to confirm and match the items with the store. Handheld will automatically shows the next store, which picker need to go. This procedure will continue until all the items on that pallet is empty or in these scenarios: still left with undistributed items or not enough items to distribute. In these cases, the picker need to re-check with distributed items in previous stores and report to the manager. Once the volume of the product in the pigeon hole is able to be consolidated into a pallet, the pallet are packed and loosely wrapped. The packing team use items in the store to build into one pallet with the height of 2.1 metres above ground then moved a pallet to Area 5.

Area 5

Area 5 is where warping machines are installed. This is for saving space and cost in the shipments. After delivery the loosely wrapped pallet on the wrapping machine, wrapping team will wrap and print out the pallet ID to identify the pallet into the IT system. This pallet ID will help Company DC to keep track and manage each pallet to delivery to customers on time.

Beyond area, the pallets of FT products are merging with Put Away pallet. The shipping and transporting area are shared between both types of products. The pallet will wait for these two circumstances; fully loaded truck, and available route to that store. Full truck load is very important as a logistics provider, because it is the optimum cost for transportation. There are three waves every day, so pallets are transported according to those waves.

To Summarize the Flow Through process, the procedures of Flow-through products are drawn in Figure 3-9.

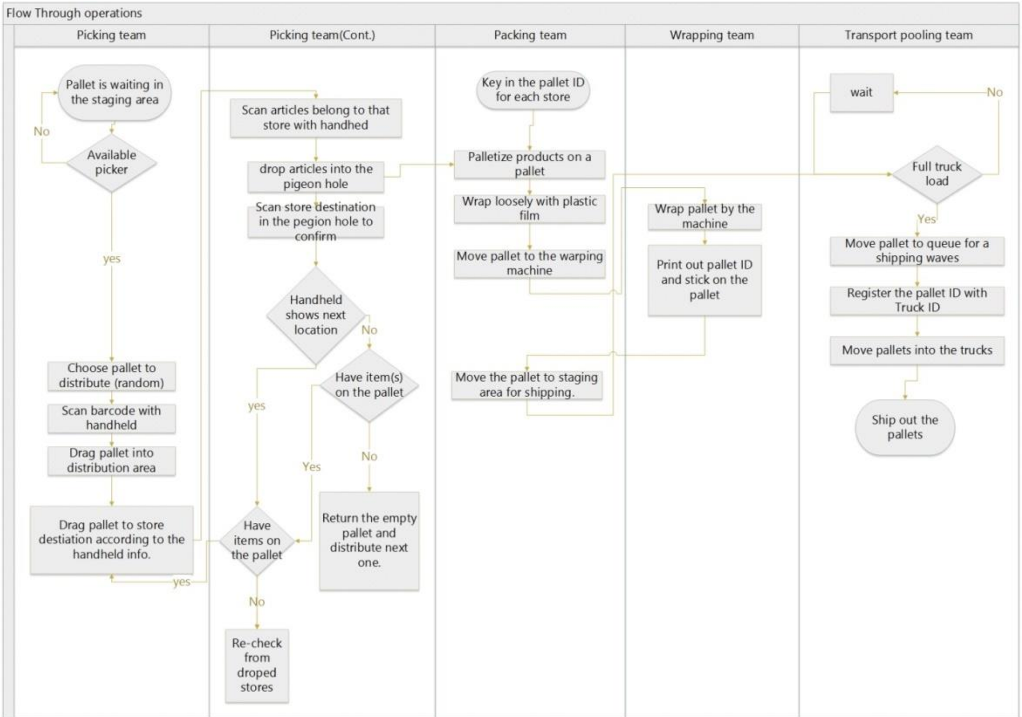


Figure 3-9 Procedure of flow-through products

Figure 3-9 is an operation procedure in Flow through area represents the flow chart and decisions in the operation of Flow through. This process starts after the product are received, put on pallets , tagged as FT product and being allocated to the staging area waiting to be distributed. Once a picker is available in the area the product on the pallet are distributed through these operations immediately. Every FT product arrived the distribution centre will already have the store destination. This is for utilizing staging area for upcoming receives. Each process are seperated and divides amongs the flow through teams (picking team, packing team, wrapping team, and transport to trucks team).

4 Analysis of Flow Through Process

As a continuation of previous discussion, this chapter aims to analyse the productivity issues in flow through process of the small- and the medium-sized products. The chapter begins with an introduction of planned workforce and general statistics of the flow through process. Then, the discussion is shifted to the analysis of current operations, particularly ordering distribution pattern, operating time in each activity, and distribution pattern. The insights of analysis would not only contribute to a better understanding of the process, but also lead to exploit underlying patterns and suggesting on an improvement in the next chapters.

4.1 Overall Status of Flow Through Process

As the major manual operating process in the case study DC, Flow through process is designed to operate 24 hours every day with exception on Sunday.

4.1.1 Workforce status

The process operates 24 hours every day in 3 consecutive shifts same as the DC's shifts since the Company DC is manually operated and consumes many labours. Similar to an essential process, it consists of three overlapped shifts and both skilled Thai employees and legal immigrant workers, as listed in Table 4-1.

Table 4-1 number of worker in Flow Through process by shift and function

	Operations	Shift 1 (06:00-15:00)	Shift 2 (14:00-23:00)	Shift 3 (22:00-07:00)
Indirect	Data coordinate	1	1	1
	Shipping Centre	1	1	1
	Coordinate	1	1	1
	Tagging articles	2	2	2
	Feeding into distributed area	2	2	2
	Feeding for packing	2	2	2
	Operating wrapping machine	1	1	1
Direct	Distributing	19	28	21
	Packing	14	14	14
Total				170

Table 4-1 divides the workforce into indirect operations-- activities in which do not contribute to value adding of product-- and direct operation-- activities in which directly contribute to transformation of product in the flow through process Because of fluctuation of workload throughout a day, each shift has different workers and employees. Nevertheless, the company tried to maintain 110 of direct operators as they are considered the most skilled operators.

4.1.2 Line as a common productivity unit

Before discussing productivity statistic of flow through process, it is essential to elaborate of a common productivity unit used throughout the document. In reality, distributing and packing different size and quantity of products require different efforts, and different amounts of time. Nevertheless, it is difficult to trace each activity of an individual worker responsible for dimension and quantity of products per handling. As a result, the productivity analysis in the warehouse is generally assumed number of SKUs for each designated location at a particular time as a common productivity unit regardless of its quantity and dimension, called *line*. Despite assuming that each has identical amount of efforts, number of lines is relatively easy to count as it appears on the picking list and fairly reflects efforts for a small size items. It is important to note that a single line could mean one unit of an item or ten units of an item.

4.1.3 Overall statistic

Before analysing flow through process, it is important to understand its nature business and to overview its relevant statistic, as shown in Table 4-2 and Table 4-3.

Table 4-2 Details of number of SKUs and pallets in terms of day and month in the receiving dock.

Item	#SKUs/day	#SKUs/month	#Pallet/day (Avg)	#Pallet/day (Max)	#Pallet/Month	Qty/day (Avg)	Qty/day (Max)	Qty/Month
PT	492	2,585	1,482	3,746	37,199	74,076	298,035	1,691,176
FT (SM)	4,233	15,766	2,711	4,288	73,836	129,317	200,976	3,510,248
FT (L)	915	3,556	994	1,464	27,448	41,119	82,157	1,134,323

Table 4-3 Details of number of SKUs and pallets in terms of day and month in the flow through operation area.

Item	#SKUs/day	#SKUs/month	Line/day (Avg)	Line/day (Max)	Line/Month	Qty/day (Avg)	Qty/day (Max)	Qty/Month
FT (SM)	6,399	15,747	16,088	24,764	477,575	123,197	206,445	3,653,225
FT (L)	1,382	3,577	3,552	5,294	105,551	38,505	60,743	1,142,280

The data in these tables represent statistics of the number of SKU, the received pallets, the distributed lines, and quantities that are transferred across flow through process during May 2016 – Dec 2016 (seven months). In, receiving activities of all processes, including put-away, are presented as the DC shares receiving workers and receiving docks. In addition, workers must place products over a pallet platform to assist the transfer after visual inspection. Hence, number of pallets is equivalent to number of lines of all destinations on a particular day. It is important to note that a supplier may place the products onto an additional pallet if quantities exceeds a certain pallet height. However, this situation is really occurs in the small-size and medium-size flow through process as their dimensions are compact. In some occasions, the DC experiences a surge in in operation. For instance, maximum SKUs per day and maximum quantity per day may be more than double of their average. This comes as no surprise if one considers the nature of construction material business. For example, a colour painting are dominantly sold in summer, but a little or no activity in rainy season.

Comparing Table 4-2 and Table 4-3, the results suggest that the DC, on average, is able to balance incoming and outgoing flows in terms of quantities, but not in terms of SKUS. Despite imbalance of SKUs, this may come as an unusual in modern trade warehouse. Nevertheless, a part of these phenomenal can be explained by the fact that the flow through process typically stops its receiving activity on Sunday, as shown in Figure 4-1.

