DEVELOPING A WAREHOUSE OPERATING SYSTEM

FOR A PLASTIC PACKAGING MANUFACTURER

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ขวัญรัตน์ พฤกษ์วัฒนา : การพัฒนาระบบปฏิบัติการคลังพัสดุสำหรับผู้ผลิตบรรจุภัณฑ์พลาสติก (DEVELOPING A WAREHOUSE OPERATING SYSTEM FOR A PLASTIC PACKAGING MANUFACTURER) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร. ปวีณา เชาวลิตวงศ์, 196 หน้า.

งานวิจัยนี้ได้พัฒนาระบบปฏิบัติการคลังพัสดุสำหรับผู้ผลิตบรรจุภัณฑ์พลาสติก โดยศึกษากรณีคลังพัสดุซึ่งจัดเก็บวัตถุดิบและสินค้าที่อยู่ในระหว่างกระบวนการผลิต การศึกษาเน้นด้านการออกแบบนโยบายสินค้าคงคลังและการจัดการคลังพัสดุทางด้านการจัดวางผังคลังสินค้า การจัดเรียงพัสดุ และเครื่องมือสนับสนุนการทำงาน โดยมีวัตถุประสงค์เพื่อส่งเสริมประสิทธิภาพของการควบคุมสินค้าคงคลังและเพิ่มความสะดวกในขั้นตอนการดำเนินงานคลังสินค้า

การออกแบบการควบคุมสินค้าคงคลังได้มีการกำหนดนโยบายสินค้าคงคลังเพื่อตอบสนองความต้องการสำหรับการผลิตและปฏิบัติตามเงื่อนไขอุปทาน โดยนโยบายมุ่งเน้นไปที่การสั่งซื้อวัตถุดิบในปริมาณที่เพียงพอต่อความต้องการและการจัดส่งได้ทันเวลา การนำนโยบายไปประยุกต์ใช้ได้ถูกนำเสนอในสองกรณี โดยในกรณีแรกได้คำนึงถึงการสั่งซื้อในกรณีฉุกเฉินของลูกค้า และในกรณีที่สองซึ่งมีการสั่งซื้อที่แน่นอนโดยไม่มีกรณีฉุกเฉินดังกล่าว ในด้านการจัดการคลังพัสดุนั้น การจัดวางผังคลังสินค้าและการจัดเรียงพัสดุได้ถูกออกแบบใหม่เพื่อเพิ่มการเข้าถึงพัสดุและเพิ่มประสิทธิภาพของการดำเนินงานคลังสินค้า โดยการออกแบบการจัดเรียงพัสดุนั้นได้จัดเตรียมพื้นที่สำหรับจัดเก็บที่เพียงพอสำหรับพัสดุแต่ละรายการ และคำนึงถึงความถี่ของการเคลื่อนไหวของพัสดุ การออกแบบยังช่วยให้ระบบการทำงานเป็นไปตามหลักการเข้าก่อน-ออกก่อน และเพิ่มความปลอดภัยในการจัดเก็บ นอกจากนี้เครื่องมือสนับสนุนการทำงานได้ถูกออกแบบเพื่อเพิ่มความพึงพอใจของผู้ปฏิบัติงาน การประเมินผลนโยบายสินค้าคงคลังนั้นขึ้นอยู่กับประสิทธิภาพของการควบคุมสินค้าคงคลัง โดยพิจารณาจากปัญหาการขาดแคลนวัตถุดิบ และมูลค่าของการถือครองสินค้าคงคลัง การประเมินผลการจัดการคลังพัสดุดำเนินการโดยใช้จำนวนพาเลทเมตรเป็นตัวบ่งชี้การเข้าถึงพัสดุ

ผลการประเมินกรณีศึกษาพบว่า นโยบายสินค้าคงคลังที่นำเสนอนั้นสามารถป้องกันปัญหาการขาดแคลนวัตถุดิบ นอกจากนี้การถือครองสินค้าคงคลังนั้นลดลง 52.19% ในขณะที่การเข้าถึงพัสดุนั้นเพิ่มขึ้น 34.80%

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KWANRAT PRUEKWATANA: DEVELOPING A WAREHOUSE OPERATING SYSTEM FOR A PLASTIC PACKAGING MANUFACTURER. ADVISOR: ASST. PROF. PAVEENA CHAOVALITWONGSE, Ph.D., 196 pp.

This thesis develops a warehouse operating system for a plastic packaging manufacturer. The warehouse of focus stores raw materials and work-in-process. The study emphasises on designing inventory policy and warehouse management concerning layout, slotting and supporting tools. The design intends to promote effective inventory control and ease of warehouse operating procedure.

The inventory control design involves determination of inventory policy which is capable to best satisfy demand for production and comply with supply condition. The lot-for-lot policy is, thus, introduced to the case study. The policy focuses on just-enough order quantity and timely arrival of raw materials. The adoption of policy is presented in two cases; one with expected emergency order from customers and the other with certain order and no emergency case. In terms of warehouse management, layout and slotting are redesigned to provide increased accessibility of items and, therefore, warehousing efficiency. The redesigned slotting provides enough space for each item which is slot with reference to its frequency of movement. The design also enables first in first out warehouse system and safety of storage. Furthermore, supporting tools are implemented in the case study aimed at better worker satisfaction. The inventory policy evaluation is based on performance of inventory control considering stock-outs and value of holding inventory. The warehouse management evaluation is also conducted using Pallets x metre as an indicator of accessibility.

The results indicate that the proposed inventory policy leads to an absence of stock-outs and a reduction of holding inventory by 52.19%. The accessibility of items in the warehouse is also improved by 34.80%.

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1. CHAPTER I INTRODUCTION

1.1 Background of the study

Thailand is strengthening its position as a leading global hub for plastic manufacture, particularly the packaging sector. The packaging is by far the heftiest consumer of plastic in Thailand. According to The Board of Investment of Thailand (2012), plastic packaging accounted for approximately 31 percent share of the country's plastic exports. In the year 2013, according to PR Web (2014), plastic packaging held the second rank in share of the total packaging materials following paper packaging. Metal and glass packaging represented the third and fourth categories, respectively. Many Thai brand company continue to choose flexible packaging over other heavy pack materials as the main type of packaging for consumer products due to its lighter weight. The plastic packaging category is expected to continually maintain high performance in the year ahead. Furthermore, with the introduction of the ASEAN Economic Community (AEC) in 2015, plastic investors will see Thailand as an attractive production centre as a result of highly skilled and affordable workforce.

To be able to step ahead of rivals in fierce competition, plastic packaging manufactures, thus, inevitably need to actively improve their performance as well as reduce costs. Supply chain is targeting as an area in which costs can be reduced.

Warehouse is now seen as an integral part of the supply chain as it is used to hold stocks needed to feed internal activities. With pressures to reduce costs as well as improve business performance levels, warehouse management, especially in terms of operating system become more challenging.

The case study company is a plastic packaging manufacturer serving a variety of products ranging from blown film, laminating film to plastic bag in either printed or unprinted types. The company was recently established in December 2009, approximately 5 years ago. As a new company, there are currently two main customers and five regular products. The five products are printed laminating and non-laminating films served to the customers as a roll. There are four main production processes including blowing, printing, dry laminating and slitting processes. The blowing process turns resins into blown film which could be further processed by printing machine yielding printed film. The dry laminating process involves attachment of two or more layers of film together. The last process of production is slitting which would slice film into finished goods with width and length specified by the customers. The production process of printed laminating film and printed non-laminating film are shown in Figure 1.1 (I) and (II), respectively. The purchased raw materials used in the production, as demonstrated in Figure 1.1, include plastic resins, purchased film, printing inks, adhesives, solvents and paper cores.

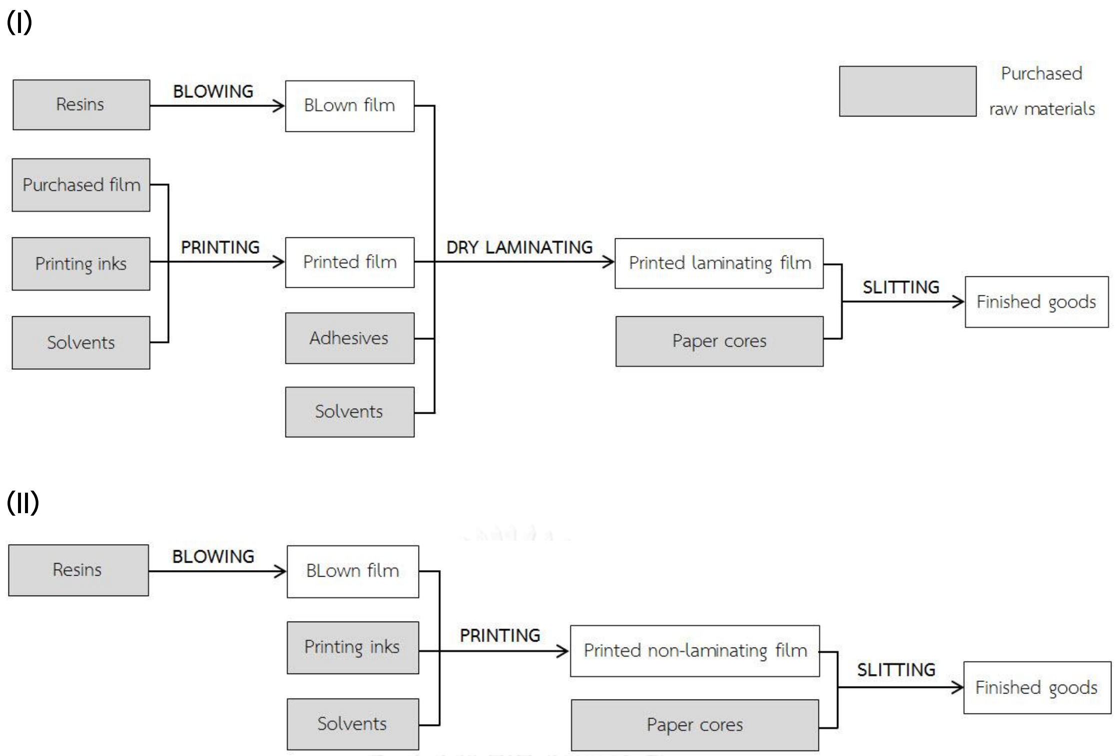


Figure 1.1: Production process of (I) printed laminating film and (II) printed non-laminating film

In addition, the company has two separated warehouses; one for raw materials and work-in-process and the other for finished goods. However, only the warehouse for raw materials and work-in-process will be discussed in the study.

1.2 Statement of the problem

As the company is newly established, there is no system regarding management of inventory and warehouse. There is also no information sharing among departments within the company for ease of the management. Procurement takes a part in supply of raw materials to the warehouse while the warehouse feeds such raw materials to the production upon requisition. Warehouse acts as an intermediary in the operating system between the procurement and production as illustrated in Figure 1.2.

