IMPROVING OPERATIONAL EFFICIENCY OF AN SME FURNITURE WAREHOUSE

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นรุตม์ ก้องธรนินทร์ : การปรับปรุงประสิทธิภาพการดำเนินงานคลังสินค้าเฟอร์นิเจอร์ธุรกิจขนาดย่อม (IMPROVING OPERATIONAL EFFICIENCY OF AN SME FURNITURE WAREHOUSE) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร. มาโนช โลหเตปานนท์, 100 หน้า.

วิทยานิพนธ์ฉบับนี้จัดทำขึ้นเพื่อศึกษาการประยุกต์ใช้วิธีการจัดการคลังสินค้า และ สินค้าคงคลังในคลังสินค้า ของบริษัท เฟอร์นิเจอร์ ธุรกิจขนาดย่อมที่ตั้งอยู่ในประเทศไทย ก่อนหน้านี้ คลังสินค้าของ บริษัท มีการบริหารคลังสินค้าเพียงเล็กน้อย แต่เนื่องจากยอดขายที่เพิ่มขึ้น จึงทำให้กิจกรรมภายในคลังสินค้านั้นเพิ่มขึ้นตามไปด้วย ด้วยเหตุนี้การปรับปรุงการดำเนินงานมีความสำคัญต่อการเติบโตของบริษัท

งานวิจัยนี้มีวัตถุประสงค์เพื่อเพิ่มประสิทธิภาพในการดำเนินงานของบริษัทกรณีศึกษา โดยลดเวลาการหยิบสินค้าและลกสินค้าที่ไม่มีการเคลื่อนไหวด้วยการใช้ลีน 5ส นโยบายการหยิบสินค้าตามใบสั่งจัด การลำดับความสำคัญด้วยการวิเคราะห์แบบ ABC (ABC Analysis) การปรับปรุงผังการจัดเก็บสินค้าตามระดับความสำคัญ

จากผลการศึกษาวิธีการดังกล่าวช่วยเพิ่มประสิทธิภาพในการดำเนินงานของการจัดสินค้าก่อนการนำส่ง ทั้งในแง่ของเวลาการดำเนินงาน โดยเวลาที่ใช้ในการเดินลดลง 71% เวลาค้นหาลดลง 84% และเวลาหยิบสินค้าลดลง 41% อีกทั้งยังสามารถลดจำนวนสินค้าคงคลังที่ไม่มีการเคลื่อนไหวลงได้อีก 8% นอกจากนั้น วิทยานิพนธ์ฉบับนี้ยังสามารถใช้เป็นแนวทางปฏิบัติสำหรับการจัดการคลังสินค้าของธุรกิจขนาดย่อมเพื่อเพิ่มประสิทธิภาพในการดำเนินงาน

ภาควิชา	ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต	ลายมือชื่อนิสิต	....
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This dissertation investigates the application of warehouse and inventory management methods on an SME furniture warehouse based in Thailand. The company's warehouse had very little implementation of warehouse management. As sales have been increasing, activities within the warehouse also increases, improvements to the operation are critical to the company's growth. The objective of this research is to increase the operational efficiency through reducing order picking time and inactive products using lean 5S, order-picking policy, ABC analysis and class-based storage location assignment policy. The methods have proven to significantly improve the operational efficiency of order-picking activity and overall inventory condition by decreasing walking time by 71%, search time by 84%, pick time by 41% and inactive products by 8.25%. This work can serve as a practical guideline to SME warehouses as a method of increasing operational efficiency.

Department:	Regional Centre for Manufacturing Systems Engineering	Student's Signature	....
		Advisor's Signature	....
Field of Study:	Engineering Management		
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1 Introduction

1.1 Rationale and Background

This project is a case study based research on a Thai furniture company: Fur-9 Company Limited. The company acquires furniture through transactional based relationship where most of its suppliers are based in China and Thailand. The company's customers are based in Thailand. There are 4 main sale channels: website, store, trade fairs and project sales. The company was established in 2009. Currently there are over 2,200 stock keeping units aggregated into 10 product lines and stored inside 5 warehouses with a total area of 3500 square meters located in Bang-na trad road, Samuntprakarn, Thailand.

Products are purchased in large quantities because of the manufacturer's minimum order quantity requirement and high lead time from manufacturing and transportation processes. The usual lead time ranges between 41 days and 90 days which sometimes can go up to more than 172 days depending on the manufacturer. Purchasing are done manually by the managing director every week through revision of the remaining stock.

The company currently has 10 product lines:

1 – Dining Chair,

2 – Office Chair,

3 – Recliner,

4 – Lounge Chair,

5 – Stool and Bar Chair,

6 – Sofa,

7 – Tables,

8 – Rattan Outdoor Furniture,

9 – Side Table, and

0 – Others (e.g., Cupboards and spare-parts).

Currently, the products are kept on shelves within the 5 warehouses layout as shown in Figure 1, where location of the product stored depends on the availability of the shelves. Moreover, allocation of the product also depends on its product line, e.g., Product Lines 1, 2, 3, 4, 5, 6, 8 and 0 are kept in Warehouses 21, 23 and 25 while Product Lines 7 and 9 are kept in Warehouse 24. Warehouse 22 will only be used to keep products that are damaged. Previously, there have been some management in the warehouse however there have been no significant actions taken. Stocks within the warehouse are rapidly increasing with the increase in product range and product sales. The sales demand for the coming year is expected to increase through enforcing higher project sales and increased product range. As inventories and movement of products within the warehouse is increasing; inefficiency caused by unmanaged warehouse also increases. The following figure 2, shows the processes and activities within the warehouse.

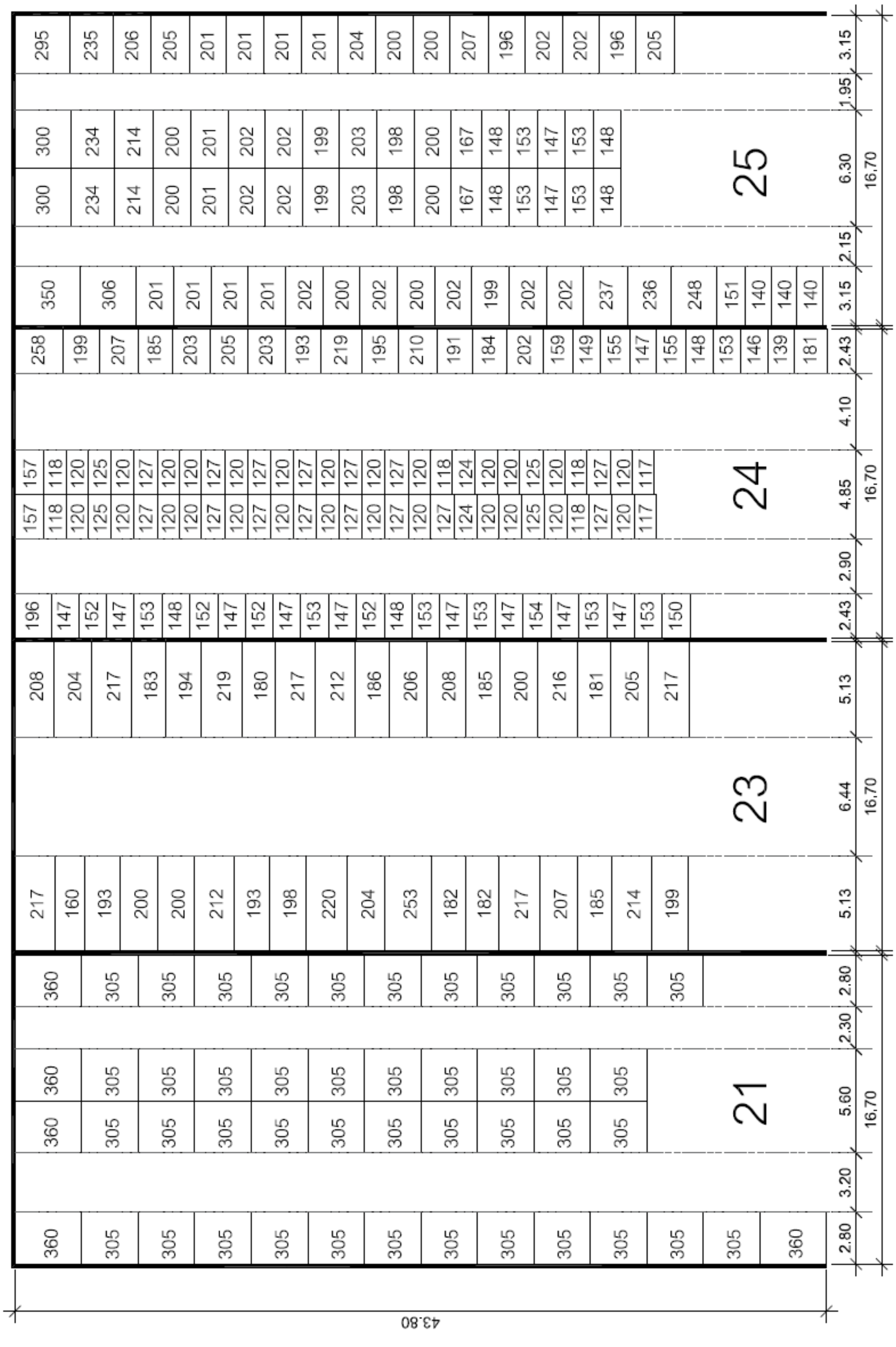

Figure 1: Warehouse Layout

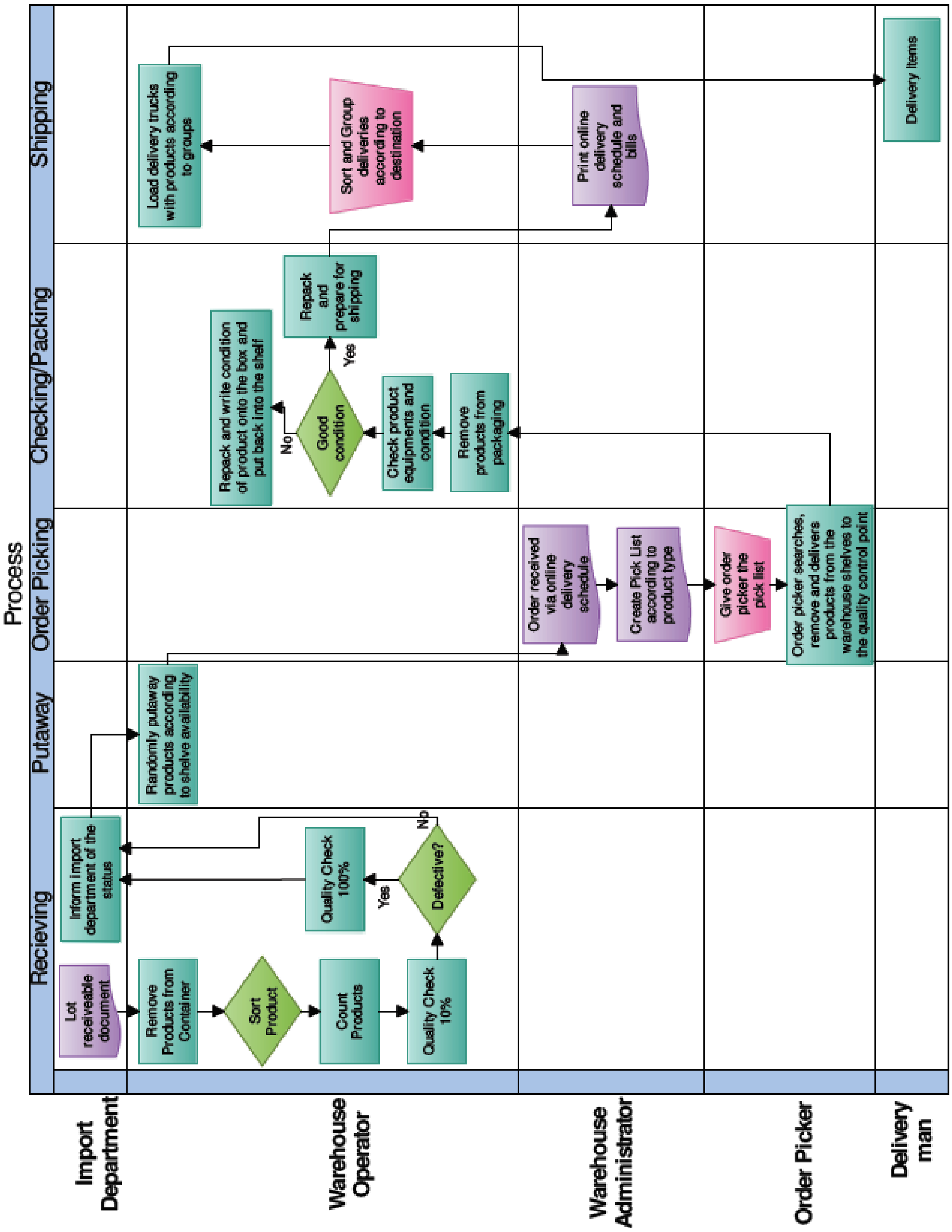

Figure 2: Warehouse Activities Swim Lane Diagram

Figure 3: Condition of Warehouses

From figure 2, major activities can be categorized into two groups: (i) receiving and put away and (ii) order picking and shipping or delivery of goods. In the first group, a schedule and product receipt document will be created and send via email from the import department to the warehouse department. Here the warehouse department will use this document to receive products. A usual 10% quality control will be enforced on the received products and if any of the products are found to be defective, a 100% quality control will be done. After the quality control procedure, the warehouse department will inform the import department of the result which will then be input into the accounting system. The products received will be put-away randomly into warehouse shelves where only product lines 7 and 9 will be allocated to warehouse 24.

In the second group, customers order will be made through 1 of the 4 channels: sales from showrooms, sales from booth, sales from projects or sales from website. Each point of sales is responsible for processing customers order into the accounting system and into the warehouse online excel delivery queue as shown below in Table 1.

Table 1: Delivery Queue

Note	POS	Delivery Date	Sales	Delivery Person	Bill Number	Customer Name	Place of Delivery	Contact	List of Products	Amount
ก่อน 12.00 น. โทรก่อนส่ง ส่งชั้น 23 ติดต่อยามว่ามาส่งของ ใส่รองเท้าผ้าใบในการขนส่ง/มีลิฟท์(ใบกำกับภาษีส่งพร้อมของ)	ลาดพร้าว	01/07/2559	วัชรพงษ์	มิ่ง096-0739859	SA055905-151	บริษัท ซิมเปิ้ล สแปซ ฯ จำกัด	อาคารคิวเฮ้าส์ พระราม 4	คุณยีน 083-0727306	00071-B สแปร์พาร์ท ขา ทอล์ค ทู (คืนจาก RS)	10
									900055-01 ท็อปไม้ particle board 80 ซม. สีขาว	10
เลื่อนจาก 29/6/2559	ลาดพร้าว	1/7/2559	พรทิพย์	ปิ๊ก092-8275677	SA055906-027	มูลนิธิ โครงการหลวง	มูลนิธิโครงการหลวง	คุณฝ้าย 099-1982519	040106-04.1เก้าอี้แฟนซี ฟอรั่ม-สีน้ำตาล	4
							มหาวิทยาลัย เกษตรศาสตร์	คุณแสวง 089-4975065	000083.1สแปร์พาร์ทขา-นิว สลิม แบล็ค	4
									90052-808967NTหน้าTopไม้ Particle Board 80*80*2.5ซม.ลามิเนต	4
แก้งาน (12.00-13.00)	ลาดพร้าว	01/07/2559	พรทิพย์	มิ่ง096-0739859	SA055906-150 16/00111	บริษัท ชริสา แมนชั่น จำกัด	ทองหล่อ	ฐิติพงศ์ 086-3870757	070210-0118.1ตะกลางวีวู้ดเลค-ท็อปสีขาว/ขาสีบีช (หน้าท็อปสีถลอกฐานสีขาวเป็นสนิม -เปลี่ยนตัวใหม่ให้ลูกค้า)	1

Once the customer's order has been processed, the warehouse department will use the delivery bill and the delivery queue to process into a blank pick list for the order pickers which will be used to pick the products within the 5 warehouses. The products will be picked on a cart and then delivered to the quality control area where products will be checked and repacked ready for delivery. Products that does not pass the quality control area will be replaced and left at Warehouse 22. Products are then loaded onto a delivery truck according to the bills.

In order for the company to improve operational efficiency and customer satisfaction, it is suggested that warehouse and inventory management is to be carried out which would eliminate different types of wastes that can be seen. According to the work experience directly within the company warehouse operations, the problems can be summarized into the following:

- Time inefficiencies occurs through order handling processes within the warehouse as products are unallocated as shown below

Table 2: Summary of order picking time

Summary	Percentage	Minutes
Walking Time	1.27	3.5
Search Time	86.17	236.98
Picking Time	12.55	34.52

- Unallocated products cause high number of stock discrepancies

Table 3: Summary of missing stocks

Date of Audit	Excess		Missing		Summary	
	Amount	Value	Amount	Value	Amount	Value
04-07/07/15	34	113,050.00	44	132,430.00	78	245,480.00
16-21/09/15	13	41,850.00	27	93,300.00	40	135,150.00
18-25/11/15	7	26,500.00	16	37,700.00	23	64,200.00
16-19/02/16	12	46,530.00	23	70,760.00	35	117,290.00
06-09/04/16	10	23,300.00	33	73,800.00	43	97,100.00
Total	76	251,230.00	143	407,990.00	219	659,220.00

- Unseparated product condition causes high number of delivery errors

Table 4: Number of delivery errors

	March	April	May	June	July
Delivery Errors	25	16	22	20	21

- High inactive and damaged stocks cause low turnover rate

- Unmanaged inventory causes bad inventory condition and cash conversion cycle

Table 5: Summary of inventory values

Inventory Value	Sales	Turnover
26,219,214.13	37,686,007	1.4373

1.2 Objectives and Aims (expected benefits)

The objective of this study is to increase the operational efficiency through reducing order picking time and inactive products while improving cash conversion cycle using warehouse and inventory management tools.

The primary aims are as follows:

- Reduce order picking time,
- Reduce inactive products and
- Improve cash conversion cycle

The secondary aims are as follows:

- Reduce stock discrepancies and
- Reduce delivery errors

1.3 Scope of study

The scope of this study is to investigate the company's warehouse and inventory system in order to analyze, plan and implement improvements to achieve the targeted aims and objective. The focus will be taken place in 4 of the 5 warehouses located in Samutprakan with 2,800 square meters of space and 2200 SKUs. There are 5 warehouses however one of the warehouse (warehouse 22) will not be in the scope of study as products are defective and waiting to be repaired or claimed from suppliers therefore doesn't effect picking time nor inventory value as defective products are excluded from this study. Information and data that will be used in this study will be obtained directly from warehouse management and accounting sector of the company which will be used to analyze, plan and implement the appropriate improvements. The study will be limited to the time frame of 3 months, which some improvements is expected to be seen. Since this is a case study based research, most of the expected results will be obtained from previous literatures which will be used as reference to this project.

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2 Literature review

2.1 Literature Review Introduction

The literature review will cover an introduction to warehouse and inventory management. The scope of warehouse management, warehouse operations will be discussed in detailed focusing on put-away and order-picking activities. The author will then introduce lean 5S defining each of the elements, its importance and benefits. The scope of inventory management will include ABC stock analysis and cash conversion cycle will be discussed in detailed. All of the elements in this literature review will be supported by case studies which will be summarized and used to define expected benefits.

2.2 Warehouse management

Warehouses has always been viewed as cost centers which does not add any value to the supply chain. However, the world we live in today is becoming more globalized, consumers are demanding more creating greater unpredictability. Warehouses serve the purpose to balance the supply and demand uncertainty achieving high customer satisfaction while minimizing costs. Statistics in the US and Europe shows that warehouse capital and operating costs is about 22% to 25% of the logistics costs (Baker and Canessa, 2009). As it is closely related to service levels and logistic costs, warehouses must be design and operated efficiently to gain competitive advantages. Mentioned by Motorola (2013) “warehouses and distribution facilities as historically underleveraged centers that can drive competitive differentiation and, by doing so, increase profitable growth.”