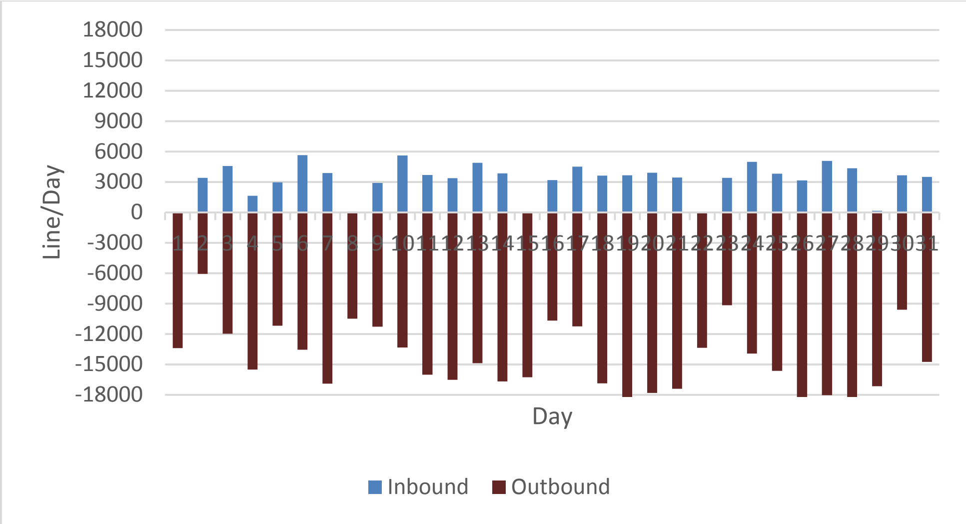


Figure 4-1: Daily lines received and distributed of small-size and medium-size flow through process

Figure 4-1 shows that the number of receiving lines is significant different than number of distributed lines since the incoming products are received as pallets, whereas distribution is typically done in a smaller handling unit, such as each or carton. The figure also reflects the fact that the DC performs a little or no receiving activity in Sunday. As there is virtually few incoming pallets, number of associated SKUs is reduced and affected the average number of receiving SKUs, while distributed products in flow through process are performed every day.

As a representation of output in flow through process, the historical line in Figure 4-1 is also very useful to calculate a productivity measurement, called *line per man-hour,* that represents efficiency of workers to complete distribute products to a designated location. Because of relatively constant workforce, the pattern of line per man-hours and the pattern of distributed lines are identical. Assuming eight working hours a day, the average line per hour of flow through process is Man-hour is total hours of labours, which work in the warehouse daily. Line per Man-Hour is 28.46 (448,152 line month/ hour)

The understanding of these data along with patterns, is later proved to be very important as they become a basic for simulation model in following chapters

4.2 Analysis of ordering pattern

To improve the performance of warehouse, warehouse manager must understand the underlying patterns through analysis and exploit them. Arguably, one of the most basic warehousing analyses is ordering pattern, called line per order. This line per order reveals characteristics and the number of SKUs in which workers are currently handled, as shown in Figure 4-2.

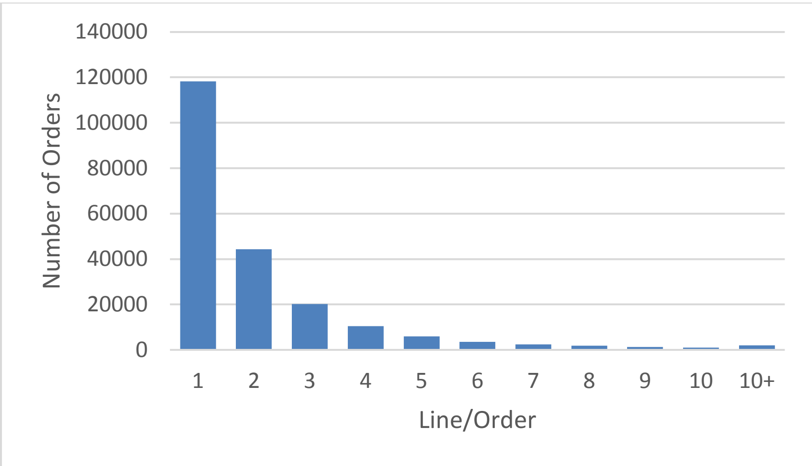


Figure 4-2: Line per order in flow through process

Each bar in Figure 4-2 represents the number of orders that shares the same number of lines. In other words, the majority of orders consists of a single product belonging to a destination in an average day. For the flow through process, where a picker needs to place a product into a pigeon hole, this requires more walking in the distributed area. As the result shown, methods of batch picking might be able to help promote higher line per order. However, in order to establish batch picking process, received products need to be consolidated together- which in DC case, it is impossible to control the SKUs and consolidates the products from multiple suppliers.

4.3 Analysis of activities

In addition, to the pattern of store orders, the duration that a product spending in each activity also indicates wastes in terms of idle time, double handling and area footprint as an incomplete pallet occupies an area and requires additional transfer. As a result, recorded timestamps of each order in each activity are plotted and shown in Figure 4-3.

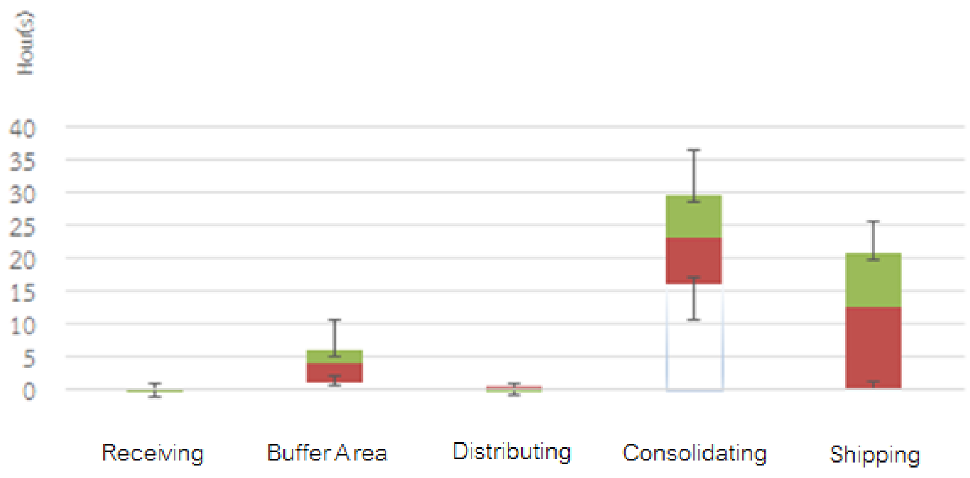


Figure 4-3: Boxplot of process in FT(S&M)

The y-axis of Figure 4-3 represents hours when each order spends and the x-axis shows five activities: two value added activities of Receiving, and Distributing and three remaining idles (in Buffer area, Consolidating, Shipping). On average, an order must spend between 30 hours in flow through process. Based on the company's policy, an order, however, should spend less than 24 hours in flow through process. As a result, it is worth to explore each activity and analyse in details.

4.3.1 Receiving

The distribution of receiving duration is represented in the first box. The activity consists of labelling, and picking where the workers print and put barcode labels on products and scan to register timestamp of the products. This interval is relatively short and has small variation comparing with others.

4.3.2 Buffer Area

After identifying the barcode using a handheld terminal, a pallet is transferred to a nearby staging area for a worker to scan the barcode again to indicate the beginning of picking activity. In the boxplot chart, this activity may take times depends on the efficiency of workers in the next activity in the sorting area. During a busy period, some product may have to wait more than ten hours.

4.3.3 Distributing

Picking activity is referred to an activity where a worker travels along aisles places the products on each pigeon hole. Without a document, a barcode terminal informs a worker designated stores and distributed quantities of each store. As a result, Figure 4-3 shows that this time interval is relatively short similar to labelling activity because all designated stores of a particular pallet may be located in the same aisle. Nevertheless, the distributing time may vary as it depends on each product type and each physical shape of the products.

4.3.4 Consolidating

Consolidating time is defined as the time interval in which a product in a pigeon hole is first selected until its shipping pallet is completely packed and temporary wrapped with a plastic sheet. As shown in Figure 4-3, the activity has the largest fluctuation time as a worker may have to wait for suitable product to provide a stable and solid at a bottom level before stack a fragile one on the top. Managers currently consider workers in this activity to be the most skilful ones as the worker must understand characteristics of products to stack them and achieve approximately two meters height.

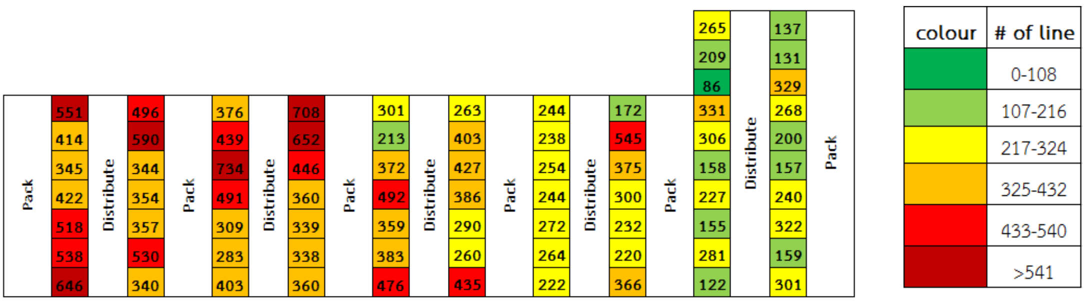
4.3.5 Shipping

Shipping is an idle time referring to the duration starts from completely wrapped a pallet, transfer a pallet to the waiting area, wait for pallet to be shipped out of the DC. The time associated with this activity contributes significantly to overall total time of the flow through process because flows through pallets are consolidated with other type of products. This process is relies on the full truck load conditions.