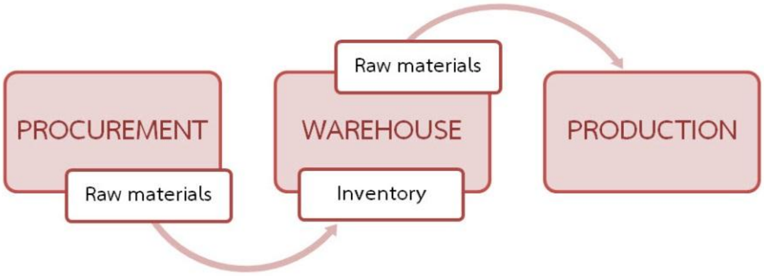


Figure 1.2: Relationship among procurement, warehouse and production

Although the three departments have to work interdependently, there is no set-up operating system to support daily operation of the departments. Due to poor management of the company, shortage of raw materials has occurred and impeded smooth operation of the production. Table 1.1 shows occurrences of shortage during May 2014 to August 2014. The case study company, thus, lose opportunity to fill pending customer orders and failed to satisfy the demand.

Table 1.1: Occurrence of raw-material shortage during May 2014 to August 2014

Type	Observed shortage of raw materials (Occurrences)
Plastic resins and additives	0
Purchased films	0
Printing inks	9
Adhesives	2
Solvents	3
Paper cores	0
Total	**14**

In addition to the inventory control of raw materials, the warehouse management of the case study could not provide ease of operating procedure especially in terms of accessibility of items in the warehouse. The case study warehouse also in need of supporting tools to enhance ease of daily operation as well as user satisfaction.

As a result, well-designed warehouse operating system has to be set up in order to improve productivity and performance of the warehouse. Such improvement enables more efficient production, so the company would be able to satisfy customers since products would always be available on demand. The designed warehouse operating system could also enable cost reduction as a result of reduced holding inventory. Business performance of the case study company would be boost up and, therefore, competitive advantage would definitely be achieved.

1.3 Objective of the study

The objective of this study is to design operating system of the warehouse for raw materials and work-in-process of the case study company. The design is aimed at effective inventory control as well as ease of warehouse operating procedure.

1.4 Scope of the study

The study focuses on inventory policy and warehouse management regarding layout, slotting and supporting tools by using a case of plastic packaging manufacturer. The scope of the study includes topics listed as follows:

1.4.1 Design of inventory policy for controlling stocks of raw materials in order to reduce shortage as well as inventory level

1.4.2 Redesign warehouse layout and slotting for better operating procedure in terms of accessibility of stored items and ease of operation

1.4.3 Implement supporting tools to promote better user satisfaction

The evaluation on inventory management involves assessing shortage and inventory value of raw materials in the existing management compared to that of proposed management. In case of warehouse management, accessibility of items stored in the warehouse would be evaluated to compare the existing and redesigned situations.

1.5 Expected benefits

The study is expected to contribute the benefits to the case study company with improvement in inventory management as well as warehouse management.

Due to such improvement, better customer and worker satisfaction would be achieved.

1.6 Study procedure

The study procedure is divided into six steps as follows:

1.6.1 Collect the data and analyse the current performance of inventory management and warehouse management

1.6.2 Study the related literatures regarding inventory management and warehouse management

1.6.3 Develop the methodology to improve the current performance of focus

1.6.4 Introduce the developed methodology to users and implement action to the case study company

1.6.5 Gather the output data, evaluate the results and compare to those of the previous method

1.6.6 Summarise the study

1.6.7 Write up the thesis and prepare for examination

2. CHAPTER II RELATED LITERATURE STUDY

There are three primary stages involved in a supply chain including procurement, production and distribution. With increased competitive pressures, companies are forced to develop supply chains so that customer needs would be quickly responded. Independently managing functions in a supply chain leads to poor behavior. As a result, companies should grab opportunities for strengthening competitive edges by coordinating the planning of all stages of the supply chain (Thomas, 1996).

Warehouse is a focal part of a business as it normally works in contact with other functions of any business. In daily operation, it relates to all departments of a company especially the procurement and production. The procurement feeds materials into the warehouse while the warehouse further supplies those materials to the production.

There are many activities which could be best achieved by cooperation between the warehouse and the procurement including controlling inventory as well as determining lot size for purchase suitable with production requirements and storage space. In addition, the warehouse and production needs to closely coordinate as the production is the main customer of the warehouse. For instance, in case there is any change in production schedule, the coordination would allow prompt corrective action (Materials management, 2015).

The related literature study includes researching on concepts of warehouse and inventory management relating to the focus of this thesis. Just-in-time technique would also be studied as its concepts are widely accepted and implemented for business improvement.

2.1 Warehouse

Warehouse is considered as a temporally place for storage of items whether the items are materials for production processes or finished goods. Warehouse keeps items which are still not prompt for consumption or currently not required by customers but ready to be delivered once there is a demand. The warehouse enables business to efficiently function despite of uncertainty in market conditions. It also takes part in improving service to customers and gains benefit of production and transportation economies of scale which allowing discounts in quantity purchase (Lambert et al, 1998).

2.1.1 Warehouse operations

The operations could be mainly separated into four functions including receiving, put away, order picking and shipping. The receiving involves unloading of items from transportation vehicles to warehouse’s receiving docks. The items would be inspected for possible deficiencies or missing delivery. The warehouse inventory record, then, is updated to note changes. The process of put away associates with movement the delivered items from the receiving docks to storage location, shipping docks or other areas within the warehouse. The order picking refers to a process of gathering required items from the storage location to satisfy requisition of customers. The picked items might pass through accumulation and sortation in case of batch picking as the items must be grouped with reference to customer orders before proceeding to shipment. The last function is shipping which deals with loading of items onto transportation vehicles for shipment to the customers. Cross-docking is conducted if the received items are directly transferred to the shipping docks. The shipping also involves inspection of products to be delivered and updating inventory records (Koster et al, 2007).

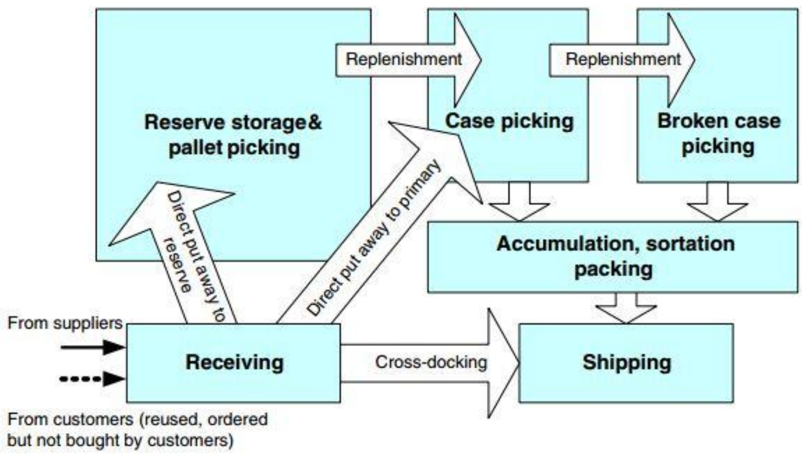


Figure 2.1: Warehouse functions and flows (Tompkins et al, 2003:p.389)

Among the warehouse operations, as shown in Figure 2.2, the process of order picking and storage account for approximately 70 percent of the total warehouse operating cost. Order picking solely contributes to a large part of 50 percent of the total cost since it normally still requires human as an operator; otherwise high investment is required in implementation of automation. Order picking, therefore, has become an area with increased attention among professionals seeking for means to improve productivity of warehouse (Frazelle, 2001).

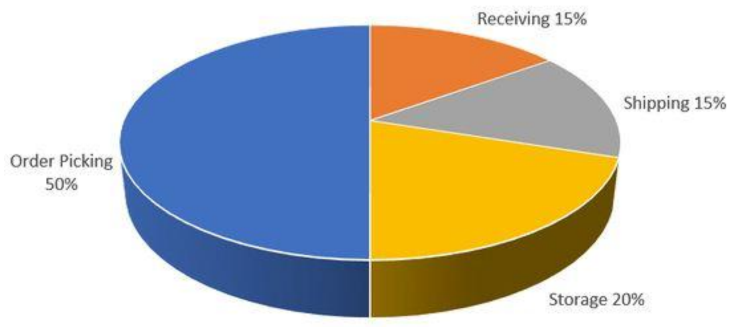


Figure 2.2: Warehouse operating cost distribution (Ogrinja, 2014)

Horvat (2012) also pointed out that the total time taken for a single picking tour is mostly spent on travelling between pick location and the depot and searching for the items as illustrated in Figure 2.3. The travel time could be a measure on performance of order picking process. Order picking is considered as area which would significantly contribute to improvement in warehouse's operating efficiency. The travel time, thus, offers a great opportunity for the improvement compared to other activities during picking process.

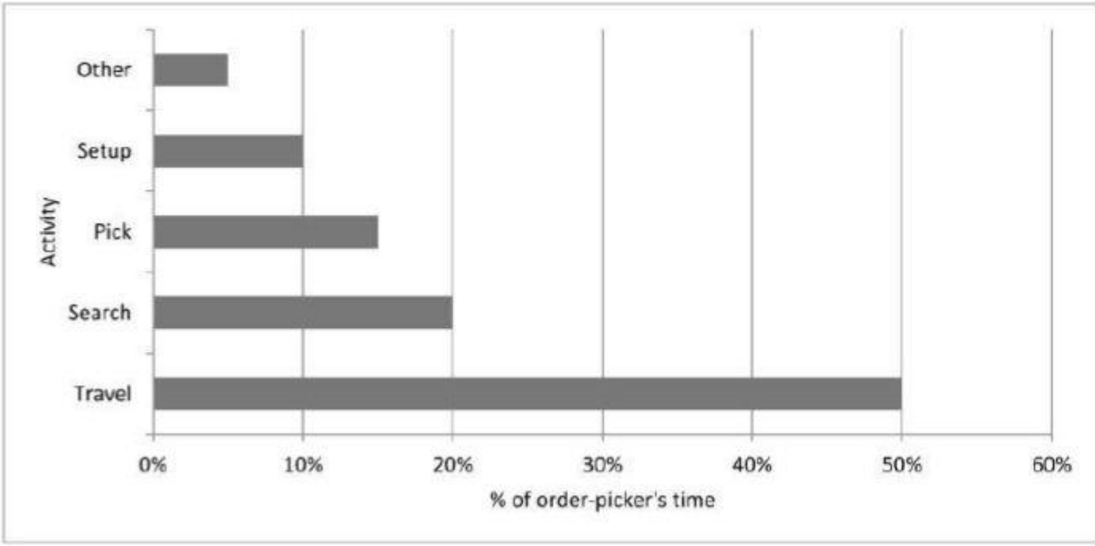


Figure 2.3: Order picker's time distribution (Horvat, 2012:p.9)

Travel time of order picking could be minimised while maintaining the maximum usage of space, labour and equipment. Such condition could be achieved by carefully designing and controlling the order picking system. There are four tactical and operational decisions on improving efficiency and performance of order picking including layout design, picking policy, storage assignment policy and routing policy. The layout design deals with layout of warehouse containing order picking system as well as layout of the system itself. The picking policy associates with decision on how orders would be picked. The storage assignment policy is determination of allocation of items to storage location. Lastly, the routing policy deals with the route that the order picker has to travel in operating order picking (Chan and Chan, 2011).