First and foremost a warehouse should act as a dock where all products received are stored in an allocated space. The product should be safe and easily recognizable within that allocated space. In dispatching, the operation should be done as quickly, effectively and efficiently as possible. The basic processes of warehouse management remain the same over time. To receive goods into the warehouse, store, secures, process orders, replenish, include some value adding services and then dispatch (Richards, 2014). Warehouse management is a technical procedure to manage storage, movement and security of the products to maintain quality, effectiveness and efficiency increasing profitability for the company and value for the customer (Cormier and Gunn, 1992).

2.3 Warehouse operations

Warehouse management relies fundamentally on managing space and time which is considered the two most valuable and costly resources. The smallest countable unit of physical products or raw material kept in the warehouse are called stock keeping unit or SKU, SKUs are usually smaller as products travel downstream in the supply chain towards the end user (Bartholdi III and Hackman, 2014). Within a warehouse, each storage space is assigned with an address which is unique and forms a location.

Warehouses need to reorganize and repack products for delivery to its customers. For example, a product arrives in a pallet scale is reorganized and repacked into cartons or pieces then sent out to each customer. This causes warehouses to be very labor intensive driving the operation costs very high, the smaller the SKU the greater the cost. The typical processes and activities of a warehouse to reorganize products can be categorized into inbound and outbound. Inbound processes include receive and put away, where outbound processes include order-picking and delivery. Within all the reorganization processes, order-picking process can be the most labor intensive activity and costly therefore will be focused on most.

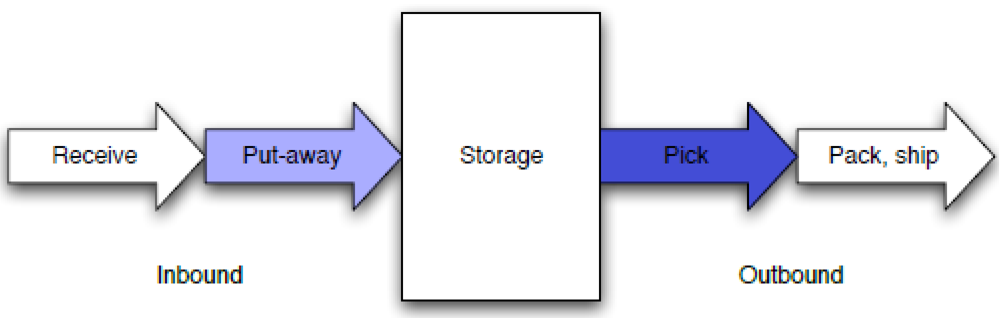


Figure 4: Warehouse processes

(Bartholdi III and Hackman, 2014)

1. Receiving

Products arriving at the warehouse will first need to be receipt into the system. The activities within the process usually involves advance scheduled receipt, unloading of products, quality inspection and documentation. The process usually costs around 10% of the warehouse operation costs.

2. Put-away and Storage

After the products are received into the warehouse, the location of storage must be determined. The determination of location for each product will largely depend on the popularity or the movement of the product as this effect the cost of retrieval. Products with more movement will need to be stored at location which can quickly and efficiently be retrieved i.e. minimize travel distance. After the products are put-away into pre-determined locations, documentation of the location must be done as this will later be used in order picking process to create an efficient pick list for order pickers. The process usually costs around 15% of the warehouse operation cost (Bartholdi III and Hackman, 2014).

3. Order-picking

As demand for a product arises, orders generated must be checked to verify product availability. A pick-list must be created according to the orders then order-picking must be performed according to the pick-list effectively and efficient to process the demands. Other documents such as delivery bills will also be prepared at this process. Within a warehouse order-picking accounts for most of the warehouse operation costs which is normally at 55% because it is very labor and capital intensive (Gu et al., 2007). The operation costs of order-picking typically consists of the following:

- Travelling 55%
- Searching 15%
- Extracting 10%
- Paperwork and other activities 20%

Referring to the figures above, it can be seen that in regular warehouse travelling is the costliest activity in warehouse operations. Order picking efficiency can be improved through increasing SKU density, the higher the density the lesser the travel and through the use of optimization order-picking techniques.

4. Checking, packing and delivery

Checking and packing products can also be very labor intensive as every product must be handled by an operator. Products are not only checked for defects however the accuracy of orders are also checked. Order accuracy is one of the most important aspect of service quality. Any mistakes made in delivery causes unsatisfied customer and also very expensive to return. Return or reverse logistic generally costs 10 times more than normal logistic costs (Bartholdi III and Hackman, 2014)

2.4 Order Picking

Order picking is a process which involves the retrieval of products from storage locations based on customer's order. As mentioned earlier, order picking can cost 50% to 75% (Petersen, 2002) of costs relating to warehouse operations (Henn et al., 2012, Petersen and Aase, 2004). This cost largely derives from the fact that the process is still reliant on labor to operate the process as the capital cost for automated system is very high. There are mainly 2 order picking systems, though it can be separated into many varieties, commonly in use which are:

- Picker to parts system – Order-pickers moves by foot or vehicle within the warehouse. Orders can be picked sequentially or in parallel.
- Low level picker to parts – Products are accessible from warehouse floor and within reach of pickers without any extra equipment, picker travels on foot
- High level picker to parts - Products are not accessible from warehouse floor, not within reach of pickers and needs extra equipment to aid picking.
- Parts to picker system – Products are retrieved from the storage location through the use of automated machines. There are many types of automated machines the most commonly used is automated storage and retrieval systems (AS/RS) (Horvat, 2012).

An attempt to reduce operating cost through the use of automated system to reduce labor in warehouse has been suggested however most warehouses still use picker to parts system, in fact over 80% of the warehouses in western Europe uses low level picker to parts due to its simplicity (Henn et al., 2012), flexibility in SKU size and shapes and low capital cost involved (Petersen and Aase, 2004). Optimization of order-picking is an alternative to reduce costs and increase efficiency of operation which in practice has shown significant reduction results. Order-picking optimization involves 4 factors, storage policy, order consolidation policy, routing policy and layout design. There are many attempts (De Koster et al., 2007) in literature to considered these factors in conjunction with each other however in practice, due to the complexity of each warehouse environment, they are considered individually. Layout design will be omitted in the discussion due to its practicality in improvement implementation.

2.4.1 Storage Policy

Storage or put-away policy focuses on the location assignment of the products when it has been received into the warehouse. The most common type of storage policy includes dedicated, randomized and class based. In dedicated, a storage location is assigned with only one product, this makes it easier and more efficient for order pickers to pick orders as they can memorize and get familiar to the storage locations. However, as storage locations are dedicated to one product, on average the utilization is only at 50% capacity. In randomized, a storage location is assigned with 2 or more products, this significantly improves utilization of space but workers will not be able to memorize locations therefore order picking efficiency decreases. This method requires warehouse to have a systematic and disciplined approach towards processes and activities (Bartholdi III and Hackman, 2014).

2.4.1.1 *Classed Based Storage*

Class based storage is a combination of random storage and dedicated storage. Each class is assigned to a dedicated area within the warehouse where products with the same class are kept in this area at random. For this, the method decreases space utilization when compared to random storage but is more efficient than dedicated (De Koster et al., 2007).

Class-based storage is similar to volume-based storage policy which separate products into classes. The classification of products can be determined in many ways such as its value, volume or turnover rate. Typically, products are separated into classes through the use of Pareto’s 80/20 rule where 20% of the SKU would contribute to 80% of the demand volume. Mostly, products are classified by its demand volume, the larger the demand for the product the closer the drop-off point. Products with the highest demand volume will be called class A product, products with the next highest demand volume is called class B products and so on. In practice, products are usually classified into class A, B and C hence the method is also called ABC class-based storage (Chackelson et al., 2011). Further classification of A, B and C products can be found in section 2.9 below. There are mainly 4 types of variations that exists for defining the class areas which are diagonal, within aisle, along front aisle and along front and rear aisle as show in figure 5 below.

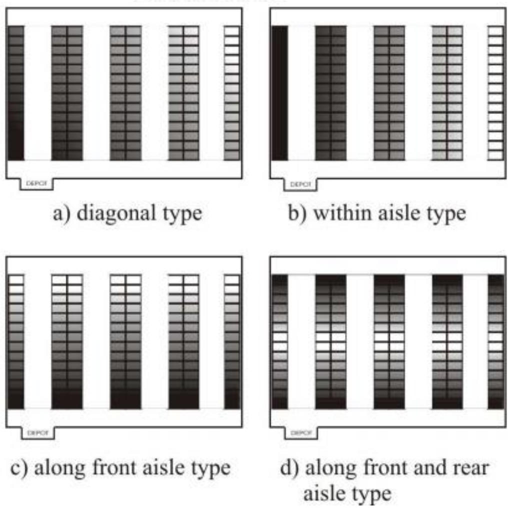


Figure 5:Storage configurations

(De Koster et al., 2007)

The two most common way in implementing class-based storage is within aisle and along front aisle or across aisle storage. It is arguable which of the two is best, Jarvis and McDowell (1991) suggests that within aisle storage is best. As proposed by (De Koster et al., 2007), across aisle storage is close to optimal with return policy. Petersen (2002) proposes that within-aisle product positioning is able to reduce travelling significantly more than across-aisle storage in a relatively large pick list however yield similar results where pick -lists are small. Nevertheless, there are no fixed rules in defining the class areas as it depends on many factors including order size, warehouse design, routing policy and order picking policy.

The benefits of classed based location assignment policy include reducing operating cost significantly as travel times are reduced (Petersen and Aase, 2004). The method is able to reduce travelling distance by over 16%. Chackelson et al. (2011), Thongsuchoti (2009) identified *that a 3.2 meters of rack-to-store travelling distance was reduced through the use of this method. Costs reduction of up to 15.7% was able to be obtained through implementing ABC—analysis together with class-based storage* policy (Tadokoro, 2014). (Petersen and Aase, 2004) recommends class based storage with 2-4 classes over volume based storage as it is easy to implement and control because it is less data sensitive requiring less administration cost. According to Petersen (1999), using class-based storage with within-aisle product positioning is able to obtain overall cost savings of 15.9 percent compared to random storage. Furthermore, Petersen and Aase (2004) shows that the use of class-based storage policy is able to obtain similar savings of 17% to 22% overall order fulfillment time to implementing order batching while being easier to implement and less sensitive to order sizes and order volume. Lastly, due to its flexibility the method is able to be implemented with all routing policies even though some routing policy in combination of warehouse layout can be more beneficial than others (Sánchez González, 2014).

2.4.2 Routing Policy

Routing policy focuses on minimizing travelling for the order picker through sequencing the pick-list generated. Routing policy can be fixed as well as customized individually to achieve the lowest travel distance. There are generally two routing algorithms which are heuristic and optimal. Optimal algorithm first introduced by

Ratliff and Rosenthal provides the optimal solution to reducing travel time (Petersen and Aase, 2004). However, in practice optimal algorithm are frequently not use due to its complexity, not appropriate to all types of warehouse layout, routes generated sometimes can be illogical which causes picker to diverge from the routing and doesn’t take congestions into account (De Koster et al., 2007). Therefore, in practice heuristic algorithm is used as routing policy which gives a near optimal solution while being more easy and flexible (Petersen, 2002). Heuristic algorithm uses mainly standardized routing which consists of return, s-shape, mid-point and largest gap. In return strategy, the picker starts from the front cross aisle, travels to all pick location within the aisle then returns to the front cross aisle then moves to the next aisle. In s-shape strategy, the picker traverses the aisle with one or more pick location entirely then reenters the next aisle with one or more pick location from the back cross aisle. In mid-point strategy, the picker traverses from either the front or the back cross aisle to the pick location depending on which cross aisle is closer to the pick location. Largest gap strategy is similar to the mid-point strategy but instead of traversing to the mid-point, the picker traverses as far as the largest gap (De Koster et al., 2007).

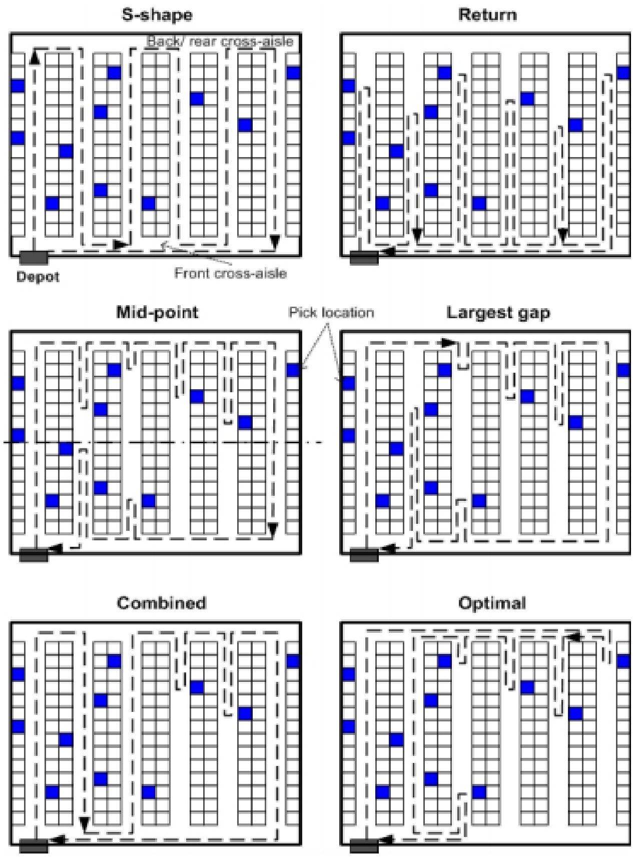


Figure 6:Routing approaches

(De Koster et al., 2007)

2.4.3 Order Consolidation Policy

Order consolidation or order picking policy is concerned with the creation of picking-lists from customer's order. Depending on the design of warehouse, the most common methods of order picking are single order picking, batch picking, zone picking. These 3 methods can be used individually or in combination to achieve the highest efficiency in terms of cost and time.

2.4.3.1 *Single Order Picking*

Single order picking is one of the most common method used as order-picking technique because of its simplicity. It is commonly used with low-level picker to parts system such as bin storage where orders are in small quantities with high variability. The complexity is reduced because one picker fulfills one customer's order. This method is usually preferable for its easily and low capital cost for implementation (Petersen and Aase, 2004). However, single order-picking is considered the costliest and timeliest order-picking method as it does not minimize travelling for order pickers.

2.4.3.2 *Batch Picking*

The second order-picking technique is *batch picking*. A method to improve efficiency of order-picking is to batch orders into a picking list. Customer's orders are batched into a picking list until the capacity of the pick-list is reached. Capacity of a pick-list can be defined by the capacity of the equipment to hold the product, weight and pick time. The batching of orders can be separated into 2 types which is static and dynamic. In static batching, all information regarding the customer's order is known when the orders are being batch however in dynamic batching, the information of customer's order are not all apparent and becomes available during picking. In most cases, a static order batching situation is assumed (Henn et al., 2012).

Since customer's orders are batched into a pick list, sorting of products is required. Sorting of products to meet customers order can be done during the picking or after the product has been picked, this is called sort while pick or sort after pick. The differences are that for sort while pick, extracting time increases as products needs to be sorted while sort after pick needs additional space and labor (Bartholdi III and Hackman, 2014). In most situations the former is more preferable as additional sorting procedure will not be required. Moreover, a customer's order will not be separated between pick orders as again, sorting and consolidation procedure will be required. There are mainly 2 criteria toward order batching which are proximity of pick locations and time windows. Generally, orders are batched according to proximity of pick locations (Patil, 2007). There are 3 heuristic approach towards batch picking using proximity of pick locations which are namely priority rule-based algorithm, seed algorithm and savings algorithm (Henn et al., 2012). All of the three batching heuristics are based on the assumption that orders are not split between pick-lists and picked as a whole (Manzini, 2012).

Batch picking help increases the picks per minute for each of the order pickers as orders with products that are close to each other are put together increasing the pick density. As the capacity of a pick list is defined by either time, capacity of equipment or weight, it lessens the chance of having imbalanced workload. Similar to single order picking, no sortation is required as products are picked by orders (Parikh and Meller, 2008).

2.4.3.3 *Zone Picking*

The method of *zone picking* heavily relies on dividing the warehouse into picking zones which one or more pickers are then assigned to a zone and only allowed to retrieve products within the assigned zone (Petersen and Aase, 2004). Zone picking can significantly improve order-picking process as it can reduce travelling, reduce congestion, picker can learn to remember locations and an order can be picked simultaneously achieving better pick times (Muller, 2007). However, as orders are split into pick order according to zones, another sorting and consolidation process is required (De Koster et al., 2007). Moreover, zone picking can cause workload-imbalances in each pick zones causing idle times of pickers (Parikh and Meller, 2008). There are normally two zoning approaches which is sequential and synchronized zone picking. In sequential zone picking, a customer order is passed sequentially through each zone, the picker in each zone fulfills the customer order putting the products into a cart then passes the customer order and the cart to the next zone until the customer order is fulfilled. In parallel zone picking, a customer order is split but not combined into many pick lists and passed to order pickers in each zone simultaneously, once each pick list has been fulfilled, the orders are then consolidated to form customers order (Gu et al., 2010).

There are many literatures which studies the effect on picking efficiency. Parikh and Meller (2008) proposes a cost model to select zone and batch picking. Petersen II (2000), contributes many literatures to this sector which includes comparing single order, batch, zone and wave picking; comparing routing policies in random storage; studying order picking policies. He argues that zone picking is able to significantly reduce order picking time as reductions in travel time can be seen and it is a method commonly used. Mellema and Smith (1988) uses simulation to study order picking efficiencies based on warehouse design layout, storage policies, batch and zoning suggesting a combination of zone and batch picking can greatly improve efficiency. Petersen (1999) supports that batch zone picking allows pickers to increase pick efficiency with the cost of order integrity which increases error rate as orders need to be consolidated. The efficiency is also argued that it will decrease as volume increases.

2.4.3.4 *Other Picking Methods*

Other picking methods suggested by many literatures includes wave picking and bucket and brigades. Firstly, wave picking is a method used for grouping customer orders to increase the pick efficiency. Wave picking can also be viewed as a combination between batch picking and zone picking. Orders are commonly grouped by carrier, ship time, specified time to pick a batch of orders or the capacity of pickers or sortation facilities. Pick-lists are then distributed in wave amongst order-pickers in each zone to fulfill customer orders. A new wave can only start once the current wave has been completed. According to De Koster et al. (2007) many researches has found that wave picking can significantly improve efficiency of order-picking. Wave picking is also able to reduce the workload imbalance between order pickers. However, wave picking requires a sophisticated warehouse management system (WMS) with accurate mapping of product locations in order to optimize the waves. Wave picking are shown to be more effective in warehouses with large order size and high volume of orders (Letart et al., 2013).

Secondly, bucket and brigades is a method used to balance workload between multiple order pickers to increase picking efficiency through reducing waiting time. Bucket and brigades coordinates workers to assemble the customer’s order. There is a simple rule for this method “pick forward until someone takes over your work; then go back for more” (Bartholdi and Eisenstein, 1996). In detail, the first order picker starts with a pick list, he picks products and at a point transfer the pick list to the next order picker and he starts a new pick list. When all the order pickers are working on separate orders, the last order picker complete the order and deposits it, he then walks back to take over the order from the next closest order picker from the end point who then takes over the order from the predecessor until the first order picker has been reach where he starts a new order. The main key factor of bucket and brigades is in defining the point at which the order picker transfer the order, usually in order for the method to work, the order pickers must be arranged according to the speed of working from slowest to fastest (slowest starts, fastest finish). The main advantages of a bucket to brigades are that the order picking line will autonomously and continuously balance the workload (De Koster et al., 2007).