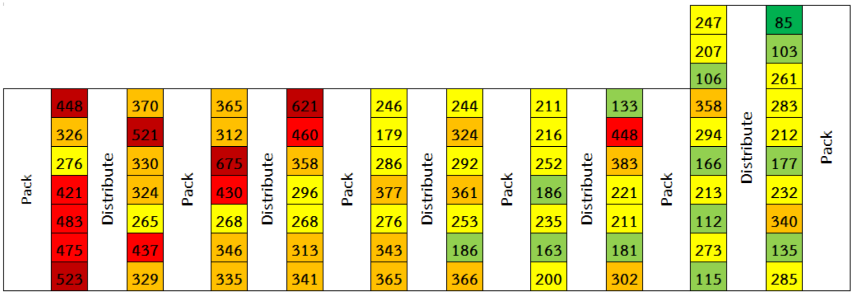
Based on Figure 4-3, flow through process consists of substantial non-value added time, particularly waiting time (in buffer area, consolidating, and shipping activities). However, the waiting time in shipping area is not be able to improve, since flow through and put away product need to be shipped together- unless DC changes the condition of outbound waves. Since the majority of time is in waiting time, which it cannot be improved directly. Nevertheless, this waiting time in buffer area and consolidating area can be improved indirectly by increasing the productivity of distributed area. By increasing the efficiency, the average of time spending in buffer area decreases. Pallets in each pigeon hole can be built faster due to more products are available to be consolidated in packing conditions.

4.4 Frequency of visits in packing area

To depict picking activity and congestion in sorting area, a visualization of visiting frequency at each pigeon hole is demonstrated as a thermal plot, as shown in *Figure 4-4*.



a) Day 1



b) Day 2

Figure 4-4: Thermal map Day1 (top) and Day 2 (bottom) with colour indicators.

Deriving from the data of two consecutive days, *Figure 4-4* serves as a spatial example of associating number of visits to colour. The warmer colour represents the higher number of visits at corresponding stores. A worker moves a cart containing products and walks across the distributed aisle to place the products to a pigeon hole. Once the products are packed into a shipping pallet, they are then transferred to the staging area through the pack aisle. It is suggested that there is relatively high traffic on the first three distributing aisles comparing to the others. Nevertheless, the arrangement of pigeon holes is ordered by the opening date of stores. For example, a pigeon hole located in the lower right corner is associated with a store that operates prior to the one located in the upper left corner. This creates traffic congestion as the most frequent visits of stores are located closely to one another.

In conclusion, from distribution of time Figure 4-3, the total time spend in the flow through process is too long (comparing to DC's KPI). However, this spending time is caused by the waiting time, depending on many factors and previous operations as well. From the thermal map, it shows the random placement of pigeon hole. If it is placed correctly, it might help in reducing traffic and lead time of the flow through product. Therefore, in order to reduce the total time spending in the flow through process, this thesis will focus on re-designing process and layout of the flow through activities. The measurement will be on the Line per Man-Hour, so that it could prove the improvement of productivity in the FT area.

5 Proposed layout and Picking Policies

To understand the characteristics and see the possibility of improvements in the distribution centre of the company, this chapter applies suggestions and applications from the literature review chapter to the distribution area of flow through operation in the company DC.

5.1 Re-designing layout and policies

This section explains the possibilities of how the distributing area could be designed according to the scope of the project proposed in the proposal and mentioned in the previous chapter. Improving points can be mainly classified into two main points. They are (1) reconfiguring the assorting policies and (2) designing new layouts for the pigeon holes for improving efficiency inside the distributing area. The proposed concept consists of 2 walking policies and 3 new layouts:

- Walking policies: one way (W1) and two ways(W2)
- Original layout (A0)
- Layout concentrating the high line density in the end of each aisle (A1)
- Layout arranged from high line density to low. (A2)

5.1.1 Assorting Policies.

Currently, the assorting policies of the Company DC allow pickers to walk inside the distributing area in one-way direction in order to avoid confusion. It is assumed that the organized walking policies could induce the orders and might result in better performance in dropping the products into the designated stores.

In this case, we try both types of walking polices and compare with the measurement of labour efficiency to see some differences:

- Walk One Way (W1): Pickers are forced to walk in one-way direction in an aisle (either from north to south direction or vice versa)

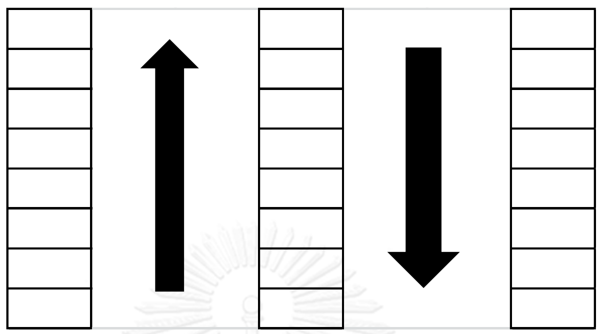


Figure 5-1: Walking policy for One way (W1)

Figure 5-1 demonstrates the top view of distributing area with black arrows representing walking directions in aisles. The direction in the first aisle (left), which is the nearest to the buffer area, is fixed to be south-to-north direction; whereas, the next aisle to the right is fixed to be opposite. Therefore, the first, the third, and the fifth aisles are south-to-north-direction. With this walking policy, a picker is forced to walk into the second aisle in order to change the direction and be able to go into the third aisle if the picker needs to visit the first and third aisles. The excess of walking creates more travelling distance and more congestion in the aisles. Hence, it reduces the efficiency of labour in the distributing area.

- Walk Two Way (W2): Pickers are allowed to walk in any direction in an aisle.

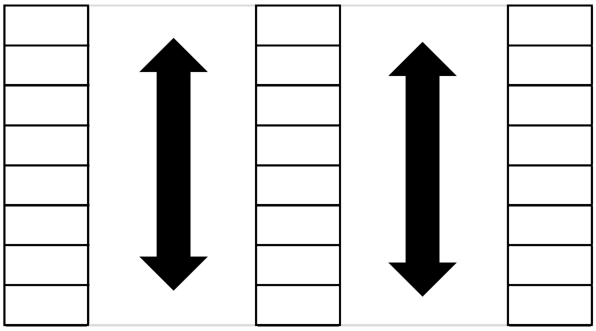


Figure 5-2: Walking policy for two way direction (W2)

Figure 5-2 demonstrates the second type of walking policy. This policy allows pickers to walk in any direction in aisles. The policy is expected to help a picker to skip some aisles, where a pallet does not need to visit. Hence, the travelling distance and congestion should be reduced.

This thesis uses only an S-shape routing method from (De Koster, Le-Duc and Roodbergen, 2007) because one pallet contains too many store destinations, so the implication of different routing policies would not help much.

5.1.2 Layout structure and store location

Another method for improving the labour efficiency in the distributed area is through re-designing the store destination for a picker to walk. From the thermal map, shown in data analysis section, it shows that the traffic is strained in the first and second aisle. By changing store locations and aisles, we can manage the congestion and traffic in the distributed area.

The first concept (A0) is the original design from the Company DC. This layout is for comparing the differences of in results after running through simulations.

The second concept (A1) is to distribute the traffic inside an aisle equally. Through equally arrange the store locations; the locations of stores change in order to equally distribute the traffic in each aisle. The concept of changing store location is demonstrated in Figure 5-3.

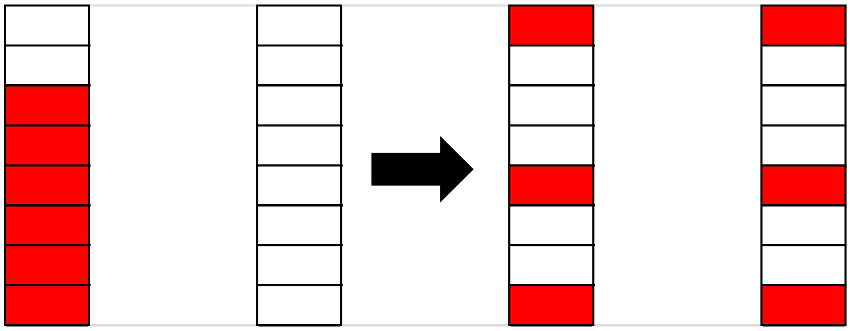
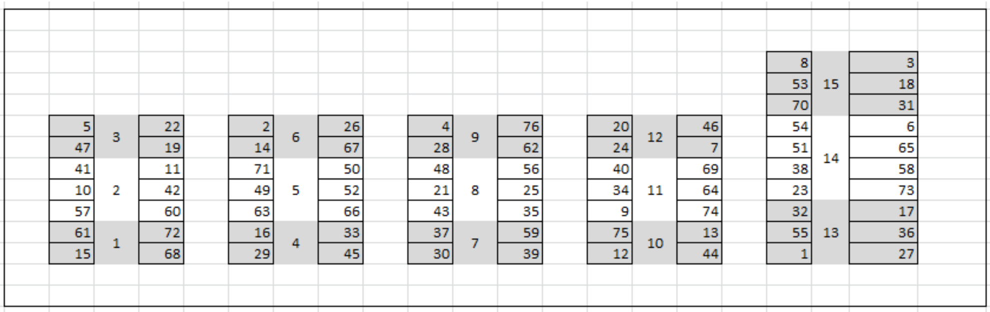


Figure 5-3: High demand stores (highlighted) are equally distributed in aisles.