2.1.2 Storage assignment policy

Chan and Chan (2011) also pointed out that the determination of storage location of items is a significant task in designing of a new warehouse or redesigning of the existing one. Many factors have impact on the storage assignment such as order picking method, layout of storage system, product characteristic, space requirement, demand trend, turnover rate and also material handling system. As there are many factors that have to be taken into consideration, it is extremely hard to come up with the best solution of storage location. The selection of an appropriate storage assignment policy, thus, offers a solution to address with the problem. The travel time should be monitored and storage locations should be designed with efficient allocation rules in order to increase the efficiency of order picking. Possible improvement in order picking can be achieved by changing the operating policies and adjusting physical layout of the warehouse (Roodbergen and Vis, 2006).

According to Koster et al. (2007), there are five frequently-used types of storage policy including random storage, dedicated storage, closest open location storage, full turnover storage and class based storage.

For the random storage, the incoming item is assigned to a randomly-selected location in the warehouse. The random storage results in high space utilization while increasing travel distance. On the contrary, in case of the dedicated storage, a specific location is assigned to a particular item. The dedicated storage allows the picker to remember the actual location, thus speeding up the picking process. Nevertheless, if there is no stock for such particular material at any one time, the slot will remain empty leading to a reduction in storage utilisation.

If the order picker is allowed to choose the storage location by itself, the employed policy is known as the closest open location storage. The first empty location that the employee encounters will be used to store the item. Such storage policy typically results in a warehouse where racking is full around the depot and gradually becomes empty when moving towards the back. Another storage policy is full-turnover storage in which the items are distributed over the storage area with reference to their turnover. The items with the highest turnover rate are stored at the easiest-accessible locations while the slow-moving items are placed in the location towards the back of the warehouse.

By combining some of the policies mentioned so far, the class based storage groups the stored items into classes and assigns dedicated storage to specific group of items. The items within a class are stored randomly, thus flexibility and high space utilization are applicable. Koster et al. (2007) also suggested that relations between items should be taken into consideration for storage assignment. In case customers tend to order a certain item together with another one, these two items should be located next to each other to facilitate order picking. Such family-grouping ensures similar items are placed in the same region within the storage area. The grouping can be combined with those of the stated storage policies.

Chan and Chan (2011) provided a research regarding storage assignment policy in a multi-level rack warehouse. A simulation study was conducted to compare the performance of class-based and random storage assignment policy. The study was evaluated by considering travel distance as an indicator. The result showed that class-based storage policy outperforming with minimum travel distance.

Chackelson et al (2011) presented a case study in which order picking was improved by the introduction of class-based storage assignment policy. The case study company is a home appliance manufacturer having a warehouse where all of the stored items are placed on pallets located in a racking system. The result from simulation model reported that class-based storage contributed to a reduced travel distance.

Khalil (2013) studied the performance of full-turnover and random storage assignment policies for many feasible warehouse layout configurations in a picker-to-parts warehouse. The experiment indicated that the full-turnover storage assignment resulted in the lowest travel distance of order picking.

2.1.3 Warehouse slotting

Warehouse slotting could be referred to the assignment of items to storage location within a warehouse. In performing slotting, profiling of item activity must be studied as it would provide necessary information required to slot items in the warehouse. The profiling should include the quantity requested for each item, the quantity shipped per period for each item and also the volumetric requirement for each item.

Implementation of slotting involves determining order or ranking of items stored in the warehouse. There are many ranking methods available such as turnover, popularity, volume, pick density and cube-per-index or COI. Turnover or demand of item refers to the total quantity of shipment during a given period of time. Popularity method would consider the number of request for each specific item. It also refers to the number of travel to a storage location of a given item during order picking. According to Frazelle (2002), popularity is the most popular method used in determining ranking for slotting. In addition, volume method uses the demand of a given item multiplied by the volume of that item. The volume method is also known as the cube movement of a given item. Another method, pick density refers to a ratio of popularity of item to the volume of that item. Pick density method would identify the items having the highest pick activity per a given space.

The last ranking method, COI, is a ratio of the cube to the turnover of an item. The COI method would rank items in ascending order of the index (Petersen et al, 2005).

Petersen et al (2005) also evaluated the aforementioned ranking method in a manual bin-shelving which could refer as a low level picker-to-part picking area with multiple stored items. The result of evaluation indicated that popularity, turnover and COI ranking methods led to lesser travel distance of order picking compared to those of volume and pick density slotting. Furthermore, popularity and COI showed the best performance for all storage assignment policies.

Kofler et al (2011) also conducted an experiment on warehouse slotting on framework for heuristic optimization assuming a rectangular warehouse with racking system. The result of study shown that slotting by pick frequency led to a highly-reduced travel distance compared to a normal random solution.

2.2 Inventory management

Inventory management involves planning, coordinating and directing activities associated with flow of inventory throughout an organization. The management of inventory is significant as materials costs normally account for more than 40 percent of total costs in case of manufacturing companies while more than 70 percent of total costs in case of merchandising companies. In order to increase net income, any company has to effectively manage costs associated with products for sale including purchasing costs, ordering costs, carrying costs, stock-out costs, quality costs and shrinkage costs.

First, the purchasing costs, as the name suggested, are costs that a consumer has to pay to acquire goods from suppliers. The cost normally contributes to the largest costs of products for sale. Discounts of the purchase as well as payment term have a significant effect to purchasing costs.

Second, the ordering costs refer to costs in preparing and issuing the purchase order as well as receiving and inspecting the delivered items. The costs also arise in matching invoices, delivery records and purchase orders in order to further process in payment. Moreover, the cost of acquiring approval on purchase and other additional processing are included in the ordering costs.

Third, the carrying costs involve costs of holding items in the form of inventory. The costs consist of opportunity cost of investment in inventory and other costs regarding storage such as space, insurance, spoilage and obsolescence.

Forth, the stock-out costs occur when there is a shortage of materials and customer demand could not be satisfied. In such case, inventory has to be actively replenished by expediting order from the supplier. Additional ordering costs and transportation costs might be charged; otherwise sales to the end customer would be lost. In case of sale loss, the stock-out costs would include opportunity costs on the sale which could not be made as well as on future sales to the customer.

Fifth, the quality costs arise when a product or service does not have features and characteristics in conformance with specifications defined by the customer. The costs, thus, are incurred to avoid product with low quality. The quality costs include prevention costs, appraisal costs, internal failure costs, and external failure costs. The prevention costs are incurred in order to avoid manufacturing of products which do not in conformance with the customer's specification. The appraisal costs refer to costs in detecting each individual unit not conforming to specification. In addition, the internal failure costs are incurred on imperfect products before shipment to the customer while the external failure costs are incurred after the shipment to the customer.

Lastly, the shrinkage costs might emerge as a result of misappropriation or error of workers and theft by outsiders. The shrinkage could be measured by determining difference between the recorded data of inventory in absence of theft or other stated incidents and the actual data of inventory acquired by physically counted. Shrinkage could be a measure of performance in management (Horngren et al, 2011).

In the management of inventory, inventory problems arise when making decisions regarding when to place a purchase order and how much to order. In order to solve such problems in decision making, Vrat (2014) recommended to consider inventory-related costs, situation variables such as demand, lead time and any uncertainties of demand and lead time and other relevant data such as quantity discounts, budget, inflationary factors and space constraints. Among the costs associated with products for sale, there are three inventory-related costs including inventory carrying costs, stock-out costs and ordering costs.

2.3 Just-in-time technique

In a highly-competitive environment, supply chain management has been introduced as a growing strategy to gain competitive advantage. Just-in-time or JIT technique has been adopted in many functional area regarding supply chain management. The adoption of JIT system in inventory management has been growing although it was originally initiated in manufacturing as a philosophy on operation planning and control contributing in continuous enhancement in product quality as well as process productivity. Supply chain planners have discovered that the system could be a beneficial approach to eliminate waste in logistic system such as transportation and warehousing. JIT technique also provides new opportunities in terms of inventory control in supply channels

2.3.1 Principles of JIT management

The JIT philosophy was developed by Mr. Taiichi Ohno, a former Executive Vice-President of Toyota Motor Corporation. The concept is commonly recognised as the Toyota Production System which was initially originated in Japan aiming to improve productivity of manufacturing industry. An application of JIT allowed Toyota to accomplish improvement in productivity and was capable to manufacture cars in higher quality as well as reliability. Since land costs in Japan are expensive, Toyota also streamlined the production to achieve minimum holding inventory and, thus, reduce space taken up by inventor (Pheng and Chuan, 2001). There are six main principles of JIT management as follows:

2.3.1.1 Elimination of waste

According to JIT, waste refers to anything with no value added to the end product. Inventory exceeding actual demand is considered as waste because stocking up inventory has no added value. It unnecessarily takes storage space, disburses capital and incurs costs associated with storage, security and insurance. In addition, excess inventory leads to risks of obsolescence as well as damage that might occur during storage.

2.3.1.2 Pull system

The principle focuses on flow of materials which is pulled by demand. The materials are not allowed to be delivered when there is no authorised pull demand. The basic concept of this principle is that resources should be provided just only in the needed amount as well as at the needed time. As a result, a relationship between supplier and customer is vital for achieving this principle.

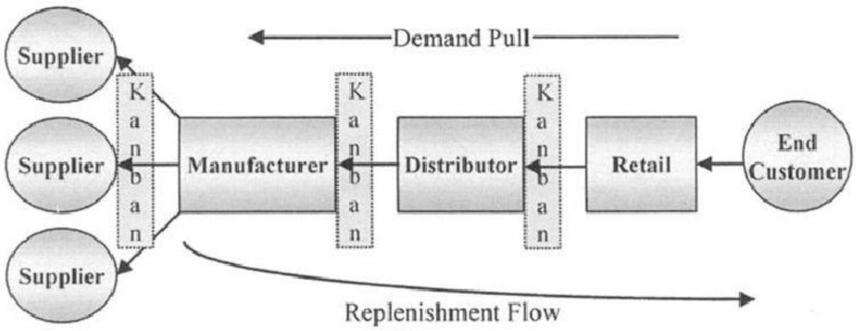


Figure 2.4: JIT synchronised supply chain (Ross, 2004:p.339)

2.3.1.3 Uninterrupted work flow

As a result of pull system, any interruption at a point within the chain would affect the entire processes. Therefore, it is essential to keep smooth operation and ensure continuous flow of steps within the chain. The concept could be promoted by avoiding unnecessary operations such as rework and inspection. Automation and maintenance of equipments and machineries would also prevent interruption occurring from breakdowns.

2.3.1.4 Total quality control

In order to achieve elimination of waste as well as uninterrupted operation, a total quality control or TQC should be implemented. The materials delivered must have good quality for prompt usage. Any rejection as a result of poor quality should be avoided since it would obstruct smooth flow within the chain. Inspection would be performed to assure the items have no defect and could be sent to the subsequent point of the chain.