2.5 Warehouse Operation with Lean 5S

Lean manufacturing was first introduced by Toyota as the Toyota production system (TPS) (Addy-Tayie, 2012). The technique is fundamentally based on the aim of maximizing value while eliminating wastes. Originally, lean manufacturing was introduced as a technique for the manufacturing industry however nowadays its applicability extends to other industries such as logistics and warehouse.

Lean is largely being used in many other sectors because of its various benefits which includes reducing waste, customer centric, increase efficiency, increase productivity, maximize profit through operation cost reduction, increase service quality and customer satisfaction through faster response to customer demands and problems (Kong, 2007).

Continuous improvement and stability as one of the most important aspect of lean must be achieved by creating a good foundation of lean environment through the method such as 5S. The method is created to achieve a work environment of self-explaining, self-ordering and self-improving (Christiansen, 2015). 5S is a method that consists of sort, set-in-order, shine, standardize and sustain (Addy-Tayie, 2012).

- Sort or Seiri in Japanese

The initial step companies must take is to eliminate all unused materials, tools and equipment from the workplace leaving only the equipment that are needed for daily operations. Benefits includes increased productivity and equipment awareness. Technique regularly use is red tagging.

- Set-in-order or Seiton in Japanese

After the unnecessary equipment are removed, all of the necessary must be organized to enable efficient and effective accessibility of the material and equipment. Benefits include eliminating misplaced or lost material or equipment, and reduction in search times. Techniques regularly used are visual indications and shadow boards.

- Shine or Seiso in Japanese

Shine is the process that focuses on keeping work place, equipment and materials clean and in order. Benefits includes safer work environment, easier identification of problems such as damages and reduction of cleaning cost as cleaning is done as a daily routine.

- Standardize or Seiketsu in Japanese

Standardize is the process that focuses on standardizing the processes and operations achieving best practices. Benefit includes increase operation efficiency and decrease defects. Techniques frequently used includes standard operating procedures, checklist and flow charts.

- Sustain or Shitsuke in Japanese

Sustain is the process that focuses on sustaining the improvements achieved from the previous 4S. Without this element, the improvements made will soon disappear and work condition will return to its former condition. Discipline and commitment is the most important factor in this element.

2.5.1 The benefits of 5S includes:

- Clean and safe work environment for the operators
- Reduce lead time through reduction in equipment and product search time
- Reduce misplaced or loss of equipment and product
- Reduce stolen equipment and product
- Reduce equipment downtime from breakage
- Improve service quality from reducing defects and errors
- Reduction in operating cost

- Increase floor space. An automotive parts company (Kotelnikov) has shown a 45% increase in floor space through 5S implementation.
- Reduce travelling and motion (Christiansen, 2015)
- Improve inventory awareness

Puspitasari and Ardila (2016) has shown that 5S in Charoen Pokphand Indonesia Semarang was reportedly able to minimize defects, over processing and minimize inventory through good housekeeping and standardization of work. Gergova (2010) argues that improving warehouse management involve improving material flow, order picking and replenishment which can be achieved through 5S. It was reported that 5S created better work environment, better space utilization, inventory awareness and improve motivation.

2.6 Inventory management

Inventory on the other hand is closely related to warehouse which is often referred together as warehouse and inventory management. The definition of inventory as defined by Jacobs et al. (2014) is the physical stock of products or raw materials to satisfy downstream demand. Inventory is needed to cope with the demand as shortages of products or raw materials will cause disruption in production or service quality (Vrat, 2014). Inventory management is one of the important part of a supply chain system which must be monitored and maintained to achieve the most economical value and provide the appropriate level of customer satisfaction (Kyei et al., 2008).

2.7 Objectives of inventory management

The main objective of inventory management is to maximize customer service level and satisfaction while minimizing inventory value and costs. There are 3 costs that must be considered associated with maintaining inventory within an organization which are the following:

1. Inventory holding costs:

Inventory holding cost is referred to as the cost of holding a unit of product or raw material for a period of time. It is all costs associated with having an inventory. This includes costs such as warehouse, human resources, heavy equipment, damaged products, obsolescence, opportunity costs and insurances which can be grouped into capital costs, storage costs, service costs and risk costs. In inventory management inventory holding cost is usually the most expensive cost which can range from 15% to 50% of the inventory value (Vrat, 2014).

2. Inventory ordering costs

Inventory ordering costs are mostly associated with the cost of paperwork and human resources used to place an order for procurement or inventory replenishment, this includes both managerial and administration costs (Jacobs et al., 2014). The cost of ordering inventory depends largely on the complexity of the procurement procedures and are usually high for manual or complex procedures, low for automated or simple procedures (Vrat, 2014). Moreover, cost of monitoring and maintaining the stocks such as systems, inspection and planning are also included (Kyei et al., 2008).

3. Inventory shortage costs

Inventory shortage costs are mostly associated with the cost of not having inventory when demand exists. The cost depends largely on the effect of the situation towards customer. For example, stock out leads to loss of sales; backorder leads to penalty costs, loss of customer goodwill, delays and opportunity costs. To balance the trade-off is very difficult as measures towards the consequences which can be tangible and intangible is difficult to be specified. Cost of inventory shortage is normally 10 times the cost of holding inventory (Vrat, 2014).

2.8 Benefits of inventory management

There are many benefits from implementing inventory management these includes:

1. Reduce discrepancies between the system

The lead time between the processes or suppliers can be viewed as replenishment lead time. Inventory helps organization to better manage the uncertainty caused by suppliers.

2. Reduce effect of demand uncertainty

Demand uncertainty exists in every type of businesses, depending on the business environment demand uncertainty has more or less effect. The greater the uncertainty the greater the effect towards the organization. Inventory help organization manages and reduces the effect of demand uncertainties in the system (Jacobs et al., 2014). Types of demand uncertainty includes seasonal demand, bullwhip effect and trend.

3. Decouple the system

Keeping finish good stock or can be referred to as safety stock helps organization decouple the supplier and the retailer. It creates a buffer between the demand and supply of the product (Beauregard, 2015).

4. Increased profit

Inventory management results in inventory reduction therefore organizations are able to see increase in profit. Statistics in the United States shows that on average inventory costs 30-35% of inventory value (Jacobs et al., 2014) therefore reducing inventory reduces operation costs increasing profit.

Referring to the objectives, the benefits of inventory management can be concluded to improved service and customer satisfaction through reducing variability in the demand and supply. Moreover, as inventories are reduced, condition of the inventory is improved and therefore ultimately increase profit and liquidity.

2.9 ABC Analysis

ABC analysis is a method of inventory management analysis which is based on the fundamental of Pareto analysis or also known as the 80/20 rule. Pareto analysis is a statistical technique used in decision-making founded on the Pareto principle that states that 80% of the stock value is accounted by 20% of the products or 80% of the company’s total revenue is accounted by 20% of the products (Addy-Tayie, 2012). ABC analysis is therefore a statistical technique used to assign products into a category A, B or C according to the selected criteria. Commonly, the criteria that will be used is the value of the product. Since inventory is one of the major costs within a company and are often manageable, priorities must be assigned to the products so that management can establish inventory policies based on the categories (Ravinder and Misra, 2014). The categories are defined as follows:

- Class A products

Products which are classified as Class A are usually accounted for a large amount of revenue but a small number of SKUs. Here the Pareto principle applies, approximately 10% to 20% of the SKUs generates 70% to 80% of the revenue. Since Class A products generate the most revenue for the company, management must closely monitor the products to reduce the cost of inventory stock-outs while balancing the holding cost and reordering cost (Grondys, 2009). Accurate monitoring of Class A products would therefore yield maximum benefits (Dhoka and Choudary, 2013). Demand planning and sales forecasts must be done accurately with tight inventory control policies to avoid stock-outs which is critical in Class A products. Class A products are monitored on a weekly or even daily basis with tight control documents and audits (Collignon and Vermorel, 2012).

- Class B products

Products which are classified as Class B are products that are in between product Class A and class C. Approximately 30% of the SKUs generates 15% to 25% of the revenue. Even though, Class B products does not generate as much revenue compared to Class A, these products are considered to have potential which management can review market and business strategies to improve the product Class (Collignon and Vermorel, 2012). Class B products must be monitored regularly to track movements of products which can be both towards Class C or Class A. Usually, Class B products are monitored on a monthly interval with adequate documentation, audits and procedures (MSG, 2016).

- Class C products

Products which are classified as Class C are usually accounted for a small amount of revenue but a large number of SKUs. Approximately 50% of the SKUs generates only 5% of the revenue (Caplice, 2006). Commonly, inventory policy of Class C products is to only have 1 unit for displaying purposes and reorders are made only when there is customer demand. This policy usually leads to a back-log situation however it is considered a suitable trade-off with holding costs because there is low demand for Class C products therefore poses higher risk of over-stocking (Collignon and Vermorel, 2012). Class C in contrast with Class A products, generate very small amount of revenue therefore are monitored at a less frequent interval. Class C products are usually monitored on a periodic basis with simple documentations and minimum procedures (MSG, 2016).

The benefits of ABC classification include:

- Minimize inventory cost through better inventory management (Grondys, 2009)
- Minimize administration cost through focused product group, efforts are largely put into Class A products
- Reduce excess inventory saving space, inventory transparency fostering easy problem identification and audits (Krajčovič and Plinta, 2012). argues that storage space may be reduced up to 15 to 30%.
- Management can focus on high value products fostering better inventory controls
- Improve inventory turnover and planning (Periasamy, 2010)

ABC analysis increases inventory management efficiency as it prioritizes inventories based on its condition, therefore management can set different policies for different product categories such as reordering, auditing and storage location policy. ABC inventory analysis is implemented as it is one of the most frequently implemented technique to classify and prioritize inventories due to its flexibility and ease of implementation (Chen et al., 2008).

The technique is found by many research to give very effective results in managing both raw material and finished goods inventory (Kumar et al., 2016). As argued by Bai and Zhong (2008) the company was struggling with stock-outs and overstock, the technique helps increases the inventory efficiency through cost savings and time reducing both of the problems. It is critical for a company to balance the inventory costs and stock-out costs, having too much or too less will damage the company (Grondys, 2009). In the effort to reducing inventory cost, the company must concentrate on inventories with high value, this can be achieved through ABC analysis (Raphella et al., 2014, Muthukumar, 2009).

2.10 Cash Conversion Cycle

Cash management is one of the most important activity in a company's financial plan. Companies must be able to balance between the amount of cash with the amount of investment or assets. Having too much of either will not be healthy for the company. A company must invest in order to grow and become competitive in the market however it must be liquid enough to pay its debts and satisfy customer's credit requirement. Working capital management is one of cash management technique that reviews the liquidity and solvency (Investors, 2011) of a company according to its current assets and liability.

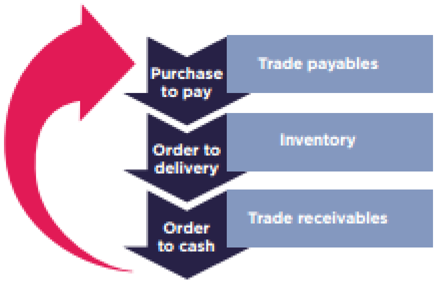


Figure 7:Working capital

(Boyce, 2014)

The fundamental of working capital management is the cash conversion cycle (CCC) (Schmitz, 2013). The CCC is a ratio considered to be a useful technique to ration a company's working capital management effectiveness which largely effects cash management (Attari and Raza, 2012) and also measure the operational efficiency of the company (Ortín-Ángel and Prior, 2004). The definition of cash conversion cycle is the length of time from when the cash is invested to when the cash received from the investment. In a trading company the cash conversion cycle starts when cash is paid for the products and ends when cash is received from the sales of product. In order to manage working capital efficiently, company must be able management CCC efficiently.

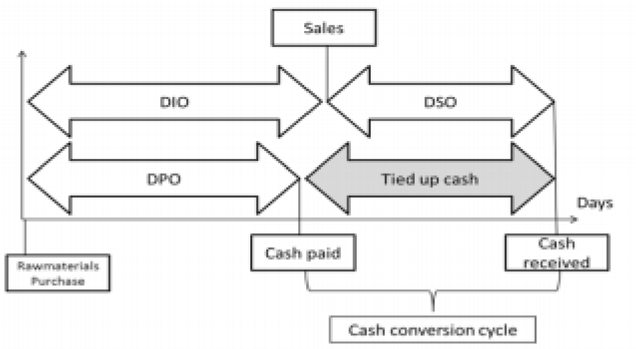


Figure 8: Cash conversion cycle

(Costa, 2014)

Cash conversion cycle is calculated using three measures which are days' inventory outstanding (DIO) or inventory turnover, days receivable outstanding (DRO) or debtor turnover, and days payables outstanding (DPO) or creditor turnover (Attari and Raza, 2012).

DIO is referred to as the time interval between the receipt of the product into the inventory and the sales of the product. A reduction in this measure is beneficial to the company. DIO is preferably kept at minimum enough to meet customers demand and avoid loss of sales due to stock-out (Costa, 2014, Boyce, 2014).

DRO is referred to as the time interval between the sales of the product to the receipt of the cash paid for the product. A reduction is this measure is beneficial to the company.

DPO is referred to as the time interval between the time of the receipt of product to the payment for the products. As the company often offer credits to its customer, suppliers will also often offer the company with a credit term which is beneficial to the company as it decreases the length of time cash is tied up in the operating cycle.

DIO and DRO forms the operating cycle in the cash conversion cycle formula. The operating cycle is referred to as the length of time from when the product is received to when cash is received from the sales of the product. Operating cycle does not take into consideration of the length of time for payables (Schmitz, 2013).

A positive CCC indicates the length of time the company must arrange funds either from cash or borrow before account receivables can be collected. In most cases, it is beneficial for companies to have lower cash conversion cycle as this implies that the company is able to manage cash efficiently and maintain liquidity. When liquidity of the company increases and cash is not tied up in the working capital, company can then leverage this cash more effectively increasing profit and productivity. A negative CCC value is in most cases very beneficial as company is able to receive cash from its AR or debtors before it has to pay its AP or creditors. Companies must try to reduce CCC to a minimum or even a negative value to achieve efficient financial management because a low CCC will reduce liquidity problems (Attari and Raza, 2012). Companies with lower CCC is likely to achieve more profitability (Costa, 2014, Nobanee, 2009) as it is able to turn its working capital more times per year which indicates that it is generating more sales (Banomyong, 2005).

Companies can reduce CCC through the reduction of the operating cycle time or through increasing DPO. There are many working capital management approaches to reduce the CCC ratio this includes (Schmitz, 2013).

- Reduce inventory – As DIO measures the length of time inventory stays in the system, reducing inventory especially inventories with low turnover rates will reduce the CCC ratio. However, reducing inventory can also reduce profitability as it could lead to inventory shortages and loss of sales (Nobanee, 2009). Techniques such as ABC analysis can be used to classify products into categories and therefore allow companies to assess inventory policies and improve inventory control. Moreover, effective inventory management such as receiving, storage and order-picking can all increase inventory turnover therefore reducing CCC (Investors, 2011).

- Reduce account receivable period – Reducing account receivable (AR) period or decreasing the credit time for customers can also reduce CCC ratio. However, reducing AR can detriment customer relations, company must come up with a policy that will allow AR to be collected as quickly as possible while maintaining good customer relations and remain competitive in the market (Boyce, 2014).
- Increase account payable period – on the other hand, increasing account payable (AP) period can also reduce CCC ratio as AP is negatively correlated with operating cycle. Similar to AR, increasing AP can create supplier relationship problems and reduce credit reputation (Nobanee, 2009), companies must manage supplier relationship effectively while increasing payment period.

Comparing CCC are mostly done through benchmarking the company within its industry or with businesses that have similar business structure. For example, companies in service industry will most likely have very low or no inventory while companies in manufacturing or retail industry will most likely have high level of inventory. The table below is compares the CCC of companies with similar business structure to Fur-9 company limited (Morningstar Incorporate, 2016).

Table 6: Cash conversion cycle of competitors

	CCC (Days)					
	2011	2012	2013	2014	2015	Avg.
Rockworth	47.73	52.24	94.33	128.75	101	84.81
Modernform	200.08	202.61	214.44	220.99	212.71	210.166
East Coast Furnitech	25.84	38.32	78.1	133.96	173.06	89.856

(Morningstar Incorporate, 2016)

2.11 Conclusion

In conclusion, the literature review has covered the content of warehouse and inventory management focusing on improving order picking efficiency and inventory value. Mentioned previously, there are mainly 5 processes in a warehouse operation system, however attention has been given to order picking as it is the costliest process in warehouse operation costs. As per the aim of the research is to improve the efficiency of the warehouse, improving picking policy is crucial.

Prior to implementing tools and techniques to improve warehouse and inventory management, warehouse environment must allow transparency to the system. 5S is used as a method prior to implementing other techniques to manage warehouse and shop floor setting standards and improving working environment. The method is able to minimize waste which occurs through defects, over processing, unnecessary inventories, increase space utilization, improve work environment, improves inventory awareness, improve visual control and improve space utilization. In order for any improvements to be made, the work environment should enable transparency of problems by setting standards and order to the work environment. Order consolidation policy or picking policy is chosen to be synchronized zoning with batching. Referring to literature review section 2.4.3, many researches has proven that a combination of zone and batch picking greatly improves the efficiency of the order picking process. Moreover, as the warehouse that the research is being carried out is limited by its design layout and routing policy, synchronized zoning with batching seems the most appropriate. According to De Koster et al. (2007), the efficiency of order picking is largely effected by each of the optimization factors, as they are interdependent of each other there are no one size fits all. In this research the layout of the warehouses as can be seen in figure 1 is clearly separated into individual warehouses where there is no connected aisle throughout each of the warehouse forcing each warehouse into zones and order pickers to return to the entrance of the warehouse to deliver the picked items. To further support the decision, the behavior of customer’s order consists of many order lines with diverse product range increasing the complexity in the order batching problem.

Lastly, ABC inventory analysis along with class-based storage is implemented to the warehouse. ABC analysis is a common method used to study the inventory as it is flexible and can be easily implemented to the current system. The method allows products to be prioritized into categories based on their values improving inventory management. Cash conversion cycle is used as a KIP to the ABC inventory analysis as it is globally used and accepted which enables results to be benchmarked. Classed-based storage policy is then used as a location assignment policy as it has proven to improve time and travel distance considerably. Products with higher value will possess higher turnover and therefore can be located closest to the exit of the warehouse in which the technique benefits by providing flexibility and high space utilization. Many research has been conducted using class-based storage where multiple configurations such as within-aisle storage and across-aisle storage is compared. Considering the limitation of the warehouse design, routing policy, product positioning and the property of the product where it is large and easily damaged, across-aisle product positioning will be used to implement only in zone 4 or warehouse 25 as movement of products can be kept at minimal. Warehouse 25 is chosen to be implemented because from statistics, is it one of the most visited warehouse. Furthermore, products within the warehouse are mostly light products and less fragile than products in other warehouses therefore it is easier to move and less prone to damage than products in other warehouses.

3 Methodology

The methodology is a chapter that is concerned with the steps taken in order to achieve the study's aims and objectives which is to improve operational efficiency of an SME furniture warehouse through the use of warehouse management technique and inventory management technique. Warehouse management technique includes 5S and order picking while inventory management technique includes ABC stock analysis and class based location assignment policy. The key performance indicators that will be used in measure the experiments are time, distance and cash conversion cycle index. The methodology will also focus on the methods and procedures taken towards analyzing current situation, data collection, information gathering, implementation, analyzing and contrasting improvements with reference to academic researches portraying the advantages and weaknesses of the approach which will form the content of this thesis.