This concept is applied from the across-aisle storage (de Koster, R., Le-Duc, T. and Roodbergen, K., 2007) and (Pan and Wu, 2012). Through arranging high frequency visited stores in the front of an aisle, the travel distance and congestion inside an aisle reduce. 4-month data is used in order to select and choose the store to fit into this criterion. An average of drops and the total quantity of products are used in calculation. The quantity is presented in the small-sized products and the medium-sized products. The quantity dropped into a store represents the frequency for pickers needed to visit that store. This can imply the congestion in aisles. However, one might argues that the total number of line should be used instead because the total number of quantity might reflect the number of visits incorrectly. Later on, we have studied that the quantity is related to the amount of time spending on placing the product into a pigeon hole. Therefore, the total quantity should be used to arrange and find the order of time spending in each store.



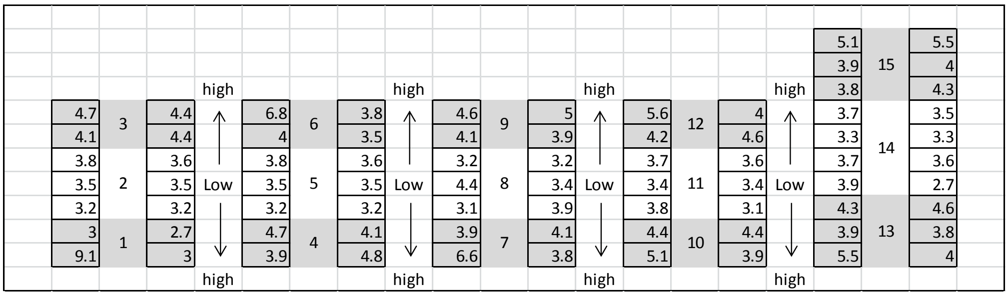


Figure 5-4: High average store at the edge of each aisle (top), average line density of each store (bottom)

Figure 5-4 demonstrates the new design of store locations matching with the DC's pigeon holes. Each aisle is separated into three zones and named by its number. This separation helps in placing store locations and easier in computer simulation models. Each end of the aisle (highlighted box) is placed with high possibility to have high congestion. We try to distribute the congestions equally in every end of aisles to avoid that one end takes more congestion than one another. The middle of every aisle is placed with low congestion stores. This is to avoid the congestion in the middle, which can block the entire aisle. The middle zones are equally distributed among the middle ones.

The third concept (A2) is to consolidate high ordering stores. This concept is adapted from (Pan, Wu and Chang, 2014), where they arrange high frequency products in the first level and the first location in the storage rack. The reduction of travelling distance is expected to be beneficial in this distributed area. This concept is expected to decrease the average total distribute time in each pallet. By combining high ordering store together, it increases the chance of a pallet to be completely distributed in the first or second aisle (Figure 5-5).

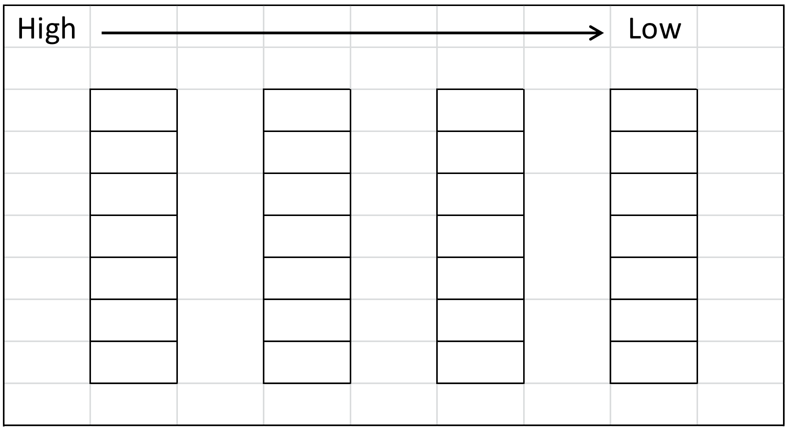


Figure 5-5: Arrange stores from highest ordering store.

Figure 5-5 demonstrates the arrangement of stores to the pigeon hole (drawn in black box). Stores with high demand are placed together. The black arrow represents the arrangement of demands from high to low. With this concept, it is expected a pallet to obtain minimal travelling distance and decrease the total time of pallet being distributed. However, this concept is a trade-off with reducing congestion in an aisle. By having high ordering stores near each other, it maximizes the congestion in an aisle as well. By using this concept, the stores location and its average quantity of each store are presented below (Figure 5-6)

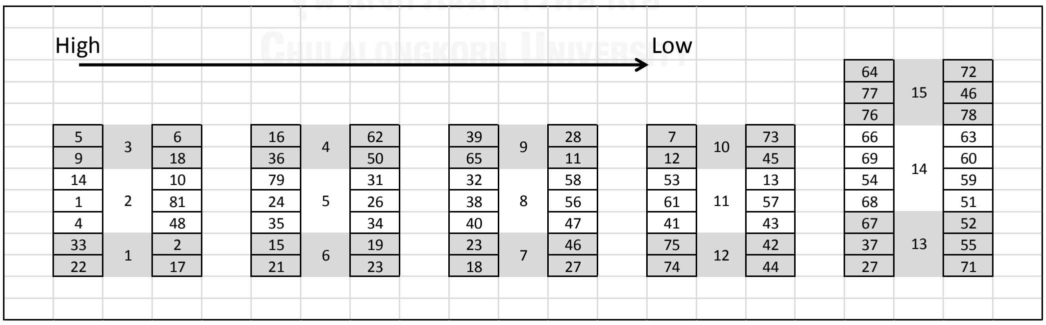


Figure 5-6: High piece density at first aisle, stores sequence by the average probability of a line into each store.

In conclusion, with two ways of assorting policies and two newly designed layouts of the distributed area is expected to yield different results with the

Company DC's original design. However, these new arrangements are based on the assumption that the characteristic of stores remain the same. The validation of these arrangements depends on the changes in store's demand and characteristics. Alternatively, the DC needs to update the store location to match with the designed layout.

5.2 Project Risk assessments and Mitigation Plan

The implementation of the proposed design should provide low risks to the company DC. These are the listed of risks and mitigation plan for the proposed design:

1. Human error and confusion can occur for two reasons: change in store locations and walking in two ways might affect low skill labours in dropping items. With the simple walking policies, the procedure keeps all pickers to walk and perform in the simplest way. With this risk, company dc should use store location to locate the destination of store to communicate with picker instead of the store's name. With this mitigation plan, Company DC can change the store destinations without changing interrupting the name in front of pigeon holes.
2. Pallet damage: Due to the limited spaced in an aisle, walking two ways might damages pallets during dragged in an aisle. Company DC should limit the speed of dragging a pallet; in order to prevent any damage occurs to pallets and products. Alternatively, they should promote the "safety first" policies to prevent such damages and injuries.
3. Simulation results might not reflect the actual outcome of an operation: This is the key limitation of simulation model. The company should not completely trust the result in simulation and blindly follow with the proposed design due to uncontrollable factors in the actual operation. It is

suggested that DC should try to implement in the small scale first. This is to see the actual results. Moreover, by trying in a new area, failures or any problems would not interrupt the operation inside the DC.

6 Parameter Analysis and Simulation Results

6.1 Introduction of Computer Simulation

In order to see improvements from new concepts in this distributed area, either the implementation or computer simulation should be done to measure and decide the feasibility and conditions for this new design.

6.2 Assumptions for Computer Simulation (SKU/pallet, line, handling time)

The major disadvantage in computer simulation is the data required to initiate distribution process. The difficulty is in the generation of creating data and design the simulation to generate similar conditions and input as the actual operation. It is impossible to re-create the exact same factors in the computer simulation, hence, the assumptions needs to be made. In this section, all the assumptions taken into the computer simulation are clarified and discussed with reasonable explanations:

1. The probabilities of products, which are ordered from each store, are independent from the SKUs number, and quantities. The probability for each store is assumed to remain the same every day. The only characteristic that each store is depending on is the type of products –small or medium size. This assumption is made to eliminate minor characteristics in some stores. For example, some stores order some product more than any other type, or some always order in small quantities of certain type of SKUs. Since the ordering characteristic is beyond the scope to explore, therefore same size products are assumed to have the same characteristics.