2.3.1.5 Employee involvement

The involvement of workers at every levels of organization is significant for success of JIT system. The effort and commitment of top management act as a driving force for JIT implementation as well as involvement of other workers. The awareness and well understanding of the workers in JIT technique is beneficial to JIT implementation. Both top management and workers have to continually participate in searching for means to improve the existing working processes.

2.3.1.6 Supplier relations

Although suppliers are external entities, they have high contribution to successful JIT. As the pull system requires delivery of right materials with right quality in required amount at the right time and place, the supply plays a significant role in

JIT implementation. In case of having a lot of suppliers, the management would have less time to coordinate in working matter and expedite orders. JIT system, thus, focuses on reducing the number of supply sources and working with a single supplier. The selection of supplier would base on ability to supply materials with perfect quality at the required time. Coordination and communication with suppliers should be effective in order to promote long-term relationship with mutual trust. With a small group of suppliers, the management would be capable to focus more on each supplier to ensure JIT production and deliveries (Mercado and Solís, 2012).

2.3.2 Effective JIT system or zero-inventory system

JIT has attracted a great deal of attention from manufacturing systems in recent years proven by a large number of articles written and published in many sources. JIT could also refer to lean supply chains as well as zero-inventory system. The concept of JIT focused on just-in-time producing and supplying whatever required, whenever required and also whenever required by trying to kept nearly no inventories.

Effective JIT system or zero-inventory system requires a lot of significant factors. A source of supply should be local as well as dependable. A chance of delay in meeting consumer requirement is not allowed as the consumer might face with stock-outs. Lifelong association with supplier should also be promoted to assure a perfect reliability. Nevertheless, an alternative supply system is built in order to ensure the flow of inventory is continuous with no interruption. In addition, supply rate has to be driven by pull-based inventory planning in which customer demand at the end point activates the pull for material or product from precedent step. Demand from one location in supply chain is driven by the next location within the chain. The pull system involves flow in supply chain on made-to-order basis. The supply rate must also match with consumption rate by employing frequent deliveries. There should be no surplus cost associated with staggered deliveries. In case a supplier faces with overcapacity, such occurrence does not pass on inventory carrying cost to a consumer. The incoming material should have a perfect quality so that rejection on supply does not occur. As a result, inspection on quality is a must to ensure a perfect supply. The delivered material would be sent directly to the point of requisition, thus there is no store of the materials. All the stated factors are prerequisites of JIT system; otherwise zero-inventory system could not be achieved (Vrat, 2014).

2.4 Conclusion

Warehouse acts as a buffer between procurement and production by balancing supply and demand of materials. It is recognised as an important part of any business and, thus, efficient operations are required in order to increase business performance and profitability. A wise inventory control also allows cost saving especially in terms of carrying costs and stock-out costs.

The study on related literature leads to better understanding regarding warehouse and inventory management. The ideas attained from the study provide supportive guideline which could be applied to the case study.

3. CHAPTER III EXISTING SITUATION STUDY

The study of existing situation begins with background of the case study company and its products. The warehouse is introduced in details regarding stored items, warehouse design and operations. The current inventory policy for replenishment of raw materials feed to the production is also studied. Other related information including sales, production plan, brief production process and capacity are, then, discussed for better understanding of the company. In addition, problems arisen as a result of the existing inventory policy and warehouse management are analysed in order to seek for opportunities of improvement.

3.1 The case study company and its products

The case study company is a plastic packaging manufacturer first established in 2009. The finished goods provided to customers ranging from blown film, laminating film to plastic bags in both roll and bag types of either printed or unprinted. The company currently has two separated warehouses for raw materials/ work-in-process and finished goods. Since made-to-order policy is employed, there is less chance of holding stocks of finished goods and, thus, warehouse management for finished goods is not complex and will not be discussed in the thesis. As a result, only the warehouse for raw materials and work-in-process would be focused in the study.

Nowadays, there are two customers and five products with regular orders. The company judges those customers and products as the first priority in managing the production. In case there is any order from other customer, the decision on accepting the order would be based on whether the company still has available capacity and raw materials to satisfy such order. Therefore, this study focuses only on the five main products, namely Product A, Product B, Product C, Product D and Product E which are printed film in roll for plastic packaging.

Product A, B, C and D are printed laminating film consisting of two layers attached by adhesive. The production process of the four products is aforementioned and shown in Figure 1.1 (I). However, the layers of film in Product A, B and C are different from those in Product D as shown in Figure 3.1. Product A, B and C are printed white-LLDPE laminating film consisting of printed Biaxially oriented polypropylene (BOPP) film and white-Linear low-density polyethylene (white-LLDPE) film. Instead of white-LLDPE film, a transparent-LLDPE film is replaced for Product D, attached to printed BOPP film and forming printed transparent-LLDPE laminating film. In addition, the BOPP film of Product A, B and C is plain type whereas that of product D is heat sealable. While Product A, B, C and D are two-layer film, Product E has only a single layer of printed LLDPE film as shown in Figure 3.1 (III). The production of Product E or printed non-laminating film is presented in Figure 1.1 (II).

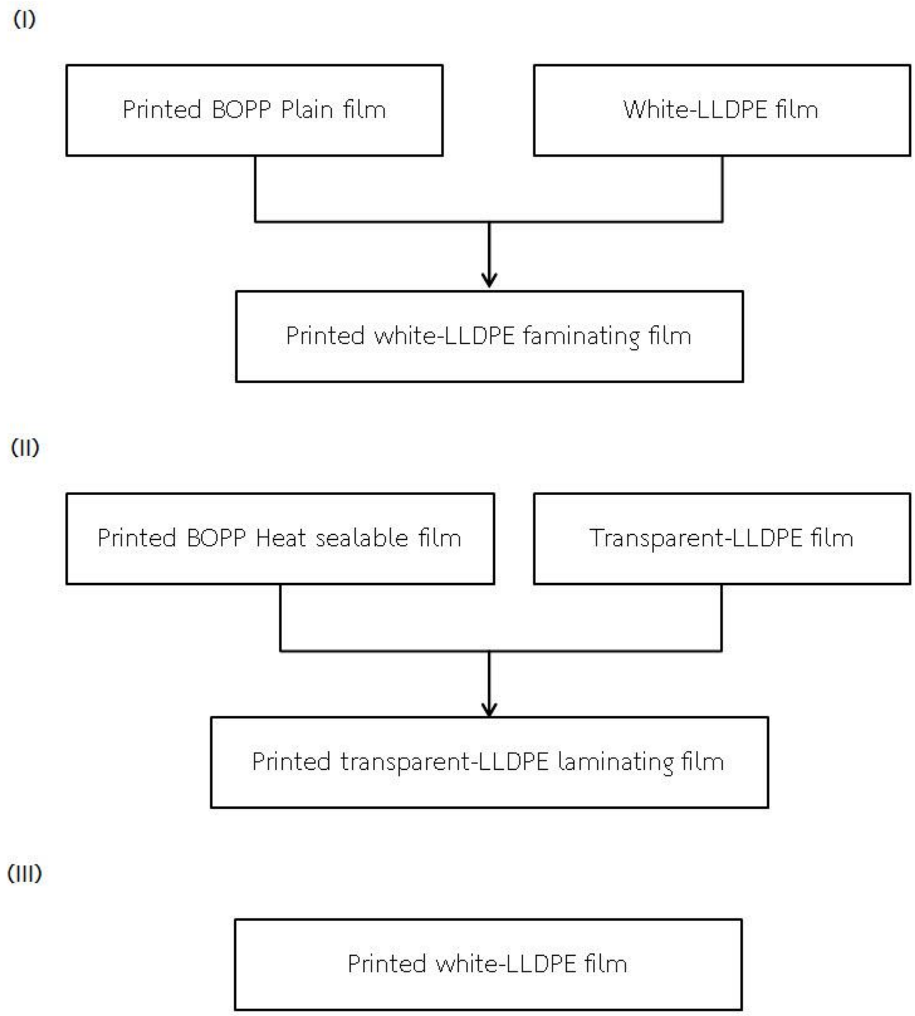


Figure 3.1: Film of (I) Product A, B and C (II) Product D (III) Product E

The summary of product specification including the number of printed colour, width and core diameter of finished goods, length and approximate net weight per one roll of finished goods as well as layers of film is presented in Table 3.1.

Table 3.1: Specification of the five main products

Item	Printed colours	Width (mm)	Length (m)	Core diameter (Inch)	Net weight (kg)	Number of layer	Type of film	
							Layer 1	Layer 2
Product A	7	362	1,050	6	39	2	Printed BOPP plain film	White-LLDPE film
Product B	4	362	1,050	6	39	2	Printed BOPP plain film	White-LLDPE film
Product C	3	362	1,050	6	39	2	Printed BOPP plain film	White-LLDPE film
Product D	7	366	1,050	6	39	2	Printed BOPP heat sealable film	Transparent-LLDPE film
Product E	3	445	1,000	3	29	1	Printed white-LLDPE film	-

3.2 The warehouse

As mentioned earlier, the warehouse of focus is the one used to store raw materials and work-in-process waiting to be further processed for completion. The warehouse is located nearby production line in order to facilitate material movement. The stored items, warehouse design, and current warehouse operations will be described in the following sections.

3.2.1 Stored items

There are six categories of raw materials and work in process stored in the warehouse of case study. Each category includes items with different grade and property. It is noted that only the items which are frequently used in production for the five main customer products are discussed in the study. Items stored in the warehouse are listed as follows:

3.2.1.1 Plastic resins and additives

There are two types of plastic resins used for blowing process including Low-density polyethylene (LDPE) and Linear low-density polyethylene (LLDPE). There are also additives used to enhance film quality and add film colour. The resins used in production of the five main customer products are LL 7410A, LL 7410D1, LD 2420D, LD 2426H, EL 5220G, EL 5401G, SP 2020H and White Masterbatch (WM). Such plastic resins and additives are purchased from more than one supplier. The plastic resins and additives are supplied in the form of bag with the weight of 25 kilograms per one bag.

Figure 3.2: Stored items - Plastic resins and additives

3.2.1.2 Films

Films stored in the warehouse can be categorised into two groups, purchased films and work-in-process films. The first group are films which cannot be blown using the existing blowing machine, thus the company has to purchase from external suppliers. There are two types of purchased film with dissimilar specification used in production of the main products; BOPP Plain (BOPP P) and BOPP Heat sealable (BOPP HS) films. The latter group, work-in-process films, refers to films blown by the blowing machine and stored in the warehouse pending for further processing. The blown films are prepared for different products with different specification based on width, length, and property.

(I) **(II)**

Figure 3.3: Stored items - (I) Purchased films (II) Blown films

3.2.1.3 Printing inks

Printing inks used in the printing process are purchased from two different suppliers. Different type of film requires different ink grade for printing images on the film surface. There are three grades of printing inks namely HI-OPP, NEW PPL and DLO. Within one ink grade, there are many shades of colour for different customer products. Some products use only few colours in printing while others use up to seven colours. Inks are stored as buckets with 16 or 20 kilograms per one bucket.