3.1 Research Overview

3.1.1 Research flow chart

Overview of the current system:

- Recognize information and material flow
- Identify problems
- Study warehouse and inventory management theories
- Collect and analyze data of the current system

↓

Implementation:

- Implement theories related to warehouse and inventory management

Data collection:

- Direct data collection after the implementation
- Specify improvements made

Analysis and discussion:

- Compare and contrast collected data with current data
- Compare improvements with case studies
- Discuss the improvements, limitations and future improvements

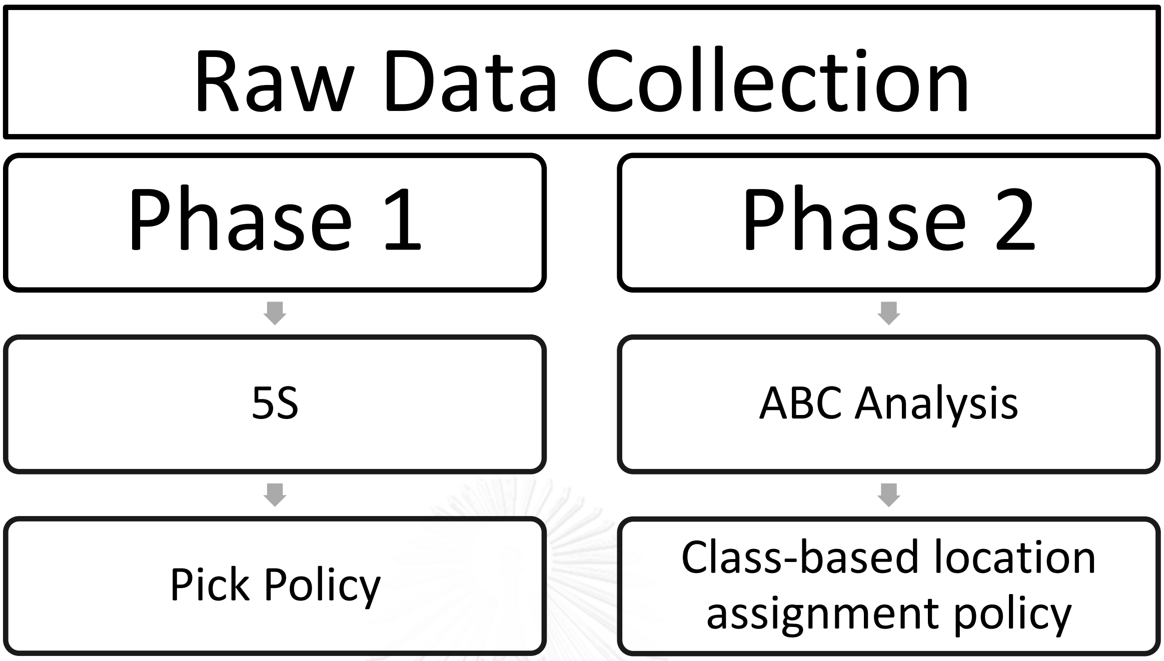
The research approach used in this dissertation is a case study analysis. Firstly, the current state of the warehouse and inventory is looked at in detail. Material and information flow was examined and portrayed using swim lane diagram in order to give an overview of the activities and processes within the warehouse and interconnected departments. The diagram also shows the responsibilities for the each of the processes. During the creation of the swim lane diagram, an overview of the processes and activities within the warehouse is collected directly through interviewing the warehouse management. Once the swim lane diagram and direct interview with the management has been completed, problems within the warehouse could be identified. According to (Bartholdi III and Hackman, 2014), warehouse efficiency is measured by time and space utilization while the performance is measured by successful throughput of the system; problems within the warehouse was identified accordingly.

A thorough research on warehouse and inventory management was conducted in order to identify possible solutions for the problems. To eliminate the inefficiencies that have been identified, research on warehouse and inventory management is made from basic understanding which includes definition, purpose, benefits of warehouse and inventory management. Then using literature reviews based on warehouse and inventory management, methods of warehouse and inventory management is selected to improve the processes within the warehouses. From the data collected previously, the two main inefficiencies that will be examined in this paper are time and inventory value. Literature review suggests that to reduce these 2 inefficiencies, warehouse management techniques should be used to reduce time whereas inventory management techniques should be used to reduce inventory value. Data collection was made before and after the implementation of proposed technique which are collected directly by the author through 2 methods:

1. Observing the daily and weekly activities within the warehouse
2. Data collection from accounting department

Results from the data collection after the implementation are used to compare with the data collected from the current state of the warehouse. Improvements of both warehouse management and inventory management are summarized in a table. The improvements obtained will then be used to compare with the expected benefits collected from the literature review. Then discussion and limitation will be made based on these improvements. Lastly, further improvements will be suggested.

3.2 Research implementation method



The research implementation begins with collecting raw data from the initial state of the warehouse. Both data collection and implementation is separated into two phases; the first phase consists of implementing 5S and order picking policy to improve warehouse management. While the second phase of the research implementation consists of ABC analysis and storage location policy which is implemented with the aim of improving inventory management. After the implementation of each phase has been completed, data is collected to measure the improvements of each tools.

Raw data of the current state of the warehouses are collected through 2 methods, observation and existing raw data collection. Observation analysis is done to collect order picking times while existing raw data collection is done to collect information of warehouse condition, current stocks, delivery errors, and number of missing stocks.

3.2.1 *Raw Data Collection*

3.2.1.1 *Raw Data Collection: 5S*

The collection of raw data for 5S is done by walking through the warehouses and collecting photos of the initial state of the warehouse. Most raw data for the method is collected initially using the swim lane diagram which portrays the systems and activities within the warehouse.

Data on delivery errors are collected through analyzing information from the delivery ques in the period of 3 months where the number of delivery/redelivery are stated in the ques with reasoning. The following is the analysis process:

1. Obtain delivery ques
2. Remove all successful delivery
3. Separate condition of redelivery/rescheduling into the following categories
    a. Defective Items – incorrect deliveries, bad product condition, defective products
    b. Late deliveries – unable to deliver products including unable to process que and miss schedule.
    c. Miscellaneous – Other reasons which concerns customer's preference.

Only the first two categories are used as miscellaneous reason are outside of the company's control. Lastly, information on stock discrepancies are obtained from the Audit department for 12-month period. Audits are conducted in 2-month interval, a document from the audit department is issued to summarize the number of stocks in each audit cycle. Information of stock discrepancies include number of excess stocks, missing stocks and its total value (sum excess stock value and missing stock value).

3.2.1.2 *Raw Data Collection: Pick Policy*

Order picking times are collected using 3 stop watches, each used to record each activity which are walking, searching, and order picking. The following procedure shows the process of data collection:

1. Order picker retrieves pick list
2. Order picker identify the location for the first pickline– walking time starts
3. Order picker reaches a warehouse for the first pick line – walking time stop, search time start
4. Order picker locates a product – search time stop, order pick time starts
5. Order picker successfully retrieves a product into the cart – order pick time stop, search time start
6. Repeat steps 2 to 4 until the pick list has been completed – stop order pick time, start walking time. If picker changes warehouse, walking time starts and search time stop until the picker reaches the warehouse.
7. Order picker transfer all the products to the quality control area – stop walk time
8. Record walk time, order pick time and search time.

The collection of order picking times are collected for 5 days for each of the 3 order pickers.

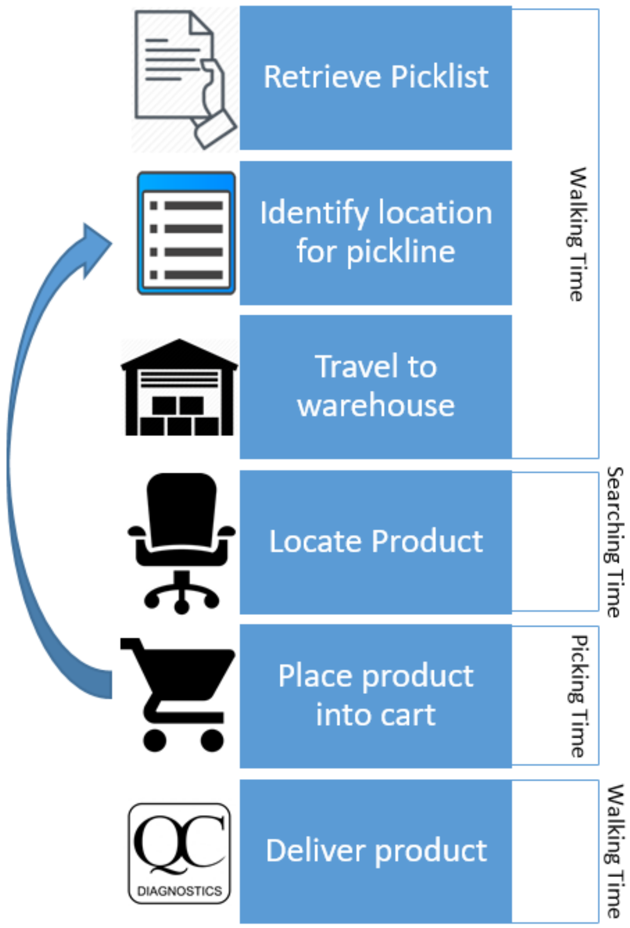


Figure 9: Order picking time data collection

3.2.1.3 *Raw Data Collection: ABC analysis*

Data on the current stocks are collected from the accounting department as the accounting program is used to control all incoming and outgoing stocks of warehouses and retail outlets. The following information is obtained:

1. Stock receivable – 3-year period
2. Remaining stock – 3-year period
3. Average selling price – 3-year period
4. Average cost – 3-year period
5. Sales Volume – 2-year period

Further to the data collected above, account payable and account receivable from January to June 2016 are also collected for the cash conversion cycle calculation.

3.2.1.4 *Raw Data Collection: Class-based location assignment policy*

Lastly, raw data for class-based location assignment is obtained through collecting the result for order picking policy after the implementation has been made. The result of the order picking policy implementation is separated into each zones (warehouse), only the result obtained for zone 4 or picker 4 will be used as an initial state for comparing the results obtained from applying class-based location assignment policy. The ABC analysis used to assign the products into its location is collected similarly to the raw data collection for the ABC analysis however only the products within the zone is considered.

The following section will explain the implementation of each of the phases in more detail.

3.2.2 Implementation Phase 1:

3.2.2.1 *Implementation Phase 1: 5S*

In the first phase, 5S is implemented to all of the 5 warehouses as an initial technique to improve the overall warehouse condition. As mentioned previously in research overview, the current state of the warehouse was studied by interviewing warehouse operators and walking through the warehouse which swim lane diagram was created and photos were also taken to show the state of the warehouse before the implementation. Based on the initial study of the current state of the warehouse and the literature review, improvements were able to be identified accordingly. During the implementation, multiple walk through in the warehouse were conducted for each of the elements in 5S. The implementation was done in the following order; sort, set-in-order, shine, standardize and sustain. Improvements of 5S will be portrayed through number of stock discrepancies, delivery errors and interview of warehouse operators with photos of the warehouse condition after the implementation. Swim lane diagram will also be used as a visual comparison of the improvements made to the warehouse. Data collection after the implementation will be the same as the raw data collection.

3.2.2.2 *Implementation Phase 1: Order Picking Policy*

After order and standards has been set through the implementation of 5S, order picking policy was then implemented. The research focuses on the use of synchronized zone picking with batch policy. The process of using synchronized zoning with batching technique are as follows:

1. Create multiple pick lists according to the zones or warehouses.
    a. Use excel spreadsheet with detailed information on the location of products in each of the warehouses created during the implementation of 5S.
    b. Use the search function (control F) in excel, each of the order lines are searched and separated into each of the zones.
    c. Picklist are arranged in decreasing number from the smallest alphabet with the largest number, after all the locations in the alphabet has been picked, the picklist is then arranged in increasing number from the next smallest alphabet with the smallest number. For example, A40, A21, A11, B3, B27, B33, C42, C17, D1, D32. Picklists are arranged this way so that each aisle is only travelled once and pickers can concentrate one side of the aisle at a time which is easier for the order picker. Furthermore, it is easier for operators to create the picklist as shelfs within an aisle can have different width, therefore are not always in sequence of each other.
2. Order pickers assigned to each of the zone collects the picklist.
3. Order pickers collect all assigned products into a cart
4. Order picker delivers the products in the cart to the quality control according to the picklist
5. Quality control process begins
6. Consolidation process is then completed after the quality control process
7. The time of every process is recorded using the same process as the collection of raw data for order picking time initially and used as a KIP to measure the improvements of the strategy.

*Note: The time used to consolidate orders will not be recorded as all products must be checked by the quality control team before consolidation which is the same as the initial state of the warehouse as shown in the swim lane diagram in figure 2.

3.2.3 Implementation Phase 2:

3.2.3.1 *Implementation Phase 2: ABC analysis*

In the second phase, ABC inventory analysis and storage location policy which is one of the four order-picking optimization factor is implemented to improve inventory and warehouse efficiency. ABC inventory analysis is implemented to separate the inventories in the warehouse into categories A, B and C analyzing the condition of the inventory. Further to ABC inventory analysis, the classification is also used for allocating products within the warehouse improving warehouse management.

As raw data needed for phase 2 has already been collected in phase 1, no further data collection is needed. Data collected in phase 1 on the stocks are put into an excel spreadsheet, in the following order.

1. Stock receivable – 3-year period
2. Remaining stock – 3-year period
3. Average selling price – 3-year period
4. Average cost – 3-year period
5. Sales Volume – 2-year period

Stock receivable and remaining stock is collected in 3-year period to study the activities of each of the stock. For ABC inventory analysis, only the remaining stock for 2016 statistics was used. The following calculations were made for ABC inventory analysis:

6. Average the average selling price of each product for the 3-year data collected hereafter will be called selling price
7. Average the average cost of each product for the 3-year data collected hereafter will be called product cost

8. Sum the sales volume for the 2-year period collected hereafter will be called sales volume
9. Calculate each sales value

$$Sales\ Value = Sales\ Volume \times Selling\ price$$

10. Calculate the cumulative sales value
11. Calculate the percentage cumulative sales value

$$Percentage\ Sales\ Product\ Value = \frac{Cumulative\ sales\ value}{Sum\ of\ product\ value} \times 100$$

12. Calculate the percentage SKU

$$Percentage\ Cumulative\ SKU = \frac{Cumulative\ SKU}{Sum\ of\ SKU} \times 100$$

13. Identify the product categories using the percentage cumulative product value, category A 0-80%, category B 80%-95% and category C 95%-100%
14. Calculate the inventory value

$$Inventory\ Value = Remaining\ Stock \times Cost$$

15. Calculate the sales value for year 2016

$$Sales\ Value\ 2016 = Selling\ price \times 2016\ Sales\ volume$$

16. Calculate turnover

$$Turnover = \frac{2016\ Sales\ Value * Selling\ price}{Inventory\ value}$$

The KIP used to measure the improvements of ABC inventory analysis is cash conversion cycle which is calculated using the equations below.

$$Days\ Inventory\ Outstanding\ (DIO) = \frac{Inventory}{Cost\ of\ good\ sold\ (COGS)} * 365$$

$$Days\ Recievable\ Outstanding\ (DRO) = \frac{Account\ Recievables\ (AR)}{Sales} * 365$$

$$Days\ Payables\ Outstanding\ (DPO) = \frac{Account\ Payables\ (AP)}{Cost\ of\ good\ sold\ (COGS)} * 365$$

$$Cash\ Conversion\ Cycle = Operting\ Cycle - DPO$$

$$Operating\ Cycle = Days\ Inventory\ Outstanding\ (DIO) + Days\ Recievable\ Outstanding\ (DRO)$$

3.2.3.2 *Implementation Phase 2: Location assignment policy*

As mentioned earlier in section 3.2.1.4, only the products within the zone is considered in the ABC analysis. The following is the method used to implement class-based location assignment policy.

1. Determine the products within zone 4 by using the stock card
2. Collect raw data for the products in zone 4 following steps 1-5 in section 3.2.1.3
3. Follow steps 1-16 in section 3.2.3.1 for ABC analysis
4. Reallocate products within the warehouse according to the ABC analysis in across-aisle storage configuration where product with classification A are placed nearest to the entrance/exit of the warehouse, classification B placed after product A and classification C placed after product B.
5. Follow steps 1-7 in section 3.2.2.2 to collect results for the implementation of class-based location assignment however, only results in zone 4 is considered

   *Note: the result of class-based location assignment is collected by order-picking time

4 Results

This section will cover the results of the implementation for each of the techniques as stated in the methodology. The structure of this chapter will mainly follow the methodology which is separated into phase 1 and phase 2. Both phase 1 and phase 2 will be implemented on the warehouse to obtain the results. The results obtained after the implementation will then be compared with the results from the initial state of the warehouse with improvements discussed.

4.1 Order Picking

5S is the first method that was implemented in the warehouse. All the 5 warehouses were implemented with this method as a foundation to eliminate wastes. The following result was implemented:

- Sort or Seiri in Japanese

Firstly, a meeting with the staffs in the warehouse was setup to discuss the equipment that are needed for daily operation. Red tagging was not conducted in the warehouse as most equipment are not used in daily activities therefore are removed from the warehouse, and relocated in the office. To prevent misplace or lost of equipment a borrow form is created and must be signed off by administration every time an equipment is needed. Further, products on the storage shelves of the warehouse that are defective are then removed and relocated to warehouse 22.

- Set-in-order or Seiton in Japanese

Warehouse storage shelves are numbered with a dedicated storage number for each shelves and numbering sequence are kept uniform throughout all the warehouses. Product stock card with storage location is created to aid in all aspects of warehouse activities. Visual instructions of different equipment and cleaning products are portrayed around the quality control area. Floor markers are used to keep equipment such as carts in place within the warehouse. Floor markings in the consolidation area are also done to separate the area into many slots where each slot is used to consolidate each order. Products within each storage shelf are identified and recorded into a stock card using excel spreadsheet. Lastly, products within the shelves are organized into groups separated by their colors and in an order, that facilitate ease of accessibility.

- Shine or Seiso in Japanese

A daily schedule of cleaning session is created 10 minutes before the start of work hour. Initially a broom stick is used to clean all the warehouses however after interviewing the warehouse staff, it is a slow and ineffective process as dusts are mostly spread from the warehouse floor onto the shelves. First, the floor of the warehouses is studied and are set with different cleaning equipment. Warehouses 21and 25 has a rough polish concrete finish where dust mop is used. The other warehouses 22, 23 and 24 has a rough concrete surface finish therefore dust mop can’t be used. New cleaning equipment was deployed using a Karcher sweeper as it is more effective and efficient in collecting dust than conventional broom stick. Additional improvement of warehouse 24 floor surface was needed as poor construction led to the concrete floor continuously letting out dust, road paint was applied to the floor.

- Standardize or Seiketsu in Japanese

A flow chart and a standard operating procedure is created for every activity within the warehouse and then kept as a manual. Regulations on customer order delivery lead time is also defined to ensure sufficient lead time to satisfy orders without errors. Also, a daily activity flowchart is created and displayed as a visual guide for staffs.

- Sustain or Shitsuke in Japanese

To sustain the 4S implemented, warehouse administration and management has agreed to set up a monthly training and recap using the operating manual. Further, a random performance evaluation will be conducted by the audit team every two months during their audit in the warehouse.

The benefits of 5S as mentioned in the methodology are portrayed through the number of stock discrepancies, delivery errors, warehouse operators and auditors interview, and lastly photos of the improved warehouse. The number of stock discrepancies can be seen below.