2. Assume a pick time remain the same in each type of product. Since the FT products come into the Company DC in different packaging, pickers take different amount of time to handle the products. However, linkage of drop time of each SKU is impossible in the computer simulation. Therefore, the drop time is assumed to be the same in every product.
3. Assume the incoming pallet, from the receiving, are always be a full pallet. The quantity of small size and medium size pallet is assume to be 110, 36 items/pallet respectively. This number of assumption came from the analysing data in the receiving area.
4. Assume that one pallet should contain only one type of product(S or M size). This is to study the behaviour of different type of products.
5. Assume that the efficiency of each picker is the same. This assumption will lead to the same walking speed and dropping time in the simulation.
6. Assume the congestion is based on the same criterion, where it is calculated with discrete information by dividing one aisle into three zones. In actual operation, congestions occur continuously and varied with time and number of pickers. However, a continuous calculation is too complex and does not significant enough. The justification of significant, in this case, is the amount of time delayed by congestion is significantly short compare to walking and dropping time. Hence, it is assume to be a constant regard to the amount of picker in each zone.

7. The drop time of one line of a product into a pigeon hole is assumed to be using one average value. This is due to the numerous type products, which the time recorded in an actual operation is relatively short compare to the walking and queuing time.

6.3 Simulation and Generating Inputs.

To easily explain and go through all the analysis and calculations, the author preferred to explain by using the process flow of computer simulation, which derives from the computer simulation flow. (see Figure 6-1)

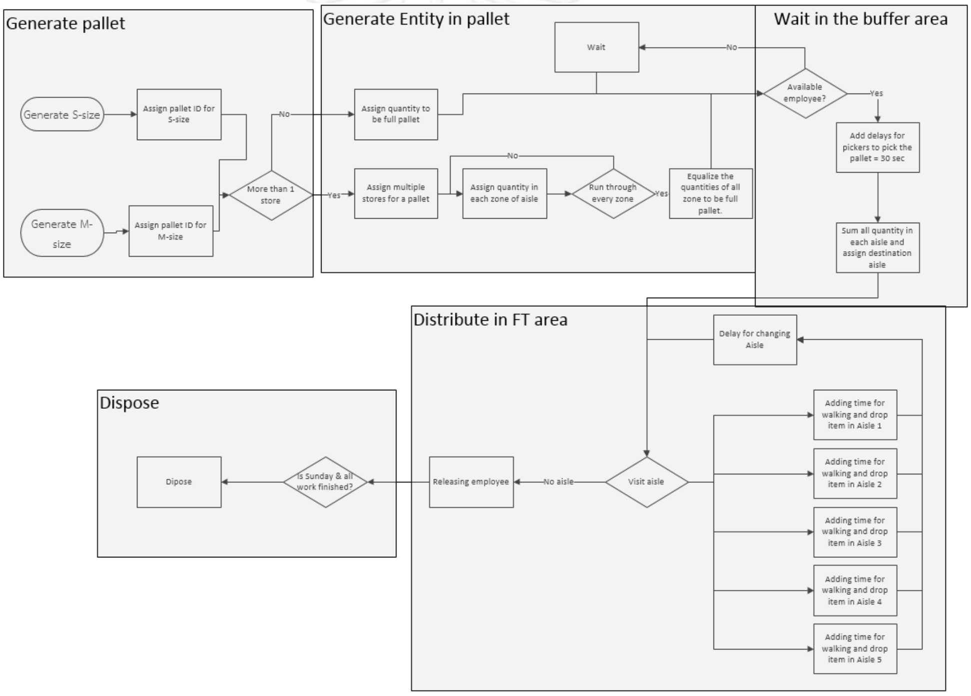


Figure 6-1: Computer Simulation Flow

Figure 6-1 is the flowchart for computer simulation. This flow is divided into five sections: Generate pallet, Generate Entity in pallet, Wait in the buffer area, Distribute in FT area, and Dispose. The detail of each section is discussed below:

6.3.1 Generate pallet

Generate Pallet section is for re-create the similar input with the actual data in order to test and compare with the original design. Both Generate S-size and Generate M-size is the input distribution, where inter arrival time is plugged in. The inter arrival time is defined as the amount of time between gap of the creation of the each entity (in this case are the S-size pallet and M-size pallet).

In order to identify the distribution of inter arrival time, the pattern of the inbound pallet need to be determined. However, the IT department of Company DC does not has such information. This is because the products are unloaded into the available pallet and arrange by the PO number. Therefore, based on the information fetched from the system, it is assumed that products which share the same PO number, vendor date and in the similar time should be in the same pallet. However, if the number of quantity in one pallet exceeds 110 (for small size) or 36 (for medium size), a new pallet is introduced. By using four months of data, the pattern of incoming pallet is noticed in the hour period (See Figure 6-2 and Figure 6-3).

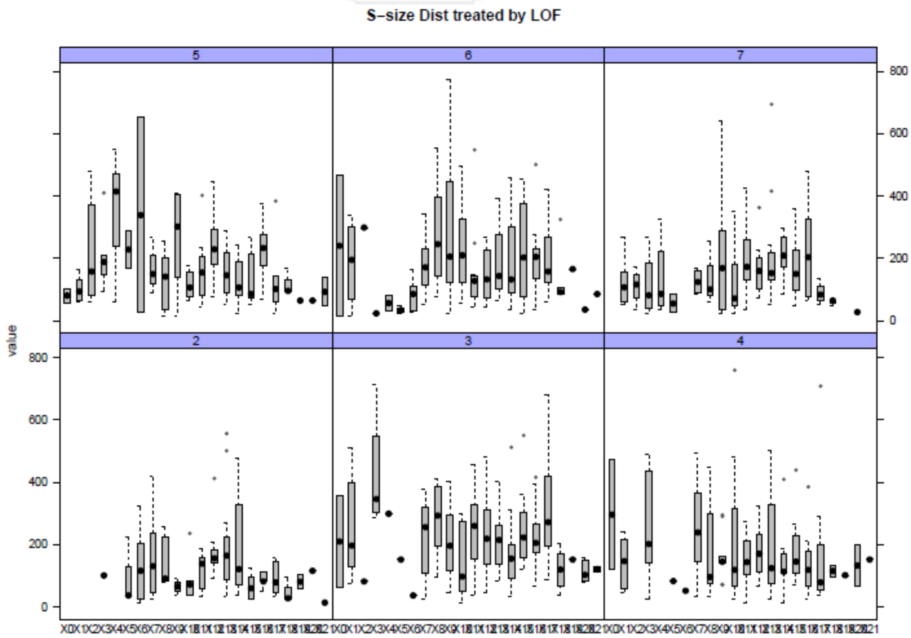


Figure 6-2: Boxplot of S-size distribution

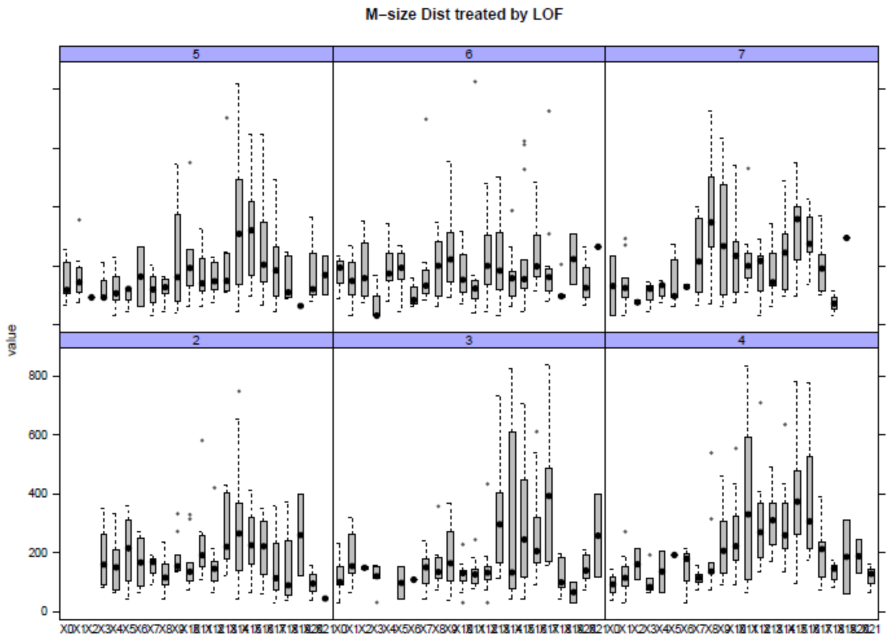


Figure 6-3: Boxplot of M-size distribution

Figure 6-2 and Figure 6-3 are the boxplot of the distribution of inbound pallet, which are Flow Through products. The value of y-axis in both of the diagram is the total number of pallets comes into the Company DC. X-axis represents the time in hours, which pallets arrive. The distribution is separated by days. Since, FT operates for 6 days, there are six charts.

According to the boxplot, the range of upper quartile and lower quartile is relatively short in many hours of the day. This implies the level of agreement at the same time for every hour of the day. Actually, based on the operation and procedure of the Inventory management, it is understandable that there is no ordering pattern for flow through because IM always order the product every day and the volume of their orders are not in batch scale.

Moreover, both of the boxplot came from the treated data. Since the size of the data is large, and there are some outliner includes in the actual data. Hence, the treated procedures are taken to clean the data. The details of treating the data are:

- Exclude the obvious outliner by observing the data.