Figure 3.4: Stored items - Printing inks

3.2.1.4 Adhesives

Adhesives are used for laminating two or more films together. Currently, there are two grades of adhesives, LA 2882F and LA 5000, used in lamination process of the main products. The process requires the two grades of adhesive mixed together, thus the adhesives are normally supplied in pairs. The adhesives are stored in the warehouse as buckets with different weight per one bucket for each grade of adhesives.

Figure 3.5: Stored items - Adhesives

3.2.1.5 Solvents

Solvents are used in the production process during printing and lamination. There are three grades of solvents currently used in production including Ethyl acetate (EA), Thinner M (Toluene: Methyl ethyl ketone: Ethyl acetate) and Thinner I (Toluene: Isopropanol: Ethyl acetate). Such solvents are stored in big buckets with 180 kilograms per one bucket.

Figure 3.6: Stored items – Solvents

3.2.1.6 Paper cores

Paper cores are used as inner cores for film delivered to customers as a roll. There are three sizes of paper cores with different thickness, width and length stored in the warehouse which are used for different products served to customers. The three sizes include 3" x (W) 445 mm x (T) 15 mm, 6" x (W) 362 mm x (T) 8 mm and 6" x (W) 366 mm x (T) 8 mm.

Figure 3.7: Stored items - Paper cores

3.2.2 Existing warehouse design

The warehouse of case study used selective racking for storage as shown in Figure 3.8. The layout of racking is separated into six zones, A to F. Zone A and B have 8 racks (17 columns for pallet storage) whereas Zone C, D, E and F have 5 racks (10 columns for pallet storage). Each rack has six levels for storage including ground floor and five upper levels. The approximate height of ground floor is 2 metres while that of each upper level is 1.2 metres. The width of each column for pallet storage is approximately 1.3 metres.

Figure 3.8: Selective racking system

The horizontal beams form the five upper levels between the vertical uprights which are fixed securely to the floor. The horizontal beams are solid structures securely held by pins. It is defined that each beam of the upper levels could withstand the maximum weight of 1,000 kg or 1 ton. According to the racking design, each level of the rack could support two pallets except those of the last rack in Zone A and B which could support only one pallet on each level. As a result, Zone A and B could support the maximum of 102 pallets per zone whereas Zone C, D, E and F could support the maximum of 60 pallets per zone. With these conditions, a total quantity of 444 pallets could be stored in racking of the warehouse. The current warehouse layout design and detailed dimension are shown in Figure 3.9.

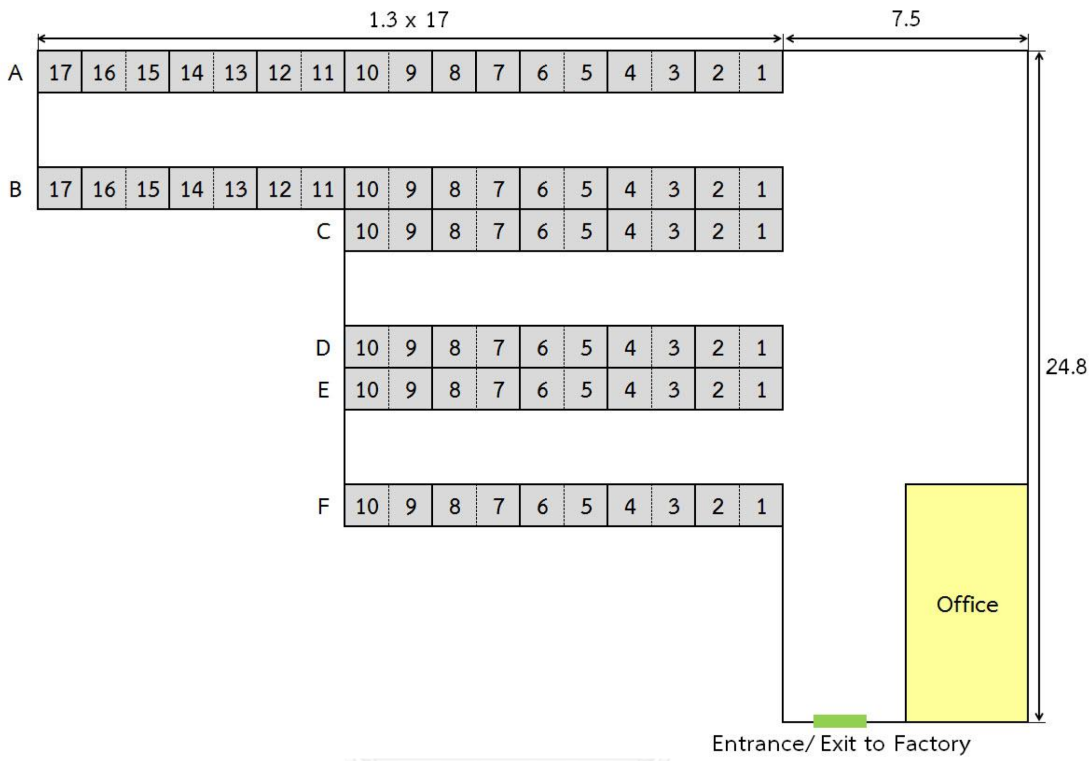


Figure 3.9: Existing warehouse layout design and dimension with the unit of metre

Currently, items stored in the warehouse could be separated into groups as listed in the previous section. Each group of items is assigned to specific storage zones as follows:

Zone A: Plastic resins and additives

Zone B: Plastic resins and additives

Zone C: Films

Zone D: Films

Zone E: Paper cores and films

Zone F: Solvents, printing inks and adhesives

In case of resins, films and paper cores, there is a fixed position for a particular item and, thus, the same items are placed adjacent to each other. There are no criteria for decision on selecting the fixed position as the position is randomly selected. However, printing inks and adhesives are randomly stored within Zone F. The inks are placed toward the front of the warehouse while adhesives are allocated toward the back of the warehouse. The existing warehouse slotting of raw materials is demonstrated in Figure 3.10, 3.11 and 3.12.

	A17	A16	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
6								LD 2420D	LD 2420D	LD 2420D	LD 2420D	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1
5								LD 2420D	LD 2420D	LD 2420D	LD 2420D	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1
4								LD 2420D	LD 2420D	LD 2420D	LD 2420D	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1
3								LD 2420D	LD 2420D	LD 2420D	LD 2420D	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1
2								LD 2420D	LD 2420D	LD 2420D	LD 2420D	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1
1								LD 2420D	LD 2420D	LD 2420D	LD 2420D	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1	LL 7410D1

	B17	B16	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1
6				SP 2020H	SP 2020H	SP 2020H	SP 2020H	SP 2020H	SP 2020H	WM	WM	EL 5220G	EL 5401G	LD 2426H	LD 2426H	LL 7410A	LL 7410A
5				SP 2020H	SP 2020H	SP 2020H	SP 2020H	SP 2020H	SP 2020H	WM	WM	EL 5220G	EL 5401G	LD 2426H	LD 2426H	LL 7410A	LL 7410A
4				SP 2020H	SP 2020H	SP 2020H	SP 2020H	SP 2020H	SP 2020H	WM	WM	EL 5220G	EL 5401G	LD 2426H	LD 2426H	LL 7410A	LL 7410A
3				SP 2020H	SP 2020H	SP 2020H	SP 2020H	SP 2020H	SP 2020H	WM	WM	EL 5220G	EL 5401G	LD 2426H	LD 2426H	LL 7410A	LL 7410A
2				SP 2020H	SP 2020H	SP 2020H	SP 2020H	SP 2020H	SP 2020H	WM	WM	EL 5220G	EL 5401G	LD 2426H	LD 2426H	LL 7410A	LL 7410A
1				SP 2020H	SP 2020H	SP 2020H	SP 2020H	SP 2020H	SP 2020H	WM	WM	EL 5220G	EL 5401G	LD 2426H	LD 2426H	LL 7410A	LL 7410A

Figure 3.10: Existing warehouse slotting of plastic resins and additives (Zone A and B)

	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1
6	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P				
5	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P				
4	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P				
3	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P				
2	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P				
1	Blown film									

	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1
6	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P				
5	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P				
4	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P				
3	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P				
2	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P				
1	Blown film									

Figure 3.11: Existing warehouse slotting of films (Zone C and D)

Figure 3.12: Existing warehouse slotting of paper cores, printing inks, adhesives and solvents (Zone E and F)

3.2.3 Existing warehouse operation

Once items arrive to receipt area, they are subjected to be checked for quantity, condition and possible damage. Certain items might require further stringent checking for quality control. Following receiving, a warehouse operator is responsible to move the items out as soon as possible since the receipt area is used for both receiving and shipping purpose. As a result, it is necessary to keep the area unoccupied in order to ensure smooth operation of all activities to be held at the receipt area.

The warehouse operator, thus, has to transfer the received items directly to the warehouse. It is noted that all raw materials delivered from suppliers would be unpacked and loaded on the company's own pallets before allocation into storage in racking. As stated earlier there is a specific storage zone for each type of raw materials and items, thus the operator has to check for specification of items before allocating them into storage.

Whenever the stored items are required for production, the warehouse operator would pick items following the acquired order lists. Currently, one forklift truck and one ladder are used to facilitate the picking process as shown in Figure 3.13. The ladder is designed to be movable and its height is about the same level as the second beam from the floor of racking. In the picking process, the operator has to search for the required items directly at the racking. In addition, the operator normally has to pick each item one by one since most of the stored items cannot be manually picked but require the forklift truck for picking. After moving out of the racking, the picked items are placed on the floor in an area in front of the warehouse before being delivered to the production.

Figure 3.13: Equipment for picking process

It should be noted that both receiving and picking processes are concluded with the warehouse operator recording the quantity of items moving in and out of the warehouse in paper notes. The daily update of the holding stock is then submitted to the warehouse supervisor and engineers who take part in controlling inventory of raw materials.

3.3 Inventory policy

Inventory control of raw materials used for production is the responsibility of both the engineers and warehouse supervisor. The two parties have to manage stocks of raw materials in order to support production process. There are six types of raw materials including plastic resins, films, printing inks, adhesives, solvents and paper cores. The warehouse supervisor takes a role in management of only printing inks, adhesives and solvents while the engineers manage the rest.

The warehouse supervisor manages inventory of raw materials based on minimum-quantity policy set by the engineers. The supervisor has to daily check for remaining quantity of each raw material from paper records of items going in and out of the warehouse provided by the warehouse operator. The three types of raw materials including printing inks, adhesives and solvents would be ordered from external suppliers when the quantity of them is below the set-up number of minimum quantity. The minimum quantity for printing inks, adhesives and solvents is illustrated in Table 3.2, 3.3 and 3.4, respectively.