Table 7: Number of stock discrepancies before implementation

Audit #	Date	Excess		Missing		Summary	
		Amount	Value (฿)	Amount	Value (฿)	Amount	Value (฿)
1	4-7/7/2015	34	113,050	44	132,430	78.00	245,480
2	16-21/9/2015	13	41,850	27	93,300	40.00	135,150
3	18-25/11/2015	7	26,500	16	37,700	23.00	64,200
4	16-19/2/2016	12	46,530	23	70,760	35.00	117,290
5	6-9/4/2016	10	23,300	33	73,800	43.00	97,100

Table 8: Number of stock discrepancies after implementation

Audit #	Date	Excess		Missing		Summary	
		Amount	Value (฿)	Amount	Value (฿)	Amount	Value (฿)
6	22-27/6/2016	3	6,600	8	30,350	11	36,950
7	22-27/8/2016	2	7,600	7	30,300	9	37,900
8	17-20/10/2016	9	36,350	9	5,350	18	41,700
9	19-22/12/2016	7	25,600	6	4,200	13	29,800

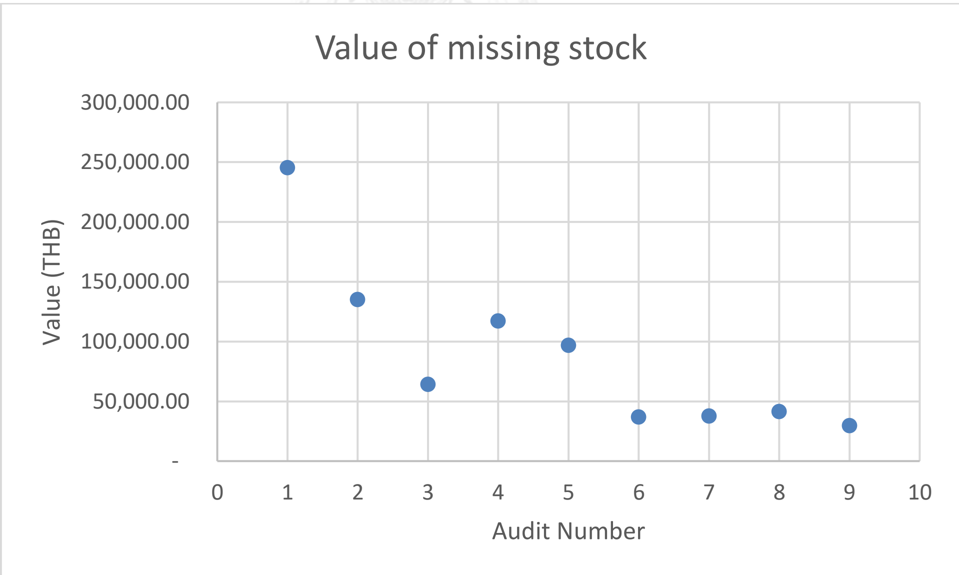


Figure 10: Plot of stock discrepanices

Referring to Table 8 and Figure 10, it can be seen that the as a result of 5S the value of stock discrepancies in the warehouse has reduce by over 69.31% comparing audit number 5 (prior to implementing) and audit number 9 (after implementation). From audit number 5 to audit number 9, the errors remain relatively consistent with an average value of 36,000 baht. The errors that still exists is believed to have caused by human error in documentation as the errors that have been obtained is from comparing accounting stock-card with warehouse stock-card. Using the warehouse stock card to check the inventory shows no error. Moreover, comparing all the picking lists with the warehouse stock card recording all input and output of the warehouse shows no error. Therefore, it can be assumed that it is caused by internal documentation error related to the accounting department however it will not be dealt with as it is out of the research scope.

The following Table 9 summarizes the results in delivery errors after the implementation.

Table 9: Delivery errors after implementation

Delivery Errors			
Initial		Final	
March	25	August	22
April	16	September	20
May	22	October	19
June	20	November	21
July	21	December	18
Total	104	Total	100

From the Table 9 above, there is a small improvement in the delivery errors. Comparing the total errors in 5 months, a decrease of 3.85% in errors has been achieved. However, referring to the numbers of errors in each month, the occurrence is still considered very high. 5S was able to improve delivery errors by a small amount as product conditions are separated which reduces the chance of delivering defective products. However, referring to the delivery report in detailed, all of the delivery errors are due to defects that are found while assembling the products. To eliminate this all the delivery defects, quality control procedures must be improved however, it is out of the research scope.

From interviewing both warehouse operators and auditors, the following benefit has been agreed:

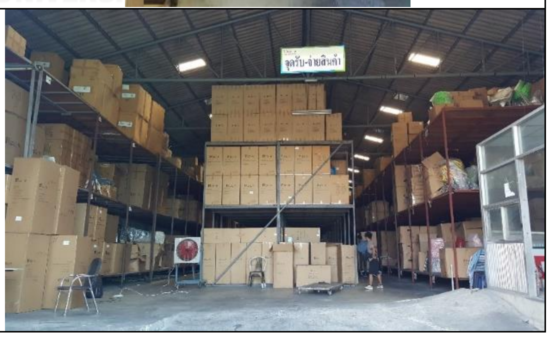
- Standardized procedures allow operators to become more responsive in decision-making
- Traceability of the product has increased as pick-lists are created and product location identified
- Organized product facilitates easier stock keeping where the quantity of products can be immediately identified
- Organizing and sorting conditions of products also benefits by reducing the workload of replacing products that are found to be defective which also reduces the workload at the quality control process
- Cleaning improves the work environment especially for warehouse 24 as dust is reduced. It is also easier to prepare products for delivery as amount of dust on products and boxes decrease
- Standard operating procedures and visual flowchart increases the quality of work output as proper steps are taken. New recruits and current operators can refer to the manual frequently

Warehouse 21	
Before	After
 	
	
 	

Warehouse 23	
Before	After
	
	
	
	

56

Warehouse 24	
Before	After
	
	
	
	

Warehouse 25	
Before	After
 	 
	

4.2 Order Picking

Synchronized zone picking with batch policy was used to improve order-picking efficiency. The below Table 10 shows the average result obtained from the improvement.

Table 10: Result of order picking policy

Results Average		
Walking (min/line)	Searching (min/line)	Picking (min/pcs)
0.17	2.02	0.55

Table 11: Order picking time improvement comparison

Average Improvement Comparison			
	Walking (min/line)	Searching (min/line)	Picking (min/pcs)
Initial	0.60	12.70	0.94
Final	0.17	2.02	0.55

We are able to obtain a reduction in walking time by 71.67%, searching time by 84.09% and picking time by 41.49%. Referring to the improvement values, we can see that significant improvements can be seen in all the values; walking time and searching time and picking time. Firstly, walking time has been improved significantly as a result of synchronized zone picking with batch policy. Here order pickers are assigned to their zones (warehouses) and only pick items within their zones as picklists are created according to the zones. This is able to significantly reduce congestion and walking as pickers does not need to travel between warehouses to pick products.

Secondly, search time has been significantly reduced as the picking policy allows pickers to become familiar with their zones. Moreover, pick lines are ordered in a sequential manner listing from location located at the front (larger location numbers) to location located at the back of the warehouse (smaller location numbers) therefore pickers travel an aisle within a warehouse once rather than travelling back and forth repetitively.

Thirdly, the result has also shows an improvement in picking time. This improvement is largely due to both the picking policy and 5S as product location are identified, product condition is separated, order pickers are enable to efficiently pick products from the storage without having to check the condition. Moreover, as products are stored in an organized manner, picking efficiency increases as identifying, accessing and retrieving of products can be done more effectively.

The overall order processing time improvement should also be noted that products are batched into a picklist based on the zoning constraints therefore, each location of the warehouse are visited only once by one order picker. Initially, if a product is ordered by multiple customers, multiple order pickers must visit the location which the product is located causing wastes in order processing times.

The following Tables 12, 13 and 14 show the walking, searching and picking times in detailed to statistically analyze the results.

Table 12: Order picking time picker 1 and picker 2

Day	Picker 1 / WH21					Picker 2 / WH23				
	Pick Items	Pick Lines	Walking (min)	Searching (min)	Picking (min)	Pick Items	Pick Lines	Walking (min)	Searching (min)	Picking (min)
1	50	17	2	37	34	14	4	1	10	7
2	108	7	2	19	67	23	4	1	8	12
3	88	10	2	21	33	79	13	1	32	37
4	90	14	2	32	36	58	12	1	29	29
5	127	15	2	23	43	76	14	1	24	20
6	50	17	2	36	32	14	4	1	9	10
7	102	6	2	12	55	3	4	1	11	5
8	82	9	2	17	41	79	13	1	31	35
9	92	15	2	28	47	58	12	1	27	31
10	126	14	2	27	65	29	6	1	14	19
11	56	13	2	25	35	28	11	1	30	16
12	84	13	2	25	45	144	10	1	19	51
13	32	4	2	9	16	70	18	1	31	30
14	102	29	2	52	39	99	46	1	65	41
15	90	6	2	13	40	15	5	1	12	9
16	66	10	2	19	29	21	5	1	15	10
17	84	8	2	17	42	5	3	1	6	3
18	46	8	2	17	29	14	7	1	22	9
19	36	8	2	16	26	12	2	1	5	10
20	42	7	2	13	25	29	15	1	21	23
21	48	6	2	13	27	0	0	1	0	0
22	47	5	2	10	25	1	1	1	2	2
23	18	4	2	8	22	18	3	1	9	11
24	274	12	2	23	164	29	7	1	15	18
25	34	8	2	14	20	35	20	1	32	26
26	158	2	2	4	95	7	3	1	6	5
27	28	9	2	19	17	14	9	1	21	26
28	28	7	2	14	13	26	7	1	15	17
29	45	6	2	13	25	66	11	1	30	36
30	27	2	2	4	13	8	3	1	4	5
Sum	2260	291	60	580	1126	1074	272	30	555	553

Table 13: Order picking time picker 3 and picker 4

Day	Picker 3 / WH24					Picker 4 / WH25				
	Pick Items	Pick Lines	Walking (min)	Searching (min)	Picking (min)	Pick Items	Pick Lines	Walking (min)	Searching (min)	Picking (min)
1	16	9	1	31	25	61	14	2	41	46
2	28	8	1	17	35	114	11	2	16	37
3	21	7	1	13	29	66	7	2	9	21
4	20	11	1	29	28	67	15	2	30	21
5	18	10	1	23	29	20	5	2	14	9
6	16	9	1	19	16	61	14	2	27	46
7	28	8	1	14	32	120	12	2	29	65
8	21	7	1	13	27	78	9	2	23	30
9	20	11	1	24	22	67	15	2	32	25
10	13	8	1	17	15	16	4	2	7	9
11	32	14	1	26	29	72	12	2	21	33
12	2	1	1	2	3	23	9	2	22	11
13	14	7	1	15	22	58	8	2	16	28
14	9	6	1	11	13	40	12	2	23	20
15	7	3	1	7	10	498	20	2	29	200
16	10	4	1	9	19	112	10	2	17	48
17	17	7	1	13	21	100	11	2	21	52
18	13	6	1	11	19	20	3	2	8	10
19	8	2	1	4	6	8	2	2	3	4
20	3	3	1	5	5	43	6	2	15	23
21	46	13	1	27	39	6	1	2	2	3
22	1	1	1	2	2	32	5	2	11	20
23	1	1	1	2	2	7	3	2	7	3
24	4	4	1	8	6	8	3	2	6	4
25	17	11	1	18	16	105	22	2	37	56
26	8	3	1	6	5	131	5	2	9	53
27	8	7	1	15	7	22	10	2	24	12
28	16	12	1	25	13	16	5	2	6	9
29	65	12	1	23	44	46	9	2	17	21
30	43	5	1	9	32	21	2	2	4	23
Sum	525	210	30	438	571	2038	264	60	526	942

Table 14: Summary of average order picking time per day

Day	SUM			SUM		Average		
	Walking (min)	Searching (min)	Picking (min)	Pick Items	Pick lines	Walking (min/line)	Searching (min/line)	Picking (min/pcs)
1	6	119	112	141	44	0.14	2.70	0.79
2	6	60	151	273	30	0.20	2.00	0.55
3	6	75	120	254	37	0.16	2.03	0.47
4	6	120	114	235	52	0.12	2.31	0.49
5	6	84	101	241	44	0.14	1.91	0.42
6	6	91	104	141	44	0.14	2.07	0.74
7	6	66	157	253	30	0.20	2.20	0.62
8	6	84	133	260	38	0.16	2.21	0.51
9	6	111	125	237	53	0.11	2.09	0.53
10	6	65	108	184	32	0.19	2.03	0.59
11	6	102	113	188	50	0.12	2.04	0.60
12	6	68	110	253	33	0.18	2.06	0.43
13	6	71	96	174	37	0.16	1.92	0.55
14	6	151	113	250	93	0.06	1.62	0.45
15	6	61	259	610	34	0.18	1.79	0.42
16	6	60	106	209	29	0.21	2.07	0.51
17	6	57	118	206	29	0.21	1.97	0.57
18	6	58	67	93	24	0.25	2.42	0.72
19	6	28	46	64	14	0.43	2.00	0.72
20	6	54	76	117	31	0.19	1.74	0.65
21	6	42	69	100	20	0.30	2.10	0.69
22	6	25	49	81	12	0.50	2.08	0.60
23	6	26	38	44	11	0.55	2.36	0.86
24	6	52	192	315	26	0.23	2.00	0.61
25	6	101	118	191	61	0.10	1.66	0.62
26	6	25	158	304	13	0.46	1.92	0.52
27	6	79	62	72	35	0.17	2.26	0.86
28	6	60	52	86	31	0.19	1.94	0.60
29	6	83	126	222	38	0.16	2.18	0.57
30	6	21	73	99	12	0.50	1.75	0.74
SUM	180	2099	3266	5897	1037	7	61	18

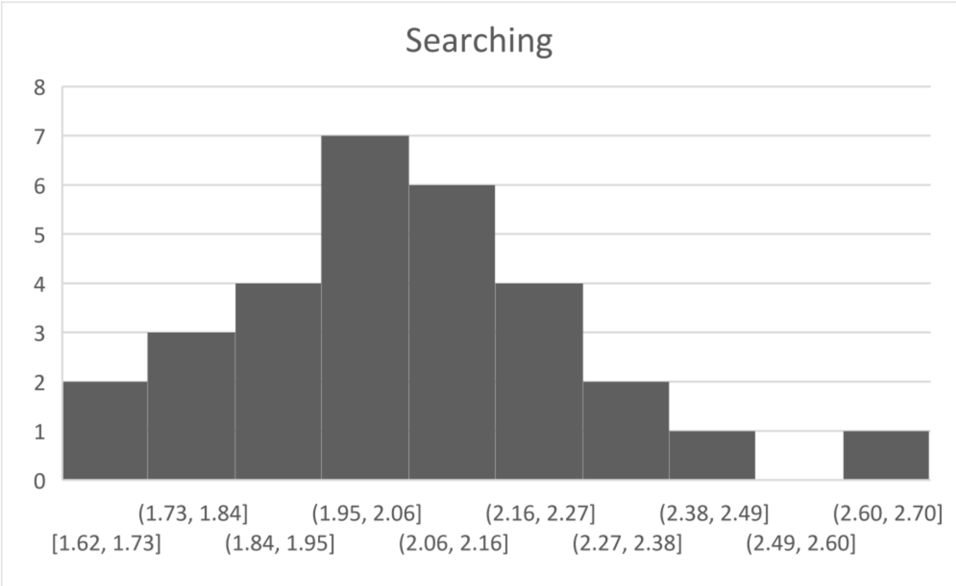


Figure 11: Plot of average searching time per day

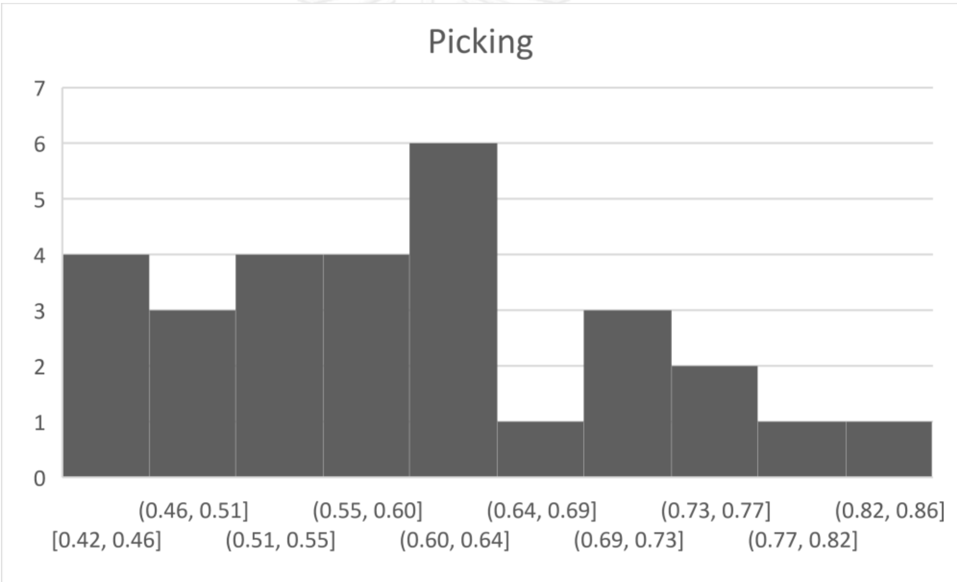


Figure 12: Plot of average picking time per day

The figures 11 and 12 above, is a histogram of both the searching and picking time showing the distribution of the collected data. Note that walking time has been exempted from the statistical analysis as it remains the same throughout the result collection. Both of the histogram is created from using the average sum of results of distribution per day in Table 14. From the graphs, it can be seen that the search time can be said that it is symmetrical and normally distributed while the picking time is not symmetric and left skewed. The search time portrays a normally distributed result and can be considered using the average sum of the results as the factors involved is only the productivity of the order picker and the location of the product. However, the factors involved for the picking time are productivity of the order picker, location of the product, packing of the product and the property of the products such as size, weight and fragility of the product making the results more complex to analyze and needs to be considered individually. Packing and the property of the product is largely what causes the picking time to become more complex therefore must be considered individually for each zone. The following table shows the average result of searching and picking time for each zone.