- Exclude the outliner, which are higher and lower than 1.5 of the inter quartile (according to the data-mining procedure)

From the data above, the "Input Analyser" program has identified it as a discrete distribution. As for that result, the discrete distribution is created to differentiate between hours and days of each distribution. Hence, there are 288 distributions (small and medium size for Monday to Saturday). Even through the distribution in every hour is the closest data, that could be achieved, the data for each hour is still different with one another. Therefore, this thesis assumes that the distribution of incoming pallet with average of each hour by using the discrete triangular distribution.

6.3.2 Generate Entity in pallet

Right after pallet is generated, the entities are plugged into the pallet information. Either from the small or medium size is assigned with the pallet ID then every pallet will have a chance for containing one store destination or more than one. From the four months data, there are certain number of pallets which contains only one store destination. If the pallet is set to have one store destination then the quantity will generated right away and shift the pallet into the buffer area. However, if the pallet contains more than one store destination, this following process will be applied.

For a pallet with more than one store destination, the probability for each store to be a destination is applied. Since the arrival time for each vendor does not fix and there is no significant pattern to distinguish or varying the distribution of store probability with time, so the store probability, in this case, is fixed and applied to every hour of every day. (See Figure 6-4)

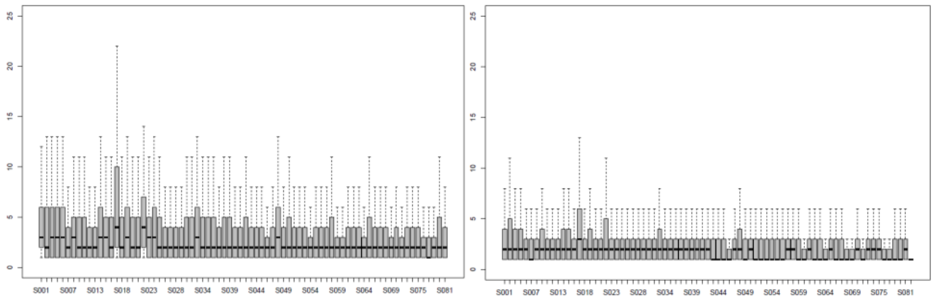


Figure 6-4: Boxplot of number of times, which S-size (left) & M-size (right) product visits in each store

Figure 6-4 shows distributions of number of visits, which a pallet has a possibility to be assigned to. X-axis represents the store destination, while Y-axis represents the number of drops in each store. The number of drop is derives from SKUs and unit. For example, if there are more than one SKU, then the number of drop will be increase accordingly. In addition, the “drop time” in distribution section is varied with the number of unit, not number of quantity. For example, a box of 20 screws is considered as 1 drop. This boxplot plotted from the four months data to show the distribution and number of visits for each store destination. For small size product the visiting values are more fluctuate because one pallet can store more quantities. For example there are on SKUs which needs to do 10-15 drops in one store per pallet. These quantities are the differences in small and medium size product.

6.3.3 Wait in the buffer area

After the type and quantity in a pallet is created, a pallet will be waited for available picker to carry and distribute through the distributed area. 30 second is added as for a delay process reserve for picker to drag pallet from the buffer area, scan the article in that pallet and ready to distribute.

6.3.4 Distribute in FT area

Distribute in FT area section is the process flow of distribution in FT area for the computer simulation to record and sum the time needed in each aisle together. The summation of the time consists of:

1. Dropping time

Table 6-1: Record data of drop time in distributing Small-Medium area

Site check : Operation Tact time (Actual operation)
Date : 03'Jun'2016
Time : 13:30-17:30

Items	Operation	Cycle unit	Sampling												Avg
FT (S,M)	Assort by Store (Put to store)	Case	1	0	0	0	0	2	0	1	0	0	0	0	
		Piece	1	5	1	10	10	1	1	0	1	10	20	10	
		Total	2	5	1	10	10	3	1	1	1	10	20	10	
		Sec	16	22	11	35	26	28	13	20	5	30	24	20	
		Avg. Sec/Unit	8.0	4.4	11.0	3.5	2.6	9.3	13.0	20.0	5.0	3.0	1.2	2.0	6.9

Dropping time is defined as the amount of time, which picker requires dropping one unit into a pigeon hole. Related to the actual operation, the component in drop time refers to scanning, finding the products, unpack, pick and drop it into the store. By observation, the drop time is calculated from an average time picker need in different type of SKUs and packages (cases, pieces). The average for small and medium size is very similar to each other. Hence the average drop time for a unit is 6.9 Unit/sec.

2. Walking time

For walking time, it should consist of two type of walking because the speed when picker walks in an aisle and across aisle does not equal. The delay process is added to reserve the time for picker to change from one aisle to another. From the collected data, the time spends to walk through one zone and changes an aisle are 14.93 sec, and 9 sec respectively. This value came from recoding data from the actual operation.

3. Delay from Congestion

Table 6-2: Delay time when congestion occur in an aisle.

No. of picker in Zone	Walk across aisle (sec)
4	6.4
5	9.8
6	13.3
7	17.5

By observation and recording data, the congestion will occur in an aisle when that aisle contains more than 4 pickers in the same area. This is because there is not enough room for a pallet to pass through without any blockage for another picker. Hence, the walking speed is increased. Table 6-2 is the recorded data in an actual operation. Additional time spent to walk through congestion in an aisle is shown in this table and measures in seconds. However, if the picker is more than seven, there is no available space for another pallet to pass through. This will create a queue in that area instead of the delay.

6.3.5 Dispose.

Dispose is the last process, which is disposing the simulation. In actual operation there are very small numbers of work in Sunday. However, to measure the total time requires for work to be done for measuring the productivity of the flow through area, the terminated condition need to be applied. Even through the pallet stop generates on Sunday, but there is still the pallet waiting to be distribute before reset to run another repetition. Hence, the requirement for disposing or terminating the simulation is the finished generated the entire pallet distribution and there is no work left for the picker to distribute.

With the process flow, a computer simulation is constructed by using Arena simulation and shown in Figure 6-5.

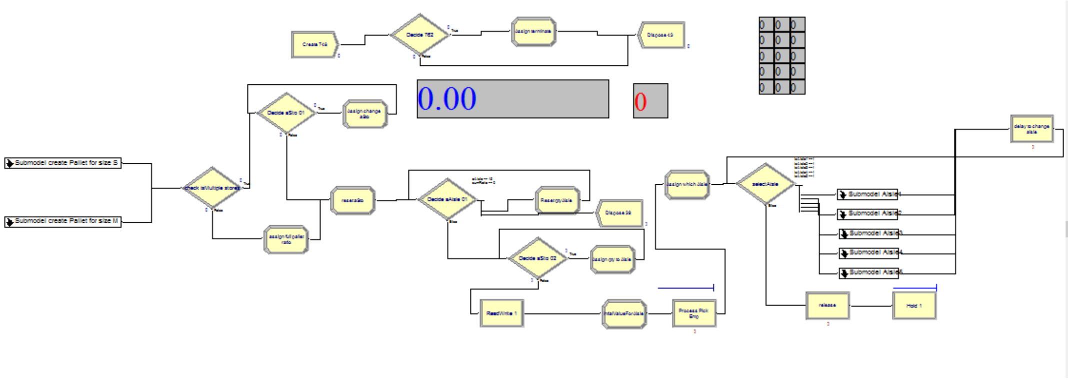


Figure 6-5: Screenshot of computer simulation

6.4 Simulation validation

Before testing for results, the simulation needs to be validated. Since, in this case study, it is impossible to implement the designs in the simulation, the only way to verify the rigidity of the result through computer simulation is by validating the whole simulation before taken any test. It is expected that a validation of input data and processes should result in the validation of the simulation results as well. Since the data from processes such as walking time. Congestion time, placing time of the picker is collected in the field. Therefore, in this section the validation is focusing on the generated input.

6.4.1 Generated input

In the simulation, there are two inputs, which are the distribution of pallets and the stores destination for each pallet to visits. To validate the information of the pallet generated by the computer simulation and the information gathered from the Company DC, this thesis use One Way Analysis of Variance (ANOVA) test is a test to determine the statistically and significantly different between two data to test for the rejection of the null hypothesis. (Table 6-3)

Table 6-3: P-value from Anova test of Small and Medium pallet.