Table 3.2: Minimum quantity of printing inks

Ink grade	Colour	Minimum quantity (Buckets)
HI-OPP	Black	5
	Yellow	7
	Magenta	5
	Medium	10
	White	8
	Violet	5
	Orange 307	3
	Orange 303	3
	Geranium	5
	Green	2
NEW PPL	Blue	7
DLO	Black	3
	Yellow	3
	Geranium	3

Table 3.3: Minimum quantity of adhesives

Adhesive grade	Minimum quantity (Buckets)
LA 2882F	20
LA 5000	20

Table 3.4: Minimum quantity of solvents

Solvent grade	Minimum quantity (Buckets)
Thinner M	4
Thinner I	3
EA	3

3.4 Sales and production plan

The company's customer order quantities of the five main products from May 2014 to April 2015 are illustrated in Table 3.5. The monthly order quantities of each product fluctuate from month to month in the year 2014 but become more stable in the year 2015. Besides fluctuation, the order quantity in the year 2014 is lower compared to 2015. Since the case study company just started production in 2014, it takes time to improve quality of the products and the company's ability to satisfy customer demand. As shown in Table 3.5, the company continually gain increased sale volumes from 2014 to 2015.

Table 3.5: Customer order quantities of Product A, B, C, D and E

Item (Unit)	Order quantity											
	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15
Product A (Roll)	100	100	100	400	200	200	400	500	500	500	500	500
Product B (Roll)	200	100	100	-	200	100	200	100	400	400	400	400
Product C (Roll)	-	-	10	-	10	50	-	100	-	100	-	100
Product D (Roll)	-	-	50	200	400	200	250	150	300	300	300	300
Product E (Ton)	2	2	-	5	-	-	5	-	-	5	-	-

In 2015, as illustrated in Table 3.5, the customer order is stable as the order quantities of the five products remain the same over four months from January to April. Normally, the customer would place an order once a month and approximately five weeks before the deadline for delivery. For example, the customer would send the company a purchasing order in the last week of March in case the ordered products are required to be delivered within April. With such consistency, the company could predetermine its monthly order and plan the production beforehand in order to adequately satisfy customer demand. The set-up production plan for each product is demonstrated in Table 3.6. The production plan of each month is set to support customer order of the following month, thus the company could ensure that it is capable to serve the predicted demand of the customer. However, the production plan could be adapted to support any emergency order or situation in which the actual customer order exceeds that of predicted. For example, the production plan of May should support the predicted customer order of June. Based on that, in each month, Product A, B and D would be produced with the quantity of 500, 400 and 300 rolls, respectively. Product C would be produced with the quantity of 100 rolls in every other month while Product E would be produced in every two months with the quantity of 5 tons or approximately 173 rolls.

Table 3.6: Production plan of Product A, B, C, D and E

Item (Unit)	Production quantity											
	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
Product A (Roll)	500	500	500	500	500	500	500	500	500	500	500	500
Product B (Roll)	400	400	400	400	400	400	400	400	400	400	400	400
Product C (Roll)	100	-	100	-	100	-	100	-	100	-	100	-
Product D (Roll)	300	300	300	300	300	300	300	300	300	300	300	300
Product E (Ton)	5	-	-	5	-	-	5	-	-	5	-	-

3.5 Production process and capacity

3.5.1 Production process

Product A, B, C and D have four production processes including blowing, printing, dry laminating and slitting while Product E has only three; blowing, printing and slitting. As the company has only one each of blowing, printing, dry laminating and slitting machine, each process could produce only one product at a time. The case study company normally applies batch production for each product, in other words, completing production for each product one by one. The sequence of products would be decided to best match with the situation in each month. A brief description of each production process is as follows:

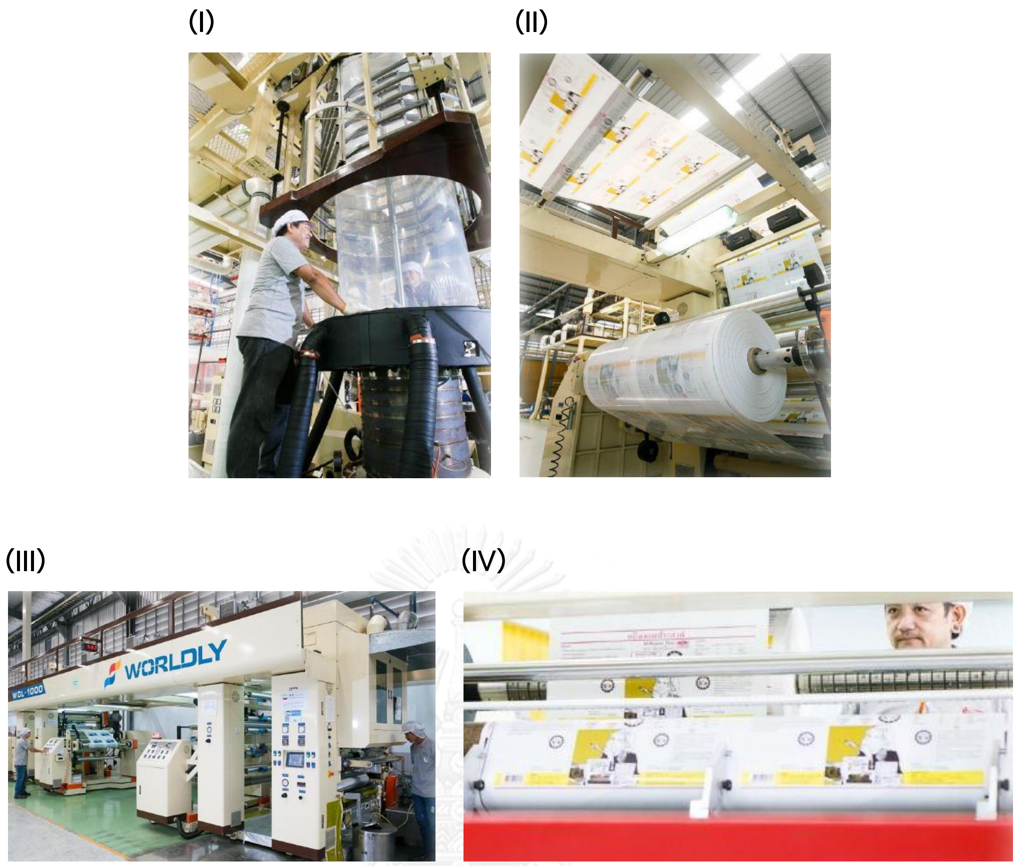


Figure 3.14: Production process (I) Blowing (II) Printing (III) Dry laminating (IV) Slitting

3.5.1.1 Blowing process

The blowing machine is capable of formulating and tailoring film structure to match with product requirement. The machine turns plastic resin and additive into blown film which would be stored in the warehouse waiting for further processing.

3.5.1.2 Printing process

The machine is capable of printing a maximum of eight colours. Since the machine could support printing long width of film, the normal printing process of

Product A, B, C, D and E yields two columns of printing artwork as demonstrated in Figure 3.14 (II). The process requires printing inks as well as solvents to operate the printing. The printed film would be directly transferred to the next working station, a dry laminating machine.

3.5.1.3 Dry laminating process

The dry laminating process allows attachment of two or more layers of film with the use of special grade of adhesives mixing with solvents. Similarly to the printing process, the dry laminating film would be sent to slitting machine for further processing.

3.5.1.4 Slitting process

During the slitting process, the two-column printed laminating film would be sliced into one-column film with one printing artwork. The finished goods with width and length in conformance with the customers' specification would, then be ready for shipment.

3.5.2 Production capacity

The daily production capacity of the four machines including blowing, printing, dry laminating and slitting machines could be calculated based on production yield and actual working hour of each machine. Due to different specification and production constraint, running speed which affects production yield of the four machines is not the same. It should also be noted that the type of film to be processed affects the running speed of machine since each type of film has different elasticity. As the running speed has some impact on elongation of the film, the film with lower elastic property would be processed with higher speed compared to that of higher elastic property. As a result, Product A, B, C and D could be processed with different running speed from Product E.

Since BOPP film of Product A, B, C and D has lower elastic property than LLDPE film of Product E, Product A, B, C and D could be processed in printing and slitting with higher running speed compared to Product E. However, in case of blowing process, the production of Product E is roughly similar to those of Product A, B, C and D as the blown film for all five products is of the same type. However, due to different width of the finished goods, the blowing process has production yield of Product A, B, C and D differently to that of Product E. Since Product E has longer width of film, its production yield is less than that of Product A, B, C and D.

The actual production process requires time to prepare both machine and raw material. The machines, thus, could not run for the whole working hours but would need some time for the preparation. The daily production capacity for each of the four machines could be calculated with reference to production yield per minute and actual working hour as demonstrated in Equation 3.1.

$$C = Y \times T$$

Where C = Daily production capacity (m)

Y = Production yield of machine (m/min)

T = Actual working duration per day (min)

Equation 3.1: Daily production capacity

Since running speed in processing of Product A, B, C and D is different from that of Product E, daily production capacity of each process for the products is not similar. It is noted that only the blowing machine would run two production shifts while the other machines would routinely operate eight working hours per one day. The production yield of the machines for each product and the actual working duration per day of each machine are shown in Table 3.7. By using the data provided in Table 3.7, daily production capacity of the machines for the five products could be calculated and shown in Table 3.8. The table shows daily production capacity calculated as length of film (2 columns) as well as the approximate quantity of finished goods which is estimated from such length of film. The details of calculation could be found in Appendix A.

Table 3.7: Production yeild and actual working duration of the machines

Machine	Production yield (m/min)		Actual working duration per day (min)
	Product A, B, C and D	Product E	
Blowing	80	60	1,320
Printing	160	60	300
Day laminating	120	-	420
Slitting	150	60	300

Table 3.8: Daily production capacity of the machines

Machine	Daily production capacity			
	Product A, B, C and D		Product E	
	Length (m)	Finished goods (Rolls)	Length (m)	Finished goods (Rolls)
Blowing	105,600	200	79,200	158
Printing	48,000	91	18,000	36
Day laminating	50,400	96	-	-
Slitting	45,000	85	18,000	36

With reference to the data shown in Table 3.8, daily production capacity of the four production processes for Product A, B, C and D is compared in Figure 3.15.

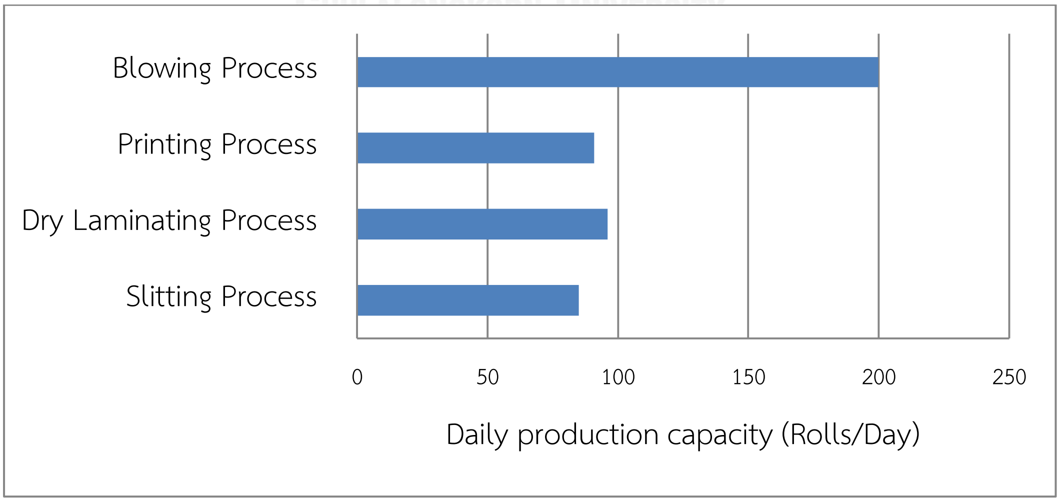


Figure 3.15: Daily production capacity of each production process for Product A, B, C and D

It can be concluded according to the comparison shown in Figure 3.15 that the slitting machine has the lowest daily production capacity. The machine, thus, is considered as a bottleneck of the whole production process. By taking into consideration the slowest process, the production capacity of the whole production process for Product A, B, C and D is 85 rolls of finished goods per one day.