Table 15: Average order picking time per picker per day

Day	Average Picker 1		Average Picker 2		Average Picker 3		Average Picker 4	
	Searching (min/line)	Picking (min/pcs)	Searching (min/line)	Picking (min/pcs)	Searching (min/line)	Picking (min/pcs)	Searching (min/line)	Picking (min/pcs)
1	2.18	0.68	2.50	0.50	3.44	1.56	2.93	0.75
2	2.71	0.62	2.00	0.52	2.13	1.25	1.45	0.32
3	2.10	0.38	2.46	0.47	1.86	1.38	1.29	0.32
4	2.29	0.40	2.42	0.50	2.64	1.40	2.00	0.31
5	1.53	0.34	1.71	0.26	2.30	1.61	2.80	0.45
6	2.12	0.64	2.25	0.71	2.11	1.00	1.93	0.75
7	2.00	0.54	2.75	1.67	1.75	1.14	2.42	0.54
8	1.89	0.50	2.38	0.44	1.86	1.29	2.56	0.38
9	1.87	0.51	2.25	0.53	2.18	1.10	2.13	0.37
10	1.93	0.52	2.33	0.66	2.13	1.15	1.75	0.56
11	1.92	0.63	2.73	0.57	1.86	0.91	1.75	0.46
12	1.92	0.54	1.90	0.35	2.00	1.50	2.44	0.48
13	2.25	0.50	1.72	0.43	2.14	1.57	2.00	0.48
14	1.79	0.38	1.41	0.41	1.83	1.44	1.92	0.50
15	2.17	0.44	2.40	0.60	2.33	1.43	1.45	0.40
16	1.90	0.44	3.00	0.48	2.25	1.90	1.70	0.43
17	2.13	0.50	2.00	0.60	1.86	1.24	1.91	0.52
18	2.13	0.63	3.14	0.64	1.83	1.46	2.67	0.50
19	2.00	0.72	2.50	0.83	2.00	0.75	1.50	0.50
20	1.86	0.60	1.40	0.79	1.67	1.67	2.50	0.53
21	2.17	0.56	-	-	2.08	0.85	2.00	0.50
22	2.00	0.53	2.00	2.00	2.00	2.00	2.20	0.63
23	2.00	1.22	3.00	0.61	2.00	2.00	2.33	0.43
24	1.92	0.60	2.14	0.62	2.00	1.50	2.00	0.50
25	1.75	0.59	1.60	0.74	1.64	0.94	1.68	0.53
26	2.00	0.60	2.00	0.71	2.00	0.63	1.80	0.40
27	2.11	0.61	2.33	1.86	2.14	0.88	2.40	0.55
28	2.00	0.46	2.14	0.65	2.08	0.81	1.20	0.56
29	2.17	0.56	2.73	0.55	1.92	0.68	1.89	0.46
30	2.00	0.48	1.33	0.63	1.80	0.74	2.00	1.10

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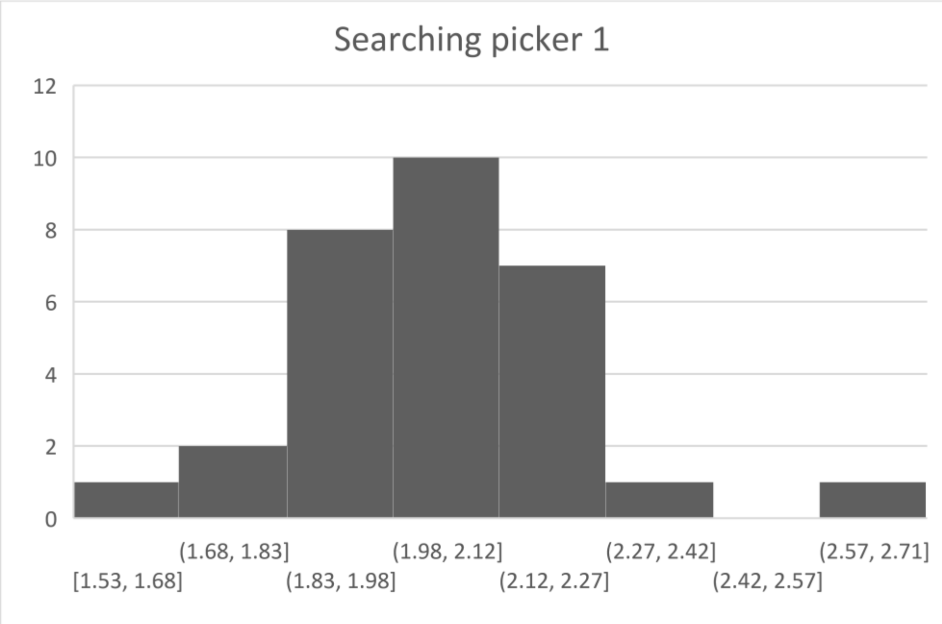

Figure 13: Plot of average searching time of picker 1

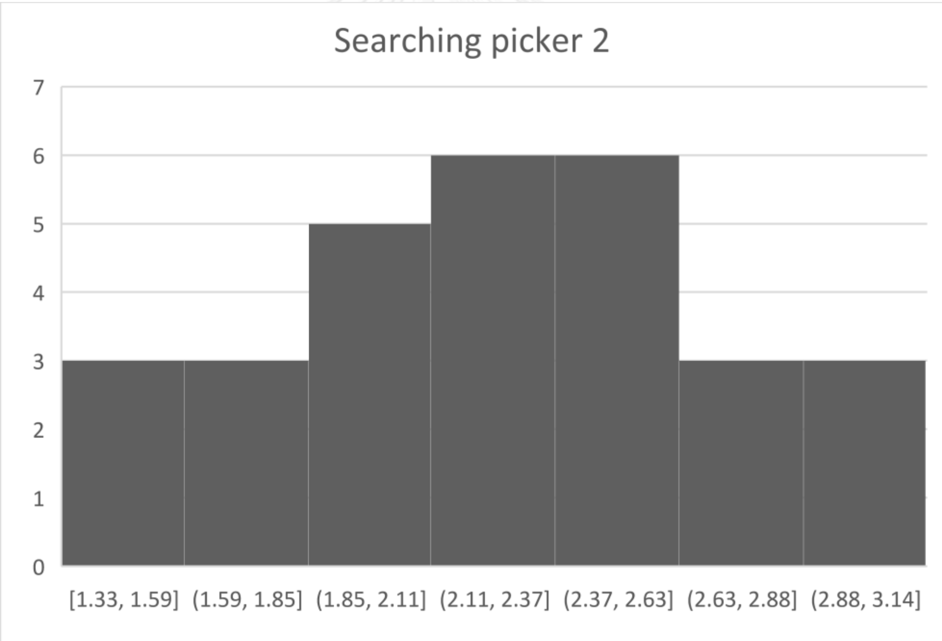

Figure 14: Plot of average searching time of picker 2

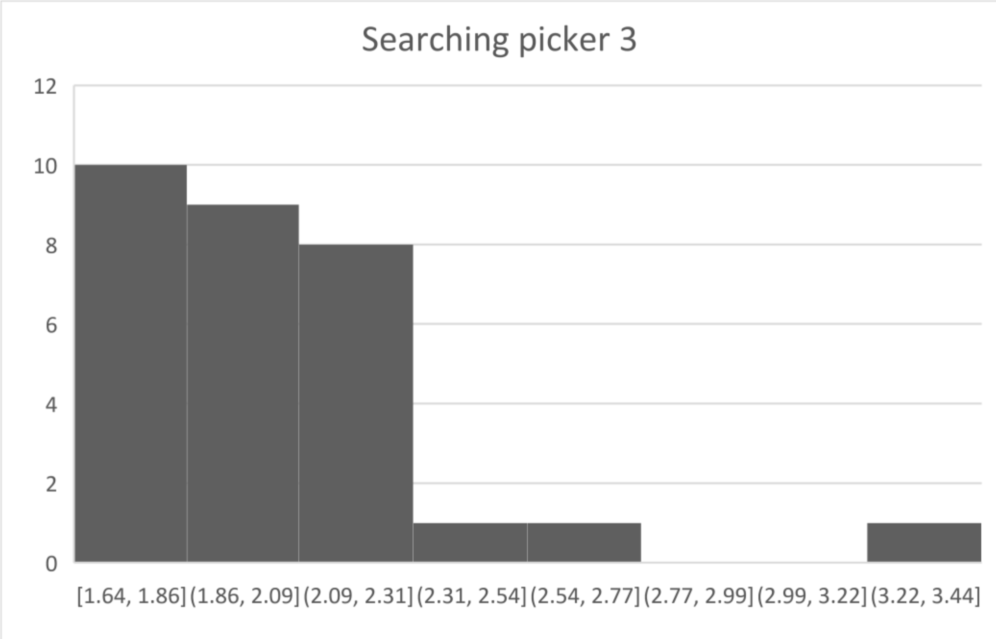

Figure 15: Plot of average searching time of picker 3

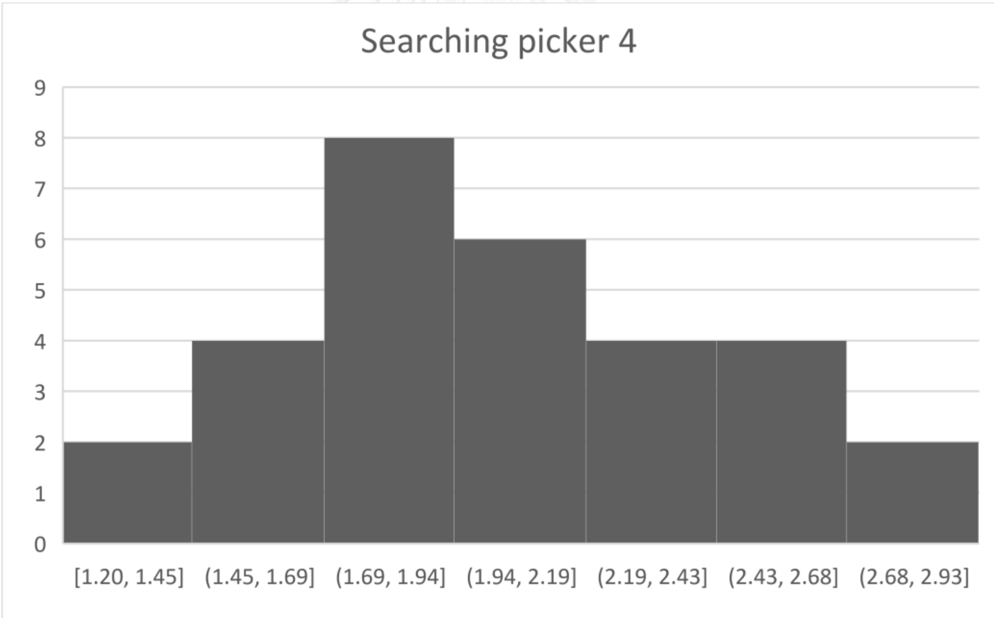

Figure 16:Plot of average searching time of picker 4

The figure 13, 14, 15 and 16 portray histograms of searching time for each zone individually. Figure 14 and 16 shows a normally distributed graph with no indication of any outliers in the results. However, as can be seen from figure 13, the graph is normally distributed however a notable outlier can be seen of the right of the graph. In figure 15, the graph is not normally distributed and left skewed, again a notable outlier can be seen towards the right of the graph.

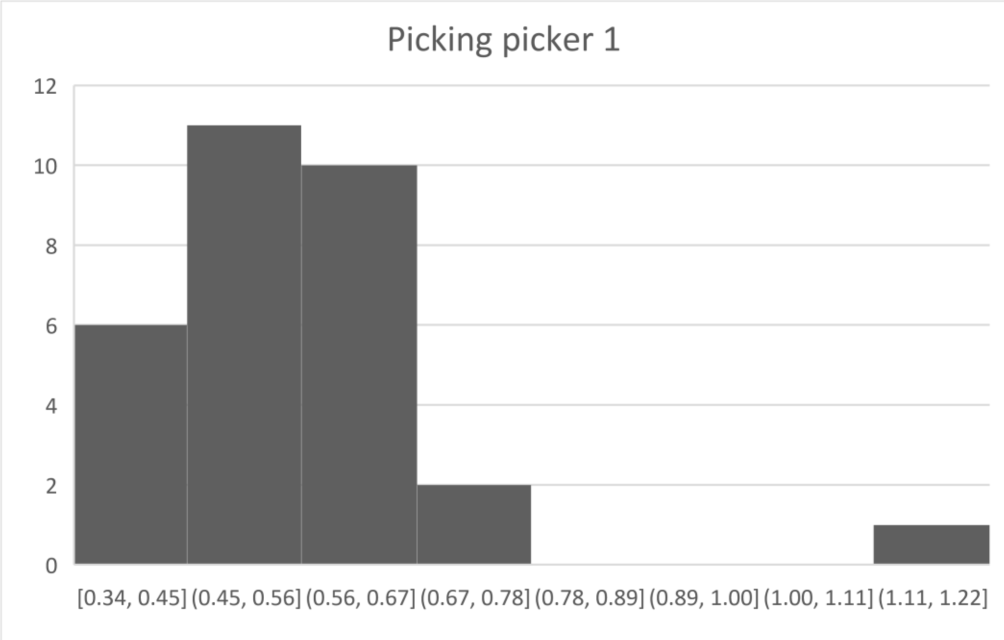

Figure 17: Plot of average picking time of picker 1

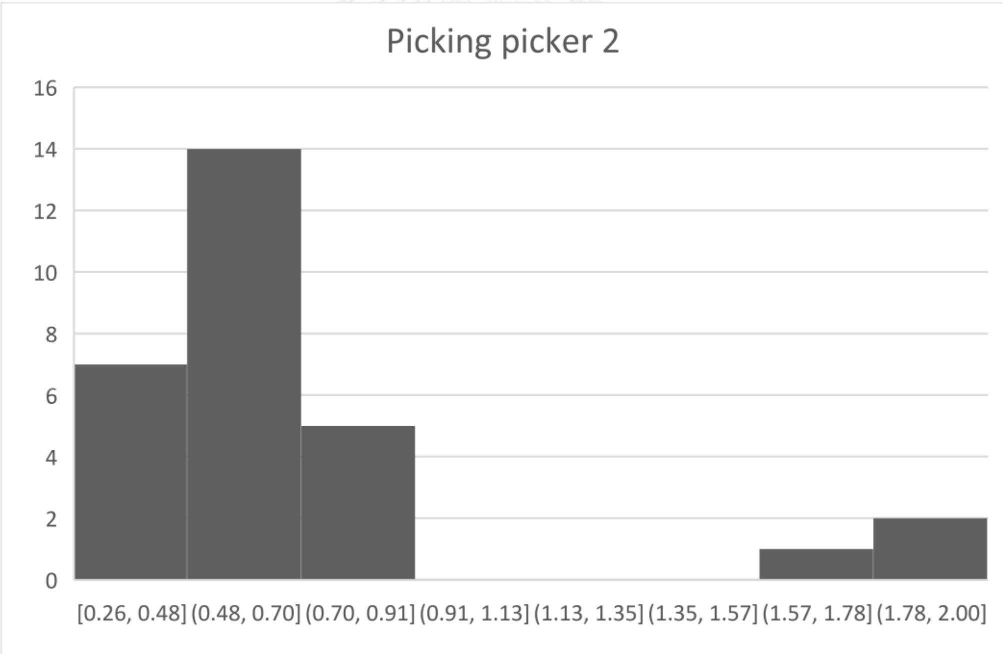

Figure 18: Plot of average picking time of picker 2

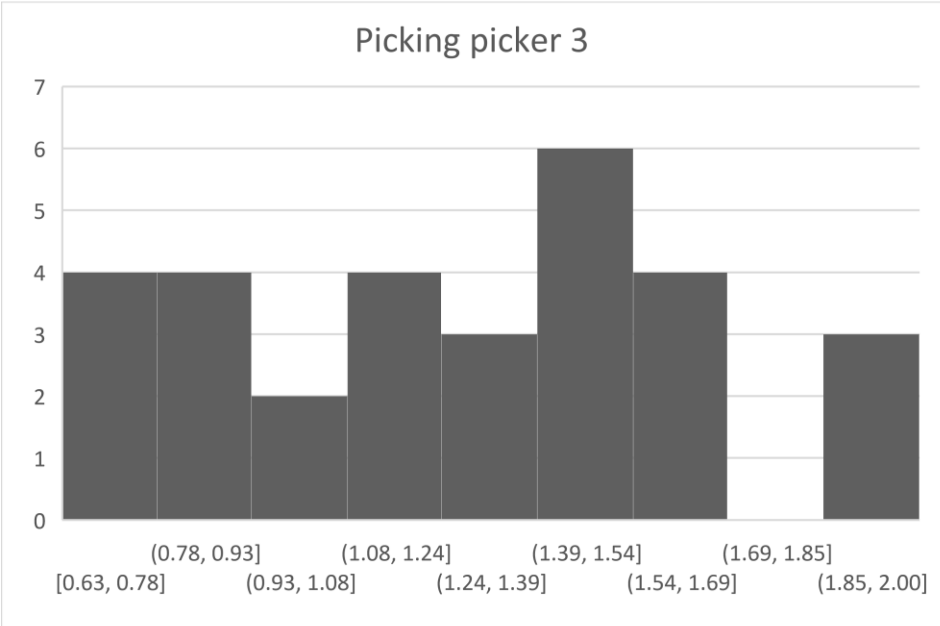

Figure 19: Plot of average picking time of picker 3

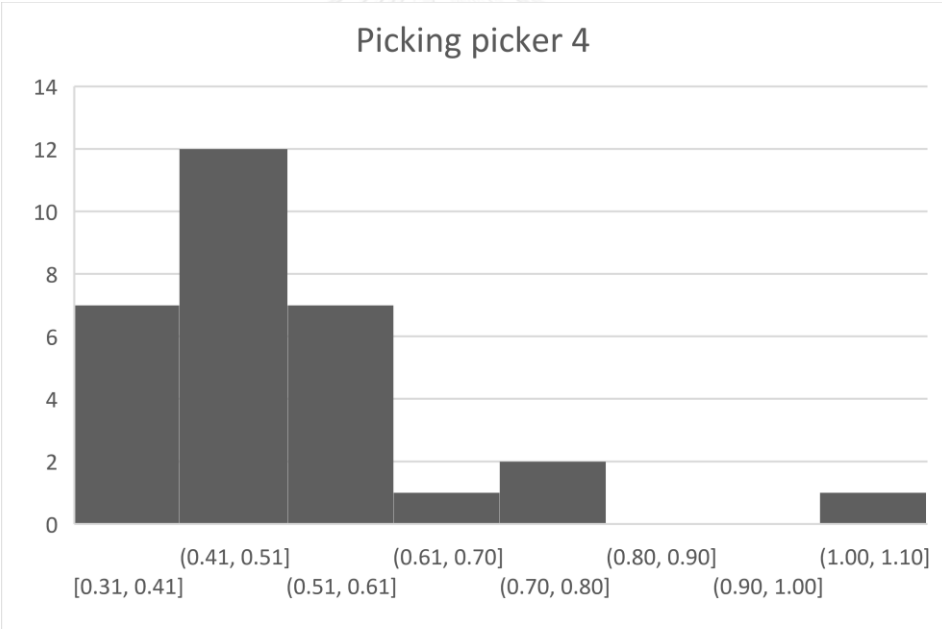

Figure 20: Plot of average picking time of picker 4

The figures 17, 18, 19 and 20 above portray histograms of picking time for each zone individually. All of the graphs above except for figure 19, is not normally distributed and left skewed. Figure 19 can be said to be uniform with no skewness or normal distribution. Again, in all of the graphs above we can see that there are outliers towards the right of the graphs.

Table 16: Identification of outliers

Day	Average Picker 1		Average Picker 2		Average Picker 3		Average Picker 4	
	Searching (min/line)	Picking (min/pcs)	Searching (min/line)	Picking (min/pcs)	Searching (min/line)	Picking (min/pcs)	Searching (min/line)	Picking (min/pcs)
1	2.18	0.68	2.50	0.50	3.44	1.56	2.93	0.75
2	2.71	0.62	2.00	0.52	2.13	1.25	1.45	0.32
3	2.10	0.38	2.46	0.47	1.86	1.38	1.29	0.32
4	2.29	0.40	2.42	0.50	2.64	1.40	2.00	0.31
5	1.53	0.34	1.71	0.26	2.30	1.61	2.80	0.45
6	2.12	0.64	2.25	0.71	2.11	1.00	1.93	0.75
7	2.00	0.54	2.75	1.67	1.75	1.14	2.42	0.54
8	1.89	0.50	2.38	0.44	1.86	1.29	2.56	0.38
9	1.87	0.51	2.25	0.53	2.18	1.10	2.13	0.37
10	1.93	0.52	2.33	0.66	2.13	1.15	1.75	0.56
11	1.92	0.63	2.73	0.57	1.86	0.91	1.75	0.46
12	1.92	0.54	1.90	0.35	2.00	1.50	2.44	0.48
13	2.25	0.50	1.72	0.43	2.14	1.57	2.00	0.48
14	1.79	0.38	1.41	0.41	1.83	1.44	1.92	0.50
15	2.17	0.44	2.40	0.60	2.33	1.43	1.45	0.40
16	1.90	0.44	3.00	0.48	2.25	1.90	1.70	0.43
17	2.13	0.50	2.00	0.60	1.86	1.24	1.91	0.52
18	2.13	0.63	3.14	0.64	1.83	1.46	2.67	0.50
19	2.00	0.72	2.50	0.83	2.00	0.75	1.50	0.50
20	1.86	0.60	1.40	0.79	1.67	1.67	2.50	0.53
21	2.17	0.56	-	-	2.08	0.85	2.00	0.50
22	2.00	0.53	2.00	2.00	2.00	2.00	2.20	0.63
23	2.00	1.22	3.00	0.61	2.00	2.00	2.33	0.43
24	1.92	0.60	2.14	0.62	2.00	1.50	2.00	0.50
25	1.75	0.59	1.60	0.74	1.64	0.94	1.68	0.53
26	2.00	0.60	2.00	0.71	2.00	0.63	1.80	0.40
27	2.11	0.61	2.33	1.86	2.14	0.88	2.40	0.55
28	2.00	0.46	2.14	0.65	2.08	0.81	1.20	0.56
29	2.17	0.56	2.73	0.55	1.92	0.68	1.89	0.46
30	2.00	0.48	1.33	0.63	1.80	0.74	2.00	1.10

The Table 16 above highlights all the outliers that has been removed from the searching and picking times of the Picker 1, 2, 3 and 4.