	P-value
S-type	0.3959
M-type	0.0306

Table 6-3 shows the p-value from the data between collected data and data generated from the simulation. Given the significant level of 97.5 percent, the P value is more than 0.025. Hence, the null hypothesis is not rejected. Information is tested between zones and days or a pallet generated in the simulation and registered by the receiving dock. (see Figure 6-6)

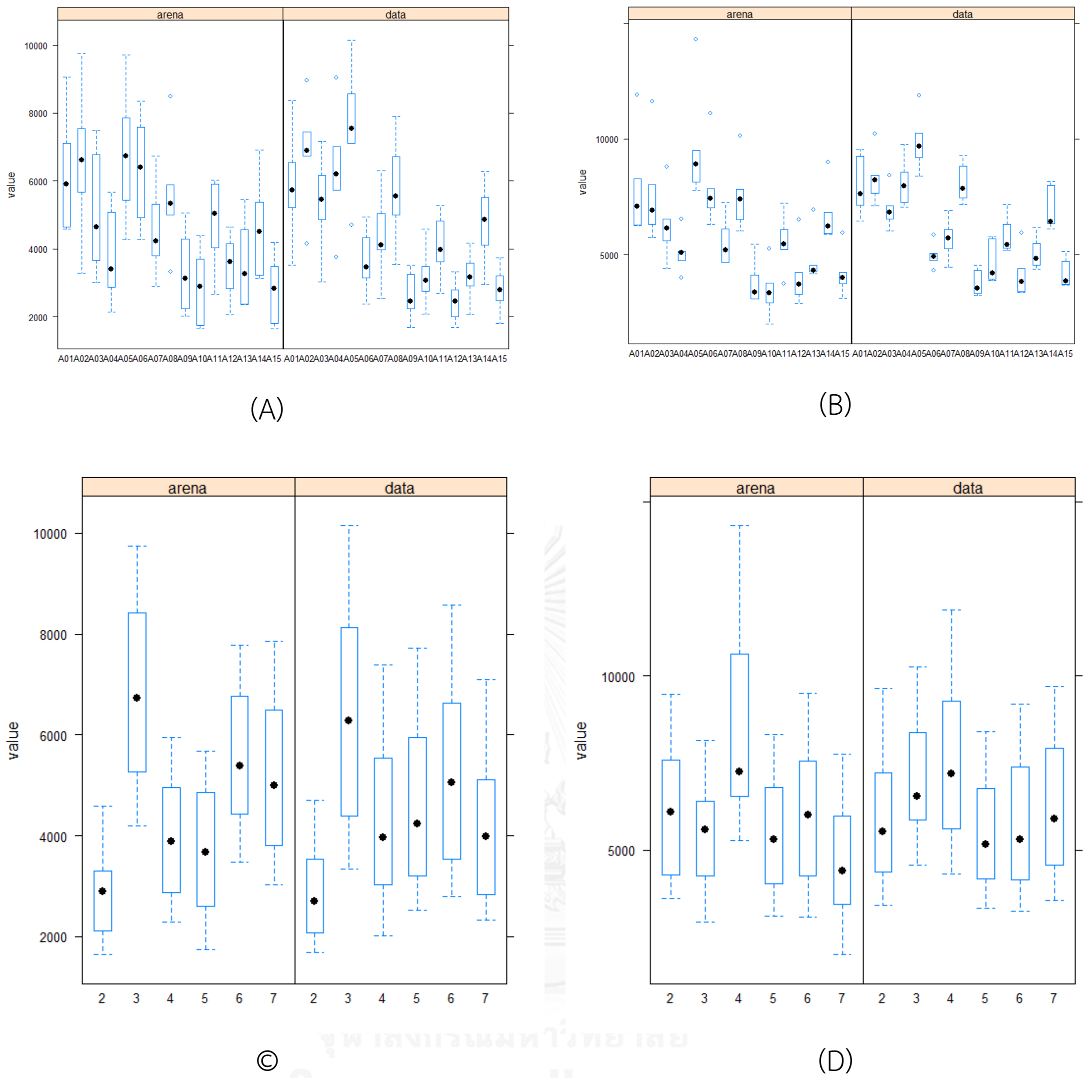


Figure 6-6: Boxplot of data from simulation and collected data compare between zones of small size (A) and medium size (B) and number of pallet in days of small size (C) and medium size (D).

Figure 6-6 shows the distributions of data compare between each zones, which pallet needs to visit. (A) and (C) are the data from small type product. (B) and (D) are from medium product. The zones are divided into 15 Zones. The days start from Monday, which represents as “2” in the graph and plotted until Saturday (since, distributed area stop on Sunday). As for the result of P-value from ANOVA test, small FT product has significant P-value where it cannot be rejected from the null hypothesis. However, the medium FT product shows a lower P-value. This is because the data is cleaned and treated before transfer into distribution expressions in the simulation. Taken the weekday "4" in the boxplot (C), the quartile, maximum and minimum of distribution is shorter than the actual collected data. This is because there is some small insignificant data eliminated during.

6.5 Configuration of simulation

These are the configuration in running computer simulation in this thesis:

1. Duration: The simulation is tested with one week of incoming pallet with 100 replications. The one week came from the pattern in scale of week days in the generated input. However, to cope with the fluctuation of data, a 100 replications should be justified.
2. Layout: A0 (base), A1 (high density at the edge), A2 (arrange from high density to low)
3. Walking policies: W1(one way direction), W2(two ways directions)
4. Terminated condition: until all work has been completed. This is to measure the time required to finish the task for labour efficiency calculation. Therefore, we cannot terminate the simulation with time conditions.

6.6 Simulation Results

Table 6-4: Computer Simulation Results.

	Line/manHr	Time in buffer area (hr)			Average time of a pallet (hr)						Picker Ultility
					S-Size			M-size			
		Average	Half width	Max	Average	Half width	Max	Average	Half width	Max	
A0W1	17.17	24.98	0.6	145.55	25.91	0.69	146.27	24.92	0.56	146.00	0.990
A0W2	33.38	3.5961	0.05	13.97	3.69	0.04	14.24	3.94	0.05	14.47	0.890
A1W1	24.94	24.848	0.69	127.30	25.78	0.80	128.10	24.79	0.63	128.24	0.990
A1W2	33.89	3.4935	0.05	14.04	3.60	0.05	14.30	3.83	0.05	14.65	0.880
A2W1	24.49	25.6314	0.71	138.20	26.65	0.82	139.00	25.52	0.66	138.95	0.989
A2W2	33.84	3.6076	0.04	14.66	3.70	0.04	14.80	3.96	0.05	15.35	0.890

The computer simulation operates by running the flow through operation for one week with 100 replications. The computation results are shown in Table 6-4.

These 100 replications are aimed to provide statistic of the distribution results. They will then be analysed for selecting the most suitable concept of the distributing area. As mentioned in chapter 5, there are 3 different store layouts. Each of them consists of two different walking policies. The possible combinations of proposed design are listed in the table.

When considering line per man hour, it turns out that the result of (A0W1) is similar to the actual data. However, the time consumption, which a pallet spends in buffer area and distributing area, is different. This is because, in reality, there is the manager who controls the flow, decides which pallet should be taking care of, and clears the area for better productivity. But in the simulation, there is no manager or algorithm help to decide.

The relationships of maximum time between small and medium size pallet are the additional maximum time in the buffer area and the distributed activity. With this relationship, the distributing time is much smaller than the waiting time.

Maximum spending time for s-size and m-size pallet can be significantly different between one way and two ways walking policies, as shown in Figure 6-7.

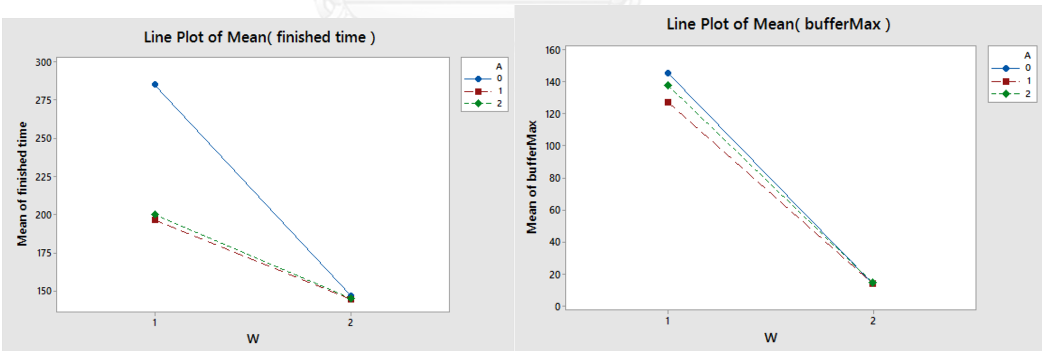


Figure 6-7: Plot of mean finished time (left) and mean maximum time in buffer area(right) with the variation of two walking policies and three layouts.

There are graphs of the finished time and maximum time for a pallet to spend in the buffer area is shown in Figure 6-7. They illustrate the results comparison of each walking policy with different layout design. For “two ways (W2)” walking policy, all three different layouts consume shorter time of operation because a picker travels in a shorter distance. As expected, the increasing of line per man-hour comes from eliminating the walking distance out of an unnecessary aisle. For the three different layouts, A1 shows the longest time of all. However, computer simulation shows an insignificant result once two ways walking policies are applied (see Figure 6-8).

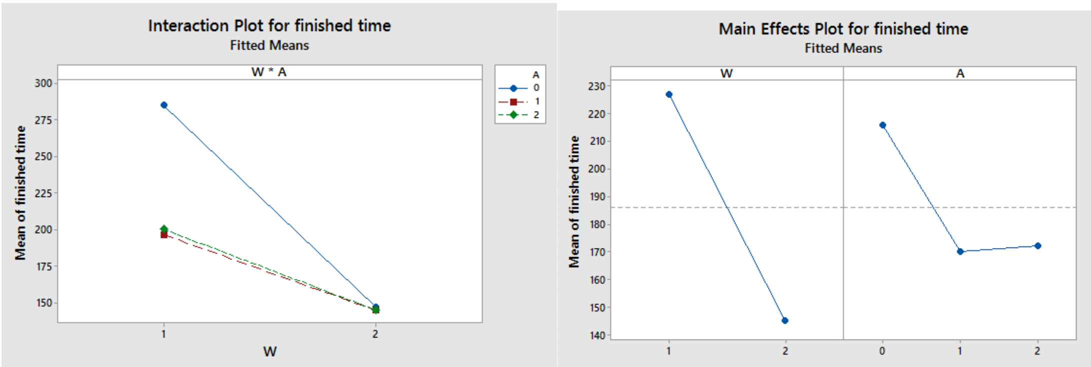


Figure 6-8: Interation plot (left) and main effect plot (right) for finished time related to the change in walking policies and layouts.