In addition, regarding Table 3.8, the daily production capacity of the three production processes for Product E is compared in Figure 3.16.

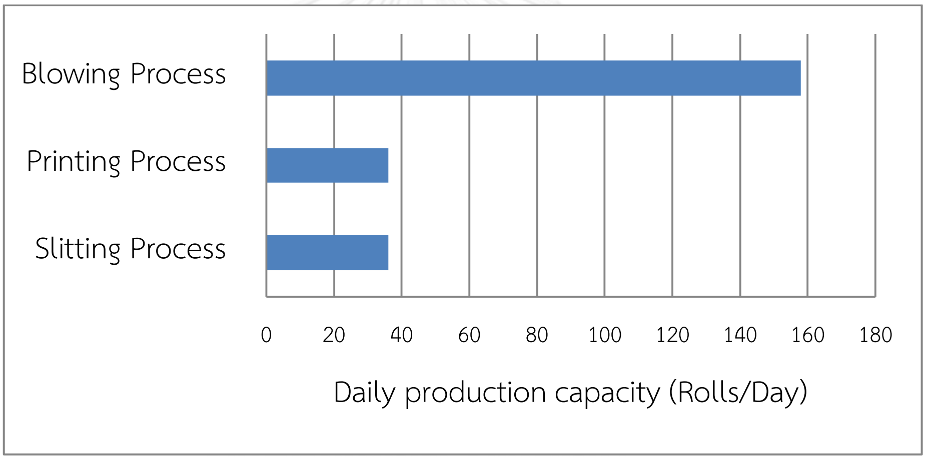


Figure 3.16: Daily production capacity of each production process for Product

The daily production capacity of Product E for printing and slitting machines is much lower than that of the blowing machine, therefore printing and slitting could be considered as bottleneck of the whole production process. The production capacity of the whole production process for Product E is 36 rolls of finished goods per one day.

By considering the production plan illustrated in Table 3.6, there would be the maximum production in January and July. The maximum production includes 1,300 rolls of Product A, B, C and D and 5 tons or 173 rolls of Product E. With reference to such maximum quantity, the distribution of working days needed to process Product A, B, C, D and E in one month (26 working days) is presented in Figure 3.17.

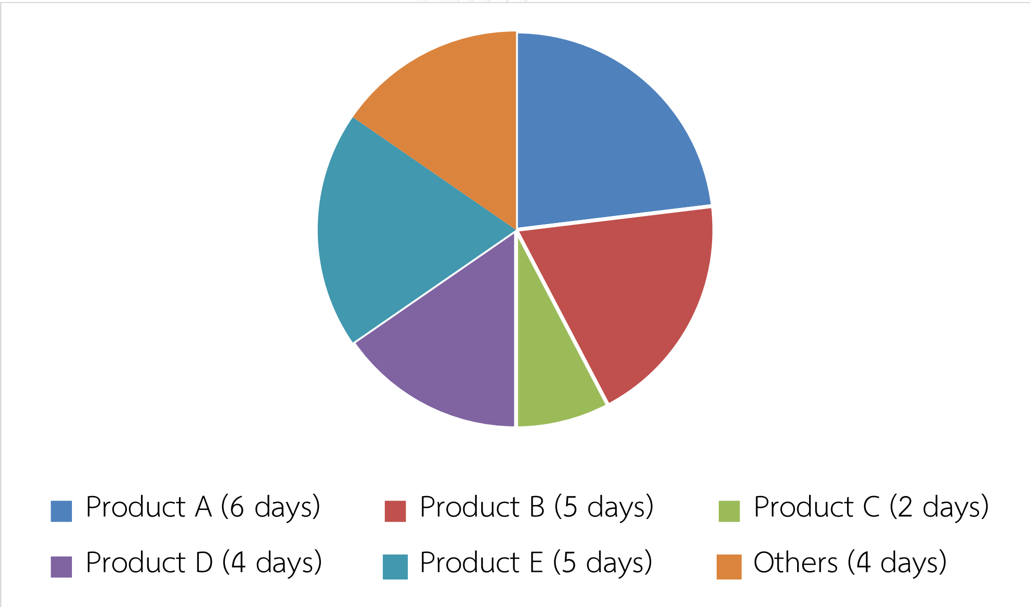


Figure 3.17: Distribution of working days needed to process the five customer products

3.6 Existing problem analysis

As stated earlier, the warehouse supervisor and engineers are responsible for inventory control. In case replenishment of raw materials is required, both parties would request the procurement department for a purchase. Due to the lack of integrated working system among procurement, warehouse and production, the company has encountered with problems regarding inventory policy as well as warehouse management described in the following sections.

3.6.1 Inventory policy

As stated earlier, the warehouse supervisor currently manages inventory with minimum-quantity policy set by the engineers. Such methodology has resulted in poor control of stock. The existing minimum-quantity of raw materials is not well compatible with the production. For example, the quantity set for fast-moving items is too low while that of slow-moving items is too high. In case of fast-moving items, with such minimum-quantity policy, the warehouse supervisor has to frequently request for a purchase to replenish the stocks leading to wasted time in processing for an order as well as receiving once the items arrive. In addition, with no information regarding suppliers' condition and delivery lead time, the warehouse supervisor has faced with a delay in receiving of raw materials. In such case, the company would not have raw materials required on time for production. By considering the performance of inventory control from May to August 2014, the company had a problem regarding shortage of raw materials previously shown in Table 1.1. The details of shortage for each type of raw materials could be found in Appendix C2.

Stock-outs have severe impacts for the business. When the business runs out of stocks, it would obstruct smooth operation of the production for a steady flow of finish goods required in filling pending customer orders. A delay of the production with an outcome of late delivery to the customers would harm the reputation of the company. The inability to fill the customer orders results in loss of revenue of the specific order. It also deteriorates customer's trust of the company which could affect decision on placement of future orders.

Furthermore, inventory level could be reduced in order to avoid overstocking of raw materials in which the company has high inventories exceeding demand of those items. Overstocking of inventory would increase unnecessary costs for the business. Other than expenses for purchasing inventory, cost of carrying inventory also consists of costs for increased warehouse space needed for storage, higher insurance costs, higher security costs and etc. Stocks might also be damaged and become expired leading to wasted money. In addition, the company might lose opportunities as money spent buying the stocks could be wisely spent for other purposes.

3.6.2 Warehouse management

As a new company, the case study company still lacks properly-designed warehouse management in terms of layout and slotting. The existing management does not conform to the warehouse operations and not support first in, first out or FIFO warehouse system in which inventory purchased first is used first while newer one is used later. For example, the item which is frequently requested by the production is stored in the location that is hard to access by the order picker. There is no system in managing first in, first out of the stored items and items with different batch numbers are not stored separately. In addition, there is no separated storage location for hazardous items which could lead to substantial damage in case of conflagration.

The warehouse layout and slotting currently employed cannot support effective warehouse operations especially in terms of put away and order picking processes regarding accessibility of the stored items and ease of the operation. The existing policy of warehouse layout and slotting does not promote accessibility of items and, thus, results in wasted time during both put away and picking processes. As the items need to be moved out of the receipt area as soon as the receiving process is finished, the allocation into storage should be done as quickly as possible. In case of picking process, the wasted time would lead to a delay of the production which affects the company's ability to satisfy customer demand. In addition, any error on picking process as a result of unsupportive warehouse management would require the warehouse operator to redo the picking. The redone process would directly affect the production. It results in either delayed production or unsmooth operation of the production.

The existing warehouse management also does not ensure first in, first out of the items stored in the warehouse. Most of the raw materials stored in the warehouse have to be used within a certain period of time due to limitation of shelf life. FIFO warehouse system ensures that the warehouse would not be stuck with expired raw materials.

Moreover, the warehouse of case study lacks supporting tools to promote ease of the operations and user satisfaction. There is only record on movement of raw materials flowing in and out of the warehouse. The warehouse supervisor uses balance quantity of each item provided in the record for controlling stocks of raw materials. All data is still manually recorded with a paper-based system. Such system leads to inaccuracy of stock records which obstructs effective stock control as the stock record is not reliable.

3.7 Conclusion

The existing situation of case study is studied in terms of the warehouse, current inventory policy and other relevant information including products and sales, production plan, production process and production capacity. The study, then, leads to analysis of the problems currently encountered by the case study company. The overview of Chapter III is presented in Table 3.9.

Table 3.9: Overview of Chapter III

Related data	Problem analysis
Warehouse	**Inventory control**
Stored items	Shortage of raw materials
Design	Possibility of reduced inventory level
Operations	
Inventory policy	**Warehouse management**
	Accessibility of items
	Difficulty of operation
	No FIFO warehouse system
	Inappropriate storage
Related information	
Sales	
Production plan	
Production process	
Production capacity	

According to the analysis regarding inventory policy, the minimum-quantity policy currently employed for controlling inventory is unable to fully support the production. The provided data is not practical since it leads to stock-outs of raw materials. In fact, the policy on inventory control should capable to support the actual demand for production by providing enough quantity of raw materials without exceeding such demand.

As a result, the policy should be designed by taking customer demand and the requirement for production into consideration. Effective inventory control could also decrease inventory costs by reducing the total amount of inventory needed to manage the business while assuring that enough raw materials are available for production and capable to meet customer demand. Furthermore, the suppliers' condition should also be considered, thus the raw materials would be properly ordered in accordance with required condition and a delay in delivery would be avoided.

In terms of warehouse management, the wasted time during put away and order picking could be avoided by altering the existing policy of slotting. Each item stored in the warehouse should be properly allocated into storage by well-designed warehouse slotting. Records would also be helpful for the warehouse operators for ease of searching to reduce wasted time and facilitate warehouse operations. Error of the operations could also be avoided. FIFO warehouse system could be promoted by designing policy to facilitate first-in-first-out picking process. Moreover, tags and records could be used to support ease of searching and, thus, the warehouse operations. Instead of paper-based system, information technology could also be employed to promote accuracy of the records.

4. CHAPTER IV INVENTORY CONTROL DESIGN

As described in the previous chapter, the existing inventory policy is based on minimum-quantity which results in inefficient stock control of raw materials. With such policy, the case study company has encountered with stock-outs of raw materials. The problem has a significant negative impact on performance of the business in terms of ability to satisfy customer demands.