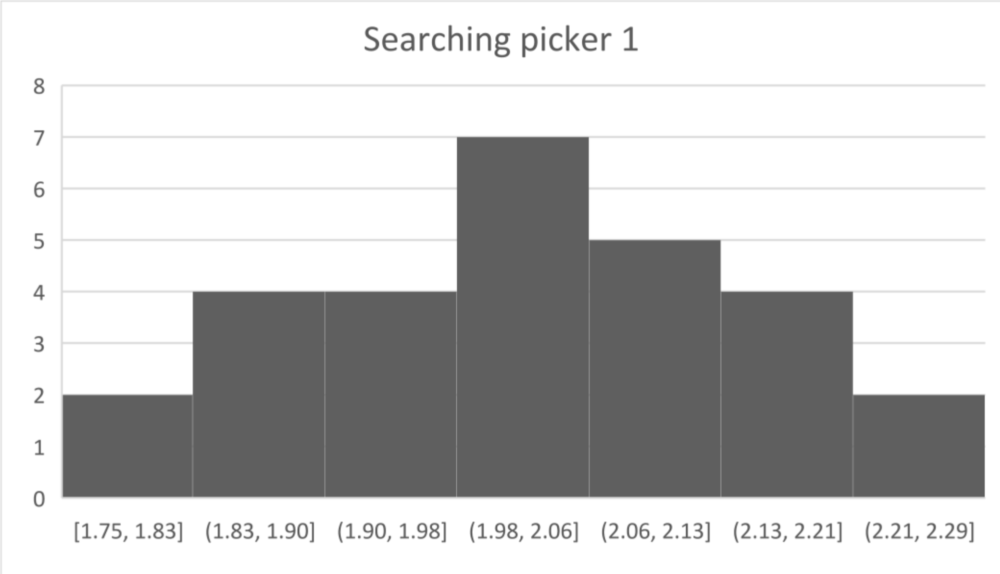

Figure 21: Revised plot of average searching time of picker 1

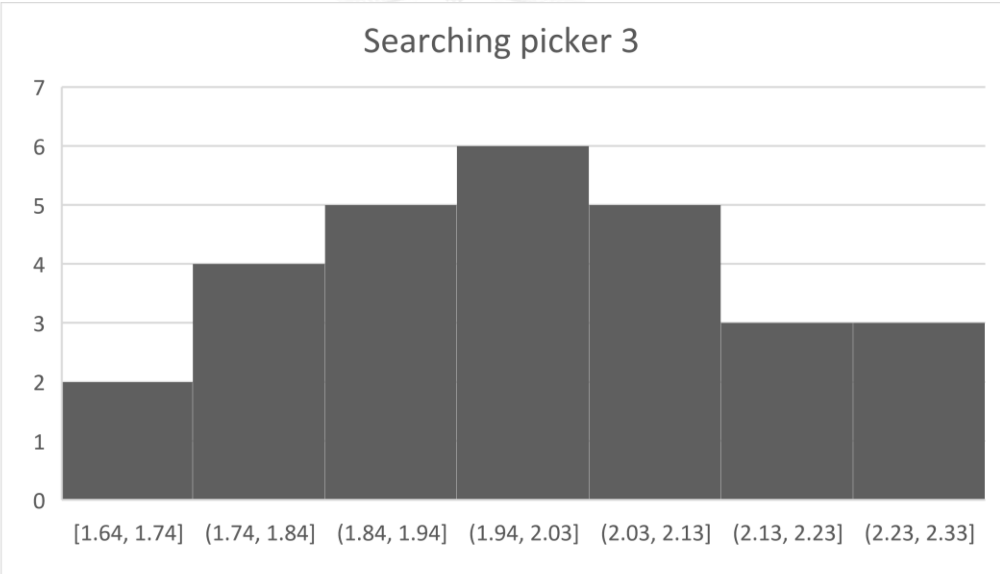

Figure 22: Revised plot of average searching time of picker 3

Table 17: Summary of outlier in searching time for picker 1

Day	Picker 1 / WH21		Average
	Pick Lines	Searching (min)	Searching (min/line)
2	7	19	2.71
5	15	23	1.53

Table 18: Summary of outlier in searching time for picker 3

Day	Picker 3 / WH24		Average
	Pick Lines	Searching (min)	Searching (min/line)
1	9	31	3.44
4	11	29	2.64

The above figure 21 and 22 shows the histogram for the average searching time for picker 1 and picker 3 after outliers has been removed. Since picker 2 and picker 4 histograms does not show any outlier, the graph therefore remains the same. After the outliers, has been removed, both graph shows a normal distribution. Tables 17 and 18 shows the data of the removed outliers in detailed. All the outliers that has been removed from the search time of picker 1 and picker 3 happens in the first 5 days after the new pick policy has been implemented therefore it can be concluded that all the outliers are caused by human error or storage location errors which causes an unusual searching time.

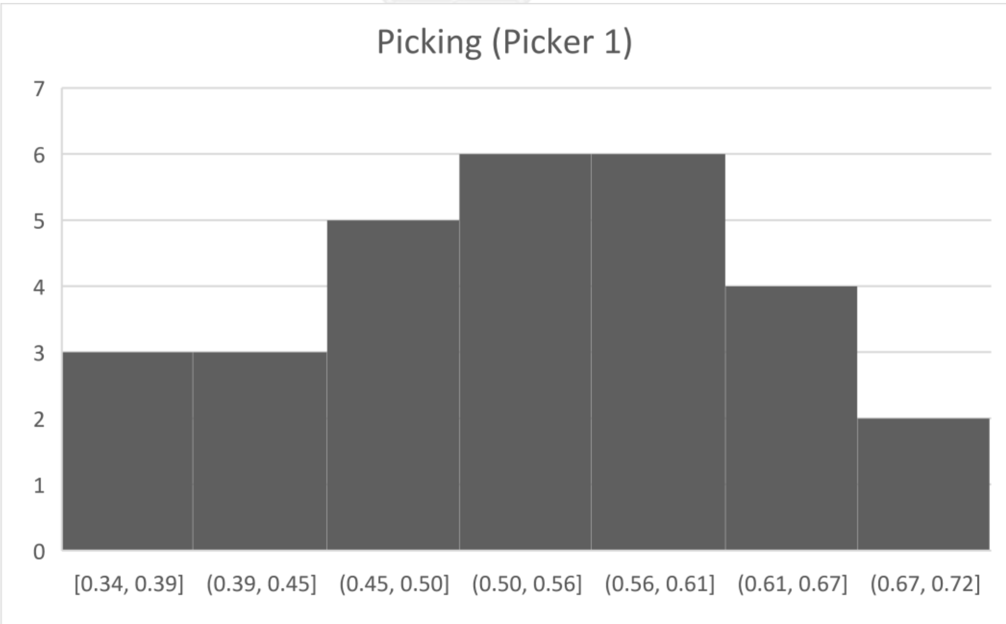

Figure 23: Revised plot of average picking time of picker 1

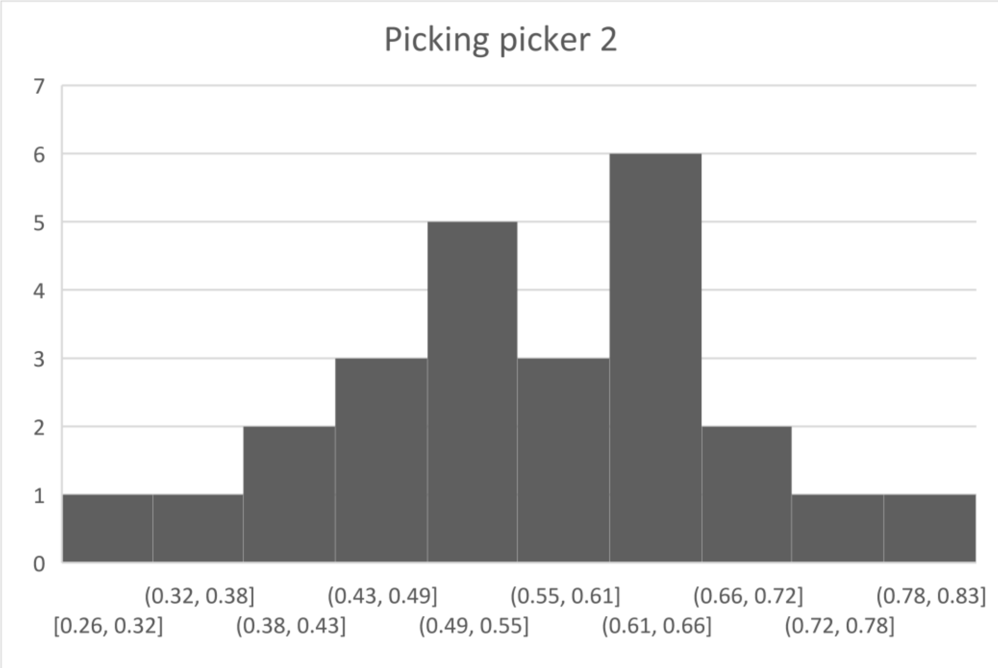

Figure 24: Revised plot of average picking time of picker 2

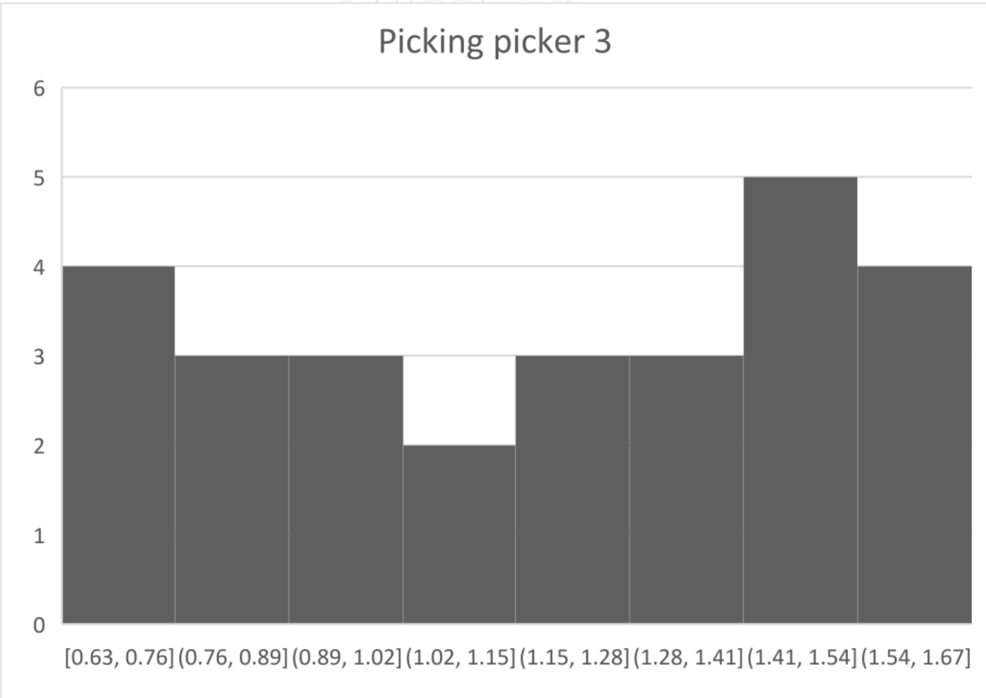

Figure 25: Revised plot of average picking time of picker 3

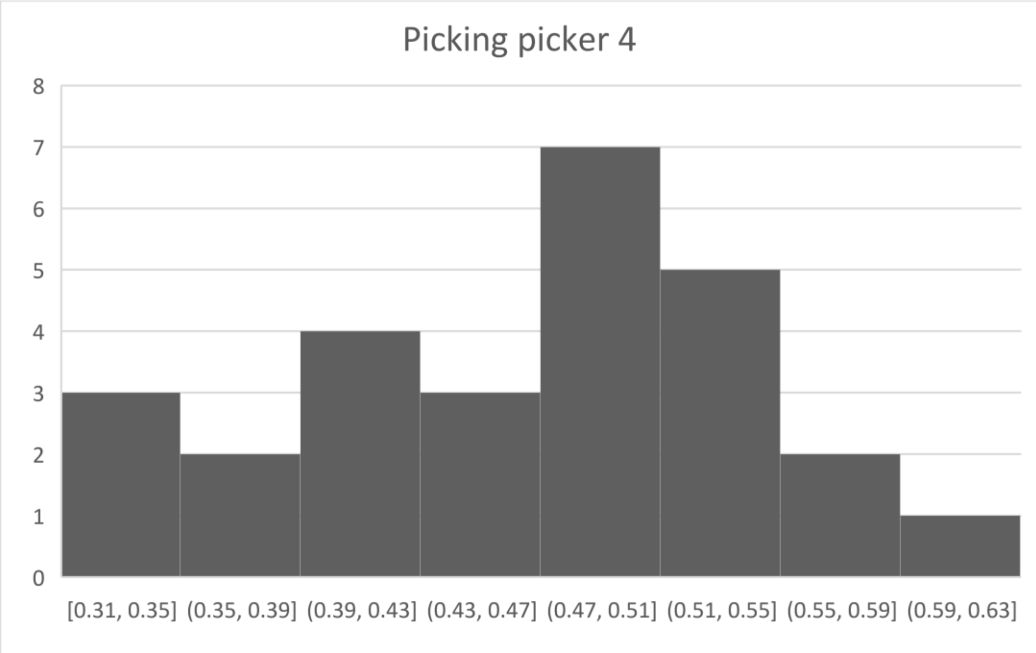

Figure 26: Revised plot of average picking time of picker 4

Table 19: Summary of outlier in picking time for picker 1

Day	Picker 1 / WH21			Average
	Pick Items	Pick lines	Picking (min)	Picking (min/pcs)
23	18	4	22	1.22

Table 20: Summary of outlier in picking time for picker 2

Day	Picker 2 / WH23			Average
	Pick Items	Pick lines	Picking (min)	Picking (min/pcs)
7	3	4	5	1.67
22	1	1	2	2.00
27	14	9	26	1.86

Table 21: Summary of outlier in picking time for picker 3

Day	Picker 3 / WH24			Average
	Pick Items	Pick lines	Picking (min)	Picking (min/pcs)
22	1	1	2	2.00
23	1	1	2	2.00

Table 22: Summary of outlier in picking time for picker 4

Day	Picker 4 / WH25			Average
	Pick Items	Pick lines	Picking (min)	Picking (min/pcs)
1	61	14	46	0.75
6	61	14	46	0.75
30	21	2	23	1.10

The figure 23, 24, 25 and 26 above shows the histogram for the average picking time for all zones after outliers has been removed. Figure 23, 24 and 26 portrays a normal distribution after outliers has been removed while figure 25 shows an unsymmetrical with right-skewed pattern. The Tables 19, 20, 21 and 22 above shows the outliers that has been removed from the histograms.

Picker 1 or warehouse 21, the average pick time on day 23 has been removed as it is an outlier which causes the histogram to have a left skewed. The possible cause of this outlier is by human error and therefore is disregarded.

Picker 2 or warehouse 23, the average picking time for day 7, 22 and 27 has been removed as it causes the histogram to have a left skewed. The first outlier that has been removed is day 7, as can be seen there are only 3 pick items while there are 4 pick lines; this means that there is one pick item that has more than one component with different pick location. This is considered unusual as products should be in only one location and therefore removed. The second outlier that has been removed is on day 22, here as can be seen there is only 1 pick item and 1 pick line therefore there are only 1 denominator for the average causing it to be very high. The last outlier that has been removed is day 27, the possible cause again is human error.

Picker 3 or warehouse 24, the average picking for day 22 and 23 has been identified as an outlier and removed. Again, there is only 1 pick item which causes the denominator to be very low resulting in a high average. Referring to the histogram graph figure 25, it is the only graph that is not normally distributed and left skewed. The main reason for this is that the properties of products stored in this warehouse is different from other warehouses. Warehouses 21, 23 and 25 mostly stores products which are easy to handle such as chairs and sofas. However, warehouse 24 is dedicated to tables of different sizes and materials. This includes glass, plastic stone, granite, wood, metal, artificial wood and artificial stone. Different materials have different fragility and weight, products with higher weight and fragility such as metal, glass and granite is harder to handle/pick and therefore takes more time than those with lower weight and fragility such as wood, artificial wood and plastic. Moreover, most of the products does not come in one box, most products come in many boxes and sizes therefore picking becomes more complex.

For picker 4 or warehouse 25, there are 3 outliers that has been removed which are in day 1,6 and 30. These average is removed due to the very high average compared to other results. In warehouse 25, the average picking time per minute is lower than other warehouses as most products are packed in bulk amount. For example, a product can be packed in boxes of 2, 4, 6 or 8 pieces therefore faster picking times are achieved.

The following section shows the result of the T-Test for searching time and picking time.

Searching Time T-Test: Two Sample Assuming Unequal Variances

Null Hypothesis: $H0: \mu 1 - \mu 2 \leq 0$

Alternative Hypothesis: $H1: \mu 1 - \mu 2 > 0$

	Variable 1	*Variable 2*
Mean	12.91569431	2.067542736
Variance	5.053806481	0.058851916
Observations	5	30
Hypothesized Mean Difference	0	
df	4	
t Stat	10.77979252	
P(T<=t) one-tail	0.000209974	
t Critical one-tail	2.131846786	
P(T<=t) two-tail	0.000419948	
t Critical two-tail	2.776445105	

Picking Time T-Test: Two Sample Assuming Unequal Variances

Null Hypothesis: $H0: \mu 1 - \mu 2 \leq 0$

Alternative Hypothesis: $H1: \mu 1 - \mu 2 > 0$

	Variable 1	*Variable 2*
Mean	0.967270932	0.615082671
Variance	0.023862531	0.033089937
Observations	5	30
Hypothesized Mean Difference	0	
df	6	
t Stat	4.594648664	
P(T<=t) one-tail	0.001856421	
t Critical one-tail	1.943180281	
P(T<=t) two-tail	0.003712842	
t Critical two-tail	2.446911851	

Referring to the number of observations used in the T-test for both searching and picking time it can be seen that the observations for variable 1 is only 5, this is due to the fact that observation of the initial state of the warehouse is very disruptive to the daily warehouse activities and uses a lot of manpower to collect the observations making the observations very hard and limited.

From the tables, it can be observed that the t Stat is greater than the critical one-tail for both the searching time and the picking time therefore we reject the null hypothesis and accept the alternative hypothesis. The observed difference between the sample means of both searching time (12.92 - 2.07) and picking time (0.97 - 0.62) is substantial to say that the average number of picking time differ significantly.

4.3 ABC Analysis

ABC analysis has been implemented to analyze the condition of the inventory by determining the inventories in the warehouse into categories A, B and C. Initially, Table 23 displays the initial condition of the warehouse before implementation of ABC analysis. The initial and final condition of the warehouse incorporate all of the products within the warehouse except products which are defective, waiting to be claimed, waiting to be repaired and damaged products.

Table 23: Before implementation of ABC analysis

	Amount SKU	SKU (%)	Inv Value (%)	Sales (%)	Turnover
A	762	34.90	39.14	79.39	2.602
B	580	26.57	25.97	15.96	0.788
C	840	38.53	34.89	4.65	0.171
Total	2183	100	100	100	1.282

The initial state of the inventory was observed on June 2016, with the total amount SKU of 2183 products. As can be seen in Table 23, product in category C contributes to a large portion of the amount of SKU 38.53% and inventory value 26.57% while contributes to very less amount of sales value 4.65% and turnover value 0.171. When compared with category A and category B, it can be seen that the amount of SKU and inventory value for category C is larger than category B while having similar value to category A. Therefore, again the aim of implementing ABC analysis is to reduce the amount and inventory value in category C products as it generates less revenue and turnover.