Figure 6-8 implies that the walking policies have a much higher effect on the productivity in the distributed area. A0 layout shows a larger gap in mean finished time than the maximum time in the buffer area. This is because many of the pallets from A0 layouts are queuing and causes the finished time to be delayed.

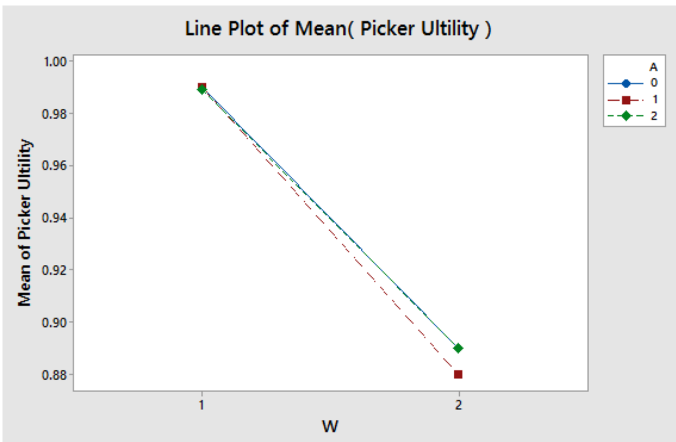


Figure 6-9: line plot of mean picker utility from computer simulation.

The line per man-hour shown in the Table 6-4 is calculated with a fixed number of pickers. In A1W2 and A2W2, the picker utilised is 0.88 and 0.89 respectively. The picker utilised from the computer simulation results include distributing activities, walking, queuing and waiting from congestions. Therefore, lower picker utilization, implies lesser waiting time. If the setting of Company DC allows pickers to work with 95 percent utilization, A1W2 and A2W2 can eliminate one or two pickers to increase the line per man-hour.

From the result, the concept of A2 layout was supposed to improve the average time to completely distribute a pallet. However, it does not show any significant differences from the A1 layout. This is because products do not only go to high probability stores, but also to low density stores. This probability forces more than half of the pallets to travel through all the aisles. (see Figure 6-10).

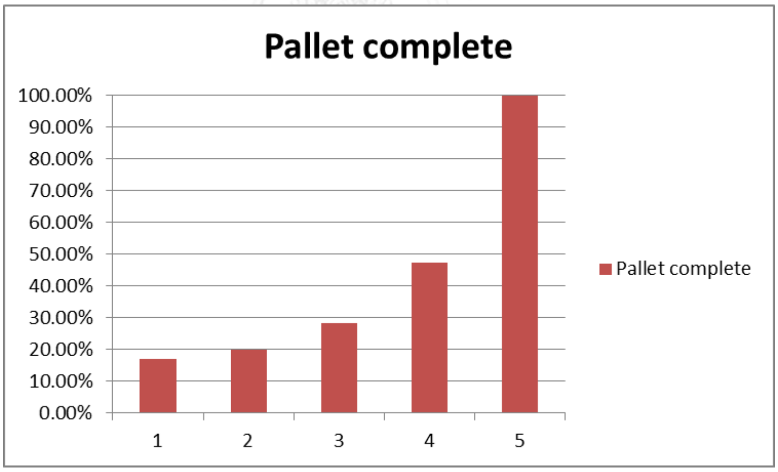


Figure 6-10: Percentage of completion in distributed pallet related to number of aisle visits.

Figure 6-10 shows the percentage of completed pallet when it is pushed through aisles. For example, 20 percent of the total pallets are completely distributed within the first 2 aisles. This explains why A2 layout does not yield better results than A1. Approximately 50 percent of all pallets need to walk through four aisles before being empty. Therefore, the concept of quickly completing a pallet is not valid for this operation.

From the simulation results, the best practice for distributed area, which Company DC should implement, is the A1W2. As mentioned, the current operation has 28.46 lines per man-hour, which the A1W2 yields 33.89 lines per man-hour according to computer simulation. The difference is approximately 19 percent increase.

7 Conclusion

In conclusion, after the implementation of walking policies and two different layouts (A1 and A2), the results from computer simulation show that the effect of walking policies has a higher impact on the labour efficiency of the distributed area. Once, the two ways walking policy is applied, relocating high visit density stores at the edge of each aisle yields the best outcome. The suitable solution for the distributed area for Company DC, based on the four months data, Company DC is to promote two ways walking policies to significantly increase the efficiency of the distributing activity. Once Company DC allows two ways walking policy, the next beneficial factor is the arrangement of store locations. As the result from computer simulation, the best result from the proposed concept if placing the most visited stores on the edge of each aisle and distribute the traffic based on the number of visits in each store to allocate the traffic equally. A1W2 yields 33.89 lines per man-hour in computer simulation. **Compared to the actual operation (28.46 line per man-hour), the A1w2 improves 19 percent from the original design**

7.1 Limitation

The new proposed designs are based on the assumption that the characteristic of stores remain the same. The validation of these arrangements is dependent on the changes of stores' demands and characteristics. Or else it would require the DC to update the store location to adjust with the current flow. Another disadvantage from changing store locations is the confusion created to a picker because, as the original, store number is arranged orderly, which a picker can easily locate it in the store. Once changes to the store are made or updating the layout frequently, the productivity might be slowed due to the confusion of a picker.

Another limitation of this computer simulation is the decision of a picker, sometimes, it does not provide the same decision with the actual operation. For example, in a simulation, if a picker need to visit only the first zone of an aisle, he/she can walk to the first zone and turn back to walk into another aisle. However, in the simulation, it does not provide the same decision making as a human does. A picker, in simulation, needs to walk through the whole aisle without any condition.

7.2 Future suggestion

For future suggestion, these are the out-of-scope suggestions if the company DC is interested to run through computer simulations:

1. Separate the distributed area for small and medium size product: Since the maximum time for S and M sizes are significantly different; the separation of distributed area might help in congestion and consolidating the products. However, consolidation onto a pallet process needs to be verified because some store might not have enough volume to build with only small FT product or medium product.
2. Clustering stores: With the in-depth study of the behaviour of each store's orders, it might be possible to cluster stores with common products. Since, the store locations in the same region might have same characteristics of demands.
3. There are studies of pre-distribution and post-distribution for flow through operations, where products are pre-distributed before arriving at the DC (Tang and Yan 2010). This might be for further studies to reduce the total sorting time of the flow through operations. However, the trade-off between reducing the workload of sorting facilities and reducing the cost of transhipments need to be concerned.

7.3 Academic Contribution

This thesis explores a gap in manual storage and walking policies with the ordering picking in cross dock operation.

Form the findings in literature reviews, most of the labour-intensive operations are focused on storage policies, and walking polices for storage area. There are several proposed concepts and suggestions to improve the productivity in the warehouse. However, there is no specific design or concept, which is mainly focused on manual order picking area for cross docks. Currently the research or the academic study has shifted into semi-automated activities and automated warehouse. Even though there are still many companies that are still practicing manual picking process due to flexibility or the procedures of products, but most of the data and concepts are protected information.

Without any doubts, the trend of automated warehouse is coming. However, automation in Thailand might take time due to the unsystematic procedure and low labour cost, many flow through distribution centres still continue to sort and distribute products manually. There are only few organisations which have developed the picking process into semi-automation or automated order picking. Therefore, if an organization needs to maintain to manual process, it must rely on either the open-source case studies or on trying to implement these processes themselves. This is how this thesis has contributed to the academic field.

The implementation and assumptions, which are stated in this thesis are able to re-configured, so that they can be adapted or implemented to other order-picking practices.

7.4 Reflective Writing

This thesis is mainly focused on applying concepts to the manual order picking operations in the flow through process of a distribution centre. However, each order picking operations of distribution centres are different. Therefore, each DC does not share the same factor as the Company DC. The amount of data being calculated and collected in the Company DC is unexpectedly massive. Even through the regulations and IT system of Company DC is well managed, the data used in this thesis needs to be clarified carefully because DC's system allows human to override data. In order to treat such massive data, deep understanding of the behaviour and activities of all operations related to the flow through activities is needed (included the area where put away product and Flow through are being consolidated). Unexpectedly, this procedure takes time.

Another "should have done" issue is the implementation of the A2W2 concept in the actual operation to see the possibility of improvement and limitation in an operation. Since, the products being distributed and policies are different among distribution centres, at least by scaling down the A2W2 concepts into small experiments, we might see the limitation of the concept better. For example, in the thesis, the average drop time is assumed and concluded into one single value. However, in actual operations, this might be different due to the sensitivity or the size of the products. The average value might not be suitable enough when concerning the variation of congestions.

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