Table 24: After implementation of ABC analysis (including new products)

	Amount	Percentage Sku	Inv Value	Sales	Turnover
A	893	33.14	40.96	81.11	4.504
B	677	25.14	26.78	14.65	1.244
C	1124	41.72	32.26	4.24	0.299
Total	2,694	100	100	100	6.05

The final state of the inventory was observed on 1 January 2017 with the total amount SKU of 2694 products. The percentage of SKU in category C can be seen to have increased by 3.19% with the decrease of inventory value by 2.63% while sales remain similar. The result portrayed experiences an increase in the amount of SKU because new products are added to the product lists which immediately falls into the category C as it has not generated sales. Moreover, products which has already been repaired/replaced which was excluded in the initial state are also added to the amount of SKU. The following table will exclude all of the new products which has been ordered from June 2016 to January 2017 however will still portray products that has been repaired/replaced.

Table 25: After implementation of ABC analysis (excluding new products)

	Amount	Percentage Sku	Inv Value	Sales	Turnover
A	790	33.73	45.56	81.83	4.605
B	610	26.05	27.80	14.19	1.308
C	942	40.22	26.64	3.99	0.384
Total	2,342	100.00	100	100	6.30

After new products, has been removed we can see that there is still a small increase of 159 products in the total SKU. Again, this increase is due to the fact that products which has already been repaired or replaced is added to the SKU. Nevertheless, referring to the inventory value of category C products, we can see that we are able to reduce the inventory value by 8.25% while increasing the inventory value of products A and B, by 6.42 and 1.83 percent respectively. Finally looking at the turnover rate for all of the products category A, B and C, it can be seen that for products category C, the ratio has improved by more than double the initial value. Turnover ratio for product category A and B also improves by s significant amount.

From interviewing operators and managers of marketing department and purchasing department, the benefits of ABC inventory analysis is reported as follows:

- Revision of inventory is more transparent resulting to easier and more efficient management
- Revision of product clearances and product sales in different product outlets are done more effectively
- Reordering of products including product selection and product quantity

Lastly, cash conversion cycle (CCC) has been used as a KIP for ABC analysis. The following results was obtained:

Initial State:

$$Days\ Inventory\ Outstanding\ (DIO) = \frac{Inventory}{Cost\ of\ good\ sold\ (COGS)} * (\frac{365}{2}) \approx 363 \text{ Days}$$

$$Days\ Recievable\ Outstanding\ (DRO) = \frac{Account\ Recievables\ (AR)}{Sales} * \left(\frac{365}{2}\right) \approx 11 \text{ Days}$$

$$Days\ Payables\ Outstanding\ (DPO) = \frac{Account\ Payables\ (AP)}{Cost\ of\ good\ sold\ (COGS)} * \left(\frac{365}{2}\right) \approx 31 \text{ Days}$$

$$Cash\ Conversion\ Cycle = DIO + DRO - DPO \approx 343$$

Final State:

$$Days\ Inventory\ Outstanding\ (DIO) = \frac{Inventory}{Cost\ of\ good\ sold\ (COGS)} * (\frac{365}{2}) \approx 334 \text{ Days}$$

$$Days\ Recievable\ Outstanding\ (DRO) = \frac{Account\ Recievables\ (AR)}{Sales} * \left(\frac{365}{2}\right) \approx 19 \text{ Days}$$

$$Days\ Payables\ Outstanding\ (DPO) = \frac{Account\ Payables\ (AP)}{Cost\ of\ good\ sold\ (COGS)} * \left(\frac{365}{2}\right) \approx 58 \text{ Days}$$

$$Cash\ Conversion\ Cycle = DIO + DRO - DPO \approx 295$$

Table 26: Result comparison of CCC

	Initial (Jan – Jun)	Final (Jul – Dec)	Change
DIO	363	334	-7.99
DRO	11	19	72.73
DPO	31	58	87.10
CCC	343	295	-13.99

Referring to Table 26 above, it can be seen that the DIO has decreased by 7.99%, DRO has increased by 72.73% and DPO increased by 87.10%. This resulted in the decrease in CCC value of 13.99%. The CCC has decreased largely due to the reduction in the DIO of 29 days. Eventhough we have significantly reduced the DIO, the result of 334 days is still very high and can be further reduced. This value reflects the inventory condition, referring to Table 25, there is still a high number of products in category C of over 40% in total SKUs contributing to 26.64% of inventory value with only a turnover ratio of 0.384.

Referring to the DRO, there is a large increase of 72.73% or an increase of 8 days from the initial value. The company mostly recieves cash before products are delivered to the customers however in large projects the company gives credit to it's customers. The increase in DRO is due to the increase in project sales during the period from July 2016 to December 2016. Lastly, the DPO has increased by over 27 days as an effort of the company's negogiation with it's supplier for longer credit terms. Initially, the company would pay upfront to most of it's suppliers at the time of product delivery, in the effort of reducing the CCC value, the company was able to negogiate credit terms with it's suppliers.

Comparing the cash conversion cycle with the company's competitor, the CCC value of 295 days though has improved but it is still considered very high when compared with it's competitors (refer to Table 6). The comapny's CCC is very high mainly due the value of DIO; this is due to the fact that the company is a trading firm and does not manufacture therefore the finish good stocks that the company hold is very large resulting to a high very high value of DIO and CCC. Also, eventhough the competitors mentioned in Table 6 are based in Thailand, they are partially traders and partially manufacturers therefore will have a lower CCC as they are able to hold less finish good inventory. Nevertheless, the CCC value can be further improved by reducing the value of products in category B and C.

4.4 Class-Based Storage

Table 27: Results of class-based storage implementation

Results Average		
Walking (min/line)	Searching (min/line)	Picking (min/pcs)
0.23	1.84	0.42

Table 28: Result comparison of class-based storage

Comparison of Results Average			
	Walking (min/line)	Searching (min/line)	Picking (min/pcs)
Initial	0.23	1.99	0.46
Final	0.23	1.84	0.42

From the tables above, we can see that the walking time remains the same to the initial value however a noticeable improvement can be seen in the searching time and the picking time. The searching time has decreased by 7.54% while the picking time has decreased by 8.70%. Both improvements is achieved as traveling distance is reduced from rearranging the storage of product to across aisle configuration locations according to their value. Higher value products are visited more frequently therefore are placed close to the entrance and exit of the warehouse.

Referring to the layout of all the 5 warehouses in figure 1, it is arguable that the most effective storage configuration will be within aisle configuration as the quality control area is located in warehouse 23 which is the middle of all 5 warehouses. Therefore, if all of product A is located in warehouse 23, a total reduction in walking, searching and picking time should improve. However, within aisle is not possible to be implemented in the warehouse as all the products need to be moved according to their value which is not economical nor practical to be done in short term as products will be damaged during reallocation and a lot of manpower will be needed. Moreover, this will disrupt the daily activities of the warehouse and again incur high costs. Warehouse 25 was chosen to be implemented with class based storage across aisle configuration as products in this warehouse is packed in bulk amounts, products are less fragile/prone to damage and most importantly, movements of products in the warehouse is considered one of the highest in all 5 warehouses referring to the amount of picked items in Tables 12 and 13.

The following Table 29 show the walking, searching and picking times in detailed to statistically analyze the results.

Table 29: Order picking time after class-based storage implementation

Day	Picker 4 / WH25					Average		
	Pick Items	Pick Lines	Walking (min)	Searching (min)	Picking (min)	Searching (min/line)	Picking (min/pcs)	Searching (min/line)
1	31	9	2	17	15	0.22	1.89	0.48
2	78	12	2	27	32	0.17	2.25	0.41
3	26	6	2	10	10	0.33	1.67	0.39
4	33	9	2	16	8	0.22	1.78	0.25
5	42	7	2	15	15	0.29	2.14	0.36
6	51	16	2	28	24	0.13	1.75	0.48
7	37	12	2	20	19	0.17	1.68	0.50
8	99	12	2	21	44	0.17	1.75	0.44
9	40	6	2	9	13	0.33	1.50	0.33
10	16	4	2	7	5	0.50	1.75	0.30
11	22	7	2	15	9	0.29	2.14	0.41
12	30	9	2	18	14	0.22	2.00	0.47
13	26	10	2	19	12	0.20	1.90	0.46
14	49	13	2	23	19	0.15	1.77	0.40
15	38	8	2	14	13	0.25	1.75	0.35
16	84	17	2	30	44	0.12	1.76	0.52
17	113	16	2	29	53	0.13	1.81	0.47
18	55	13	2	22	24	0.15	1.69	0.44
19	39	6	2	11	15	0.33	1.83	0.37
20	16	2	2	3	9	1.00	1.50	0.56
21	36	6	2	11	14	0.33	1.83	0.38
22	71	10	2	19	29	0.20	1.90	0.41
23	14	3	2	6	5	0.67	2.01	0.35
24	38	5	2	9	13	0.40	1.80	0.35
25	22	5	2	10	10	0.40	2.01	0.44
26	16	3	2	5	5	0.67	1.67	0.33
27	39	9	2	16	16	0.22	1.78	0.42
28	24	4	2	7	9	0.50	1.75	0.38
29	31	12	2	22	17	0.17	1.84	0.55
30	42	11	2	22	15	0.18	2.01	0.36
Sum	1258	262	60	481	530	9	55	12

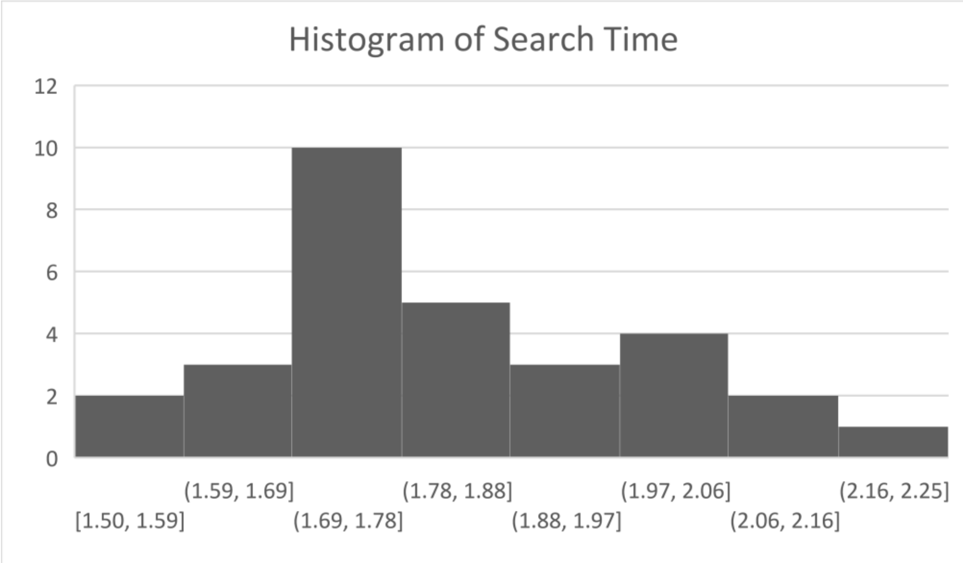

Figure 27: Plot of search time for picker for after class-based storage implementation

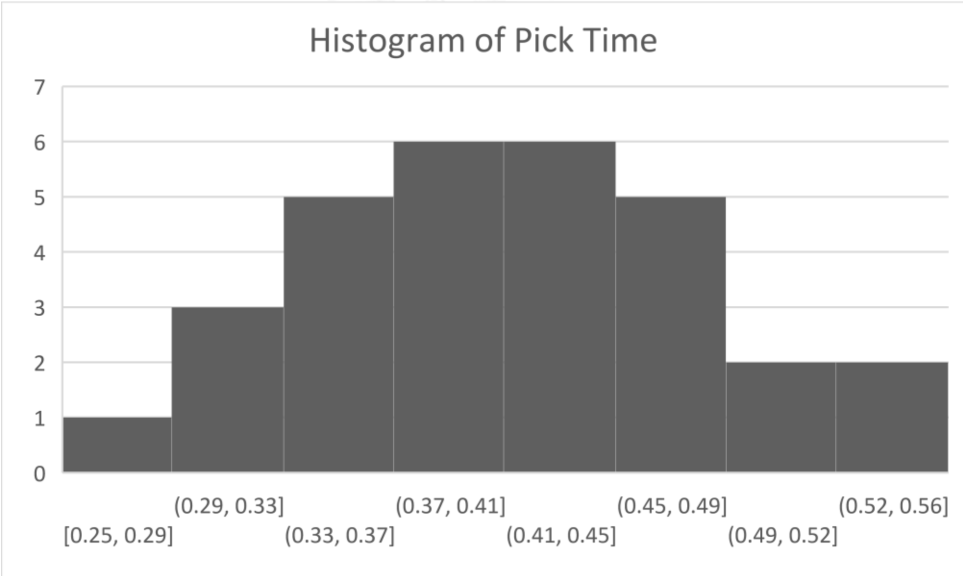

Figure 28: Plot of pick time for picker for after class-based storage implementation

Searching T-Test: Two Sample Assuming Unequal Variances

Null Hypothesis: $H0: \mu 1 - \mu 2 \leq 0$

Alternative Hypothesis: $H1: \mu 1 - \mu 2 > 0$

	Variable 1	*Variable 2*
Mean	2.061462241	1.830762678
Variance	0.221332931	0.030124302
Observations	30	30
Hypothesized Mean Difference	0	
df	37	
t Stat	2.519853736	
P(T<=t) one-tail	0.008093281	
t Critical one-tail	1.68709362	
P(T<=t) two-tail	0.016186562	
t Critical two-tail	2.026192463	

Picking T-Test: Two Sample Assuming Unequal Variances

Null Hypothesis: $H0: \mu 1 - \mu 2 \leq 0$

Alternative Hypothesis: $H1: \mu 1 - \mu 2 > 0$

	Variable 1	*Variable 2*
Mean	0.528368882	0.41176937
Variance	0.031623006	0.005382659
Observations	30	30
Hypothesized Mean Difference	0	
df	39	
t Stat	3.31988665	
P(T<=t) one-tail	0.000980433	
t Critical one-tail	1.684875122	
P(T<=t) two-tail	0.001960866	
t Critical two-tail	2.02269092	

Referring to the number of observations used in the T-test for both searching and picking time above, it can be seen that the observations for both variables 1 and 2 are 30, which is enough to conduct a reliable t-test for the results obtained. From the values above, it can be observed that the t Stat is greater than the critical one-tail for both the searching time and the picking time therefore we reject the null hypothesis and accept the alternative hypothesis. The observed difference between the sample means of both searching time (2.06 - 1.83) and picking time (0.53 - 0.41) is substantial to say that the average number of picking time differ significantly.

5 Conclusion

This research study is conducted with the objective of increasing the operational efficiency of an SME furniture warehouse through the use of warehouse and inventory management tools where the main aims are to reduce time consumption in order-picking and the overall inventory condition. It is crucial that the company must improve these factors in order to expand its growth and increase the competitive advantages in the Thai furniture market. There are 5 processes in warehouse operations, however focus is given to order-picking as it is the costliest operation. Initially, the company was facing several problems including long order processing times, unlocated products causing traceability and stock discrepancies issues, high inventory value with low turnover ratios. In the effort to improve the operational efficiency of the warehouse, 4 warehouse and inventory management tools namely, lean 5S, order picking policy, ABC analysis and class-based storage have been implemented. These tools are implemented in 2 phases, phase 1 consists of implementing lean 5S and order picking policy. Phase 2 consists of implementing ABC analysis and classed-based storage. Raw data collection was obtained through interviews, direct observations and data collection through accounting department. The results are measured using several KIPs such as photos, interview, stock discrepancies, delivery errors, time, cash conversion cycle (CCC) and inventory value. The research objective and aims were achieved and the findings were obtained as follows.

Firstly, lean 5S has been implemented in phase 1 to improve overall condition of the warehouse environment setting standards and order to the initial system. Supported by many literatures, the method is a foundation to implementing other warehouse and inventory management methods. 5S was able to majorly reduce stock discrepancies, improve delivery errors and improve traceability of the inventories as product conditions and location are defined and sorted which reduces the chance of order processing and inventory auditing errors. Furthermore, as reported from the warehouse operators, the method was able to improve stock keeping effectiveness and efficiency, reduce workload from order pickers and quality control operators.

Secondly, order picking policy have been implemented to directly improve the time consumption in order-picking process. Order-picking time can be separated into 3 categories which are walking, searching and picking time. Synchronized zone picking with batch pick policy was implemented to the warehouse in place of single-order picking. The method was able to greatly reduce the order-picking time in all of the 3 categories especially searching time in combination with lean 5S. The result obtained was also verified using the T-test statistical analysis method in which the observed difference between the sample means of both searching time and picking time is substantial to say that the average number of picking time differ significantly.

Thirdly, after the implementation and result collection of phase 1, ABC analysis was implemented to improve the overall condition of the inventory. ABC analysis has been implemented as a method to analyze the condition of the inventories. The analysis obtained were then used in other departments such as marketing and sales, import and accounting to plan promotions, reordering of inventory and liquidity of the company. ABC analysis was able to improve the turnover ratio of products in categories A, B and C especially in category C by a significant amount from initial value. As reported by management, the increase in transparency of the inventory conditions in the warehouse makes it easier and more efficient to manage the inventory. Additionally, the cash conversion cycle (CCC), was reduced significantly as well.

Lastly, class-based storage policy has been implemented to further improve the time consumption in order-picking process. Class-based storage allocation has been used to define the location of products according to its value A, B and C in across aisle storage configuration. The method has proven to increase the efficiency of both searching and picking time improving the overall order processing time. The improvement was achieved by reduction in travel distance as products with higher activity are rearranged closer to the entrance/exit of the warehouse. The result obtained was again verified using the T-test statistical analysis method in which the observed difference between the sample means of both searching time and picking time is substantial to say that the average number of picking time differ significantly.

There are 3 main limitations to this research these are warehouse design, routing policy and product storage method. The warehouse the research is being carried is separated into 5 warehouses with no connecting aisle within the warehouses as can be seen in figure 1. The warehouse design is limited and cannot be changed as the company does not own the warehouse limiting the ability to modify the design. The warehouse design also limits the possibility of modifying the routing policy in order-picking process. As mentioned, there are no connecting aisles between the warehouses nor connecting aisles within each warehouse, therefore the routing policy has been forced to use return routing policy. Referring to figure 1 again, it can be argued that the most effective routing policy should be within aisle storage configuration as the middle warehouse (warehouse 23) is where the quality control procedure is located, therefore every product must be consolidated in warehouse 23 before it is delivered to the customers. However, because of the storage method used in the warehouse, the research is limited to using across aisle storage configuration. The storage shelfs are not standard racks and are built by the company itself. As storage shelfs are not standardized, it does not fit to the size of pallets forcing the storage of products to be placed onto the shelfs without pallets. This limits to flexibility of moving the products as it puts a lot of work on the operators because the products must be moved manually. Furthermore, as products must be handled manually along with the product being prone to damage, the company risks causing a lot of damages to the products being moved.

Nevertheless, there are a lot more improvements that can be made. The recommendation for further research would be to improve the current system through modification of the warehouse design, routing policies and picking methods in combination with the new warehouse design and routing policy comparing cost savings and increase in efficiency through the use of simulation methods. Simulation was not used in this study because the condition of the warehouse did not facilitate data collection. Moreover, this research serves as a benchmark for the simulation in order to compare the efficiency increase and cost savings in order for the company to consider the feasibility in investing in the suggested changes and methods. Inventory storage location policy and storage configurations can also be studied with the change in warehouse design with standardized shelfing system.

The contribution to the field of this research is the uniqueness of the environment in which the research is being carried out. Firstly, the research is based on a rented Thai SME furniture company warehouse. The routing policy and warehouse layout are therefore fixed. Moreover, the storage shelves are not standardized therefore also limits the ability to store products on pallets. With these limitations, we were able to apply warehouse and inventory management literatures to the warehouse thus improving the operational efficiency of the warehouse.

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APPENDIX

VITA

Narut Kongtoranin was born on 9th February 1993 in Bangkok, Thailand. After graduating high school from New International School of Thailand (NIST), he continued his bachelor degree education in Manufacturing and Management Engineer from the University of Nottingham, United Kingdom.