Efficient inventory policy would definitely give the company a competitive edge since better stock control would be achieved. With smooth flow of raw materials into production, more efficient production would be attained. As a result, customer satisfaction will be guaranteed since products would be available on demand. The well-designed policy also allows the company to minimise inventory carrying costs which includes all the expenses for owning inventory such as costs of capital, storage cost and risk cost. Furthermore, it results in a more organised warehouse as suitable storage space could be assigned to each item in order to improve warehouse operation. Inventory policy of the case study, therefore, should be improved to lower business costs, improve efficiency and assure production to meet customer demand.

4.1 Inventory policy

As previously mentioned in Chapter III, the inventory of raw materials could be separated into six categories including resins, films, printing inks, adhesives, solvents and paper cores. The materials would be fed to the production yielding finished goods served to the customers. With predicted customer demand, the company is able to plan the production beforehand to sufficiently support customer orders.

Since demand of raw materials depends on the production, an appropriate inventory policy should be designed to best satisfy such demand. In addition to the demand, supply of the materials has to be considered. The supply constraints of the case study are minimum order quantity or MOQ as well as delivery lead time. The MOQ refers to the minimum quantity the company would need to buy in placing an order to the supplier while the delivery lead time of raw materials refers to the period of time between the placement of an order and the receipt of such order into the system. In order to best address with the demand and comply with the supply, the design of inventory policy should take both factors into consideration.

The policy on production of the case study is based on batch production with reference to the production plan. As a result, inventory policy should be able to support such batch demand. The lot-for-lot inventory policy, thus, would be applied to the case study. Based on the policy, the supply of raw materials from suppliers would correspond with the demand of production. The monthly plan of production leads to the determination of consumption of raw materials on monthly basis. Such volume of consumption could be determined from historical production data. With known consumption and production plan, raw materials would be ordered in just-enough quantity for each production lot and supplied to the company just when they are required for production instead of ordering in advance for weeks or months. Therefore, shortage of raw materials would be prevented and just-enough inventory would be kept without having too much stock in the warehouse. The lot-for-lot policy also complies with JIT technique to ensure the company has the right material in the right amount and right place at the right time.

Furthermore, suppliers' supply condition, MOQ and delivery lead time would be taken into consideration. The MOQ and delivery lead time for each raw material can differ depending on the supplier. The suppliers' condition of MOQ is a critical constraint to be concerned in placing an order for raw materials. Delivery lead time also plays a significant role for the timing of decision on purchase order.

The proposed inventory policy takes into account both demand and supply of raw materials to improve inventory control of the case study.

4.2 Demand of raw materials

The policy on inventory control should be able to fully satisfy the demand of raw materials both in terms of quantity and punctuality. The consumption of raw materials would be used to plan for the quantity of demand while detailed production plan outlining the sequence of production processes enables timely arrival of raw materials.

4.2.1 Consumption of raw materials

The consumption of raw materials would be determined on monthly basis with reference to the production plan illustrated in Table 3.6. The plan quantifies the production of each customer product in each month and, thus, leads to estimation of consumption of raw materials determined from historical production record. Regarding the production plan shown in Table 3.6, the consumption of each raw material would be determined in the following sections.

4.2.1.1 Plastic resins and additives

Plastic resins and additives are used in blowing process to form white-LLDPE film of Product A, B, C and E as well as transparent-LLDPE film of Product D. The two types of film are produced from different grade of resins. For example, white-LLDPE film needs additives in order to add white colour to the film. Even for the same type of film, white-LLDPE of Product A and B, of Product C and of Product E are also formed by using different grades of resin due to dissimilar specification. Although such films share some common grade of resins, the ratio of those resins used in production process is not the same.

Table 4.1 shows the approximate quantity of each resin grade used for production of each customer product (100 rolls for Product A, B, C, D and 5 tons for Product E). For example, the production of white-LLDPE film for 100 rolls of Product A needs resin of grade LL 7410A, LL 7410D1, SP 2020H, LD 2420D and WM with the quantity of 275, 1,400, 650, 775 and 150 kg, respectively. For Product E, the production for 5 tons of the finish goods needs 3,800 kg of LL 7410D1, 1,725 kg of LD 2426H and 175 kg of WM.

Table 4.1: Quantity of plastic resins and additives used for production of Product A (100 rolls), Product B (100 rolls), Product C (100 rolls), Product D (100 rolls) and Product E (5 tons) with the unit of kilogram

Resin grade	Quantity used for production (kg)			
	Product A and B	Product C	Product D	Product E
LL 7410A	275	-	450	-
LL 7410D1	1,400	-	1,350	3,800
LD 2420D	775	-	-	-
LD 2426H	-	675	775	1,725
EL 5220G	-	750	-	-
EL 5401G	-	700	-	-
SP 2020H	650	575	650	-
WM	150	150	-	175

In regard to the production plan shown in Table 3.6, the quantity of plastic resins and additives consumed in each month could be determined as shown in Table 4.2.

Table 4.2: Consumption of plastic resins and additives with the unit of kilogram

Resin grade	Quantity used for production (kg)											
	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
LL 7410A	3,825	3,825	3,825	3,825	3,825	3,825	3,825	3,825	3,825	3,825	3,825	3,825
LL 7410D1	20,450	16,650	16,650	20,450	16,650	16,650	20,450	16,650	16,650	20,450	16,650	16,650
LD 2420D	6,975	6,975	6,975	6,975	6,975	6,975	6,975	6,975	6,975	6,975	6,975	6,975
LD 2426H	4,725	2,325	3,000	4,050	3,000	2,325	4,725	2,325	3,000	4,050	3,000	2,325
EL 5220G	750	-	750	-	750	-	750	-	750	-	750	-
EL 5401G	700	-	700	-	700	-	700	-	700	-	700	-
SP 2020H	8,375	7,800	8,375	7,800	8,375	7,800	8,375	7,800	8,375	7,800	8,375	7,800
WM	1,675	1,350	1,500	1,525	1,500	1,350	1,675	1,350	1,500	1,525	1,500	1,350

4.2.1.2 Films

There are two types of BOPP film, BOPP P and BOPP HS films, used in printing for the four products, Product A, B, C and D. Product A, B and C use BOPP P film while Product D uses BOPP HS film. As a result, the demand of each type of BOPP film is not the same due to the difference in customer order of each product. For the printing process, the machine could be able to print two columns at a time. The additional percentage loss for printing defect that might occur from production failure would be included in the calculation for demand of film. Thus, the total BOPP film used for production can be calculated from Equation 4.1.

$$\text{Total BOPP film used (m)} = \frac{\%\text{ Loss} \times \text{QFG} \times \text{LFG}}{2}$$

Where	% Loss	=	Percentage loss (%)
	QFG	=	Quantity of finished goods to be produced (rolls)
	LFG	=	Length of one roll of finished goods (m)

Equation 4.1: Total BOPP film used for production

The four products have the same length of one roll of finished goods but dissimilar estimated percentage loss in printing process. The estimated percentage loss of BOPP film used for Product A and D is different from that of Product B and C since the percentage loss would be determined depending on complication in printing process of the products. As mentioned earlier in Chapter 3, both Product A and D have seven printing colours while Product B and C has four and three printing colours, respectively. With the higher number of printing colours, the printing process of Product A and D is more complicated than that of Product B and C. The percentage loss of BOPP film for Product A and D would be estimated higher compared to that of Product B and C due to more complications in the printing process. The estimated percentage loss of BOPP film in printing of each product as well as other data used in calculation of film demanded for production are presented in Table 4.3.

Table 4.3: Data for calculation of total BOPP film used for production

Product	Percentage loss (%)	Quantity of finished goods (Rolls)	Length of finished goods (m)
Product A	6	500	1,050
Product B	4	400	1,050
Product C	4	100	1,050
Product D	6	300	1,050

Per the data shown in Table 4.3, the estimated BOPP films demanded for production of each customer product could be determined and demonstrated in Table 4.4. The detailed calculation could be found in Appendix B.

Table 4.4: Quantity of BOPP P and BOPP HS films used for production of Product A (500 rolls), Product B (400 rolls), Product C (100 rolls) and Product D (300 rolls) with the unit of metre

Film grade	Quantity used for production (m)			
	Product A	Product B	Product C	Product D
BOPP P	420,000	294,000	73,000	-
BOPP HS	-	-	-	252,000

With reference to the production plan illustrated in Table 3.6, the consumption of BOPP P and HS films in each month could be determined as shown in Table 4.5.

Table 4.5: Consumption of BOPP P and HS films with the unit of kilometre

Film grade	Quantity used for production (km)											
	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
BOPP P	787.5	714	787.5	714	787.5	714	787.5	714	787.5	714	787.5	714
BOPP HS	252	252	252	252	252	252	252	252	252	252	252	252

4.2.1.3 Printing inks

The five customer products have different printed artwork and, thus, require different set of inks for printing process. The approximate quantity of printing inks used for production of each customer product is illustrated in Table 4.6.The data shows quantity of inks, with the unit of kilogram, used in printing for 100 rolls of Product A, B, C, D and 5 tons of Product E. For example, printing 100 rolls of Product C used approximately 30 kg of HI-OPP Black, 1 kg of HI-OPP Yellow, 5 kg of HI-OPP Magenta, 30 kg of HI-OPP Medium and 12 kg of HI-OPP Orange 303. Although the five products require different set of ink in printing, there are some common colours as shown in Table 4.6.

Table 4.6: Quantity of printing inks used for production of Product A (100 rolls), Product B (100 rolls), Product C (100 rolls), Product D (100 rolls) and Product E (5 tons) with the unit of kilogram

Ink grade	Colour	Quantity used for production (kg)				
		Product A	Product B	Product C	Product D	Product E
HI-OPP	Black	7	30	30	10	-
	Yellow	41	2	1	23	-
	Magenta	11	5	5	10	-
	Medium	44	25	30	9	-
	White	195	-	-	200	-
	Violet	55	-	-	-	-
	Orange 307	-	6	-	-	-
	Orange 303	-	-	12	-	-
	Geranium	-	-	-	60	-
	Green	-	-	-	1	-
NEW PPL	Blue	27	9	-	3	-
DLO	Black	-	-	-	-	150
	Yellow	-	-	-	-	162
	Geranium	-	-	-	-	145

According to the production plan demonstrated in Table 3.6, the consumption of printing ink in each month could be determined as shown in Table 4.7.

Table 4.7: Consumption of printing inks with the unit of kilogram

Ink grade	Colour	Quantity used for production kg)											
		Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
HI-OPP	Black	215	185	215	185	215	185	215	185	215	185	215	185
	Yellow	283	282	283	282	283	282	283	282	283	282	283	282
	Magenta	110	105	110	105	110	105	110	105	110	105	110	105
	Medium	377	347	377	347	377	347	377	347	377	347	377	347
	White	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575
	Violet	275	275	275	275	275	275	275	275	275	275	275	275
	Orange 307	24	24	24	24	24	24	24	24	24	24	24	24
	Orange 303	12	0	12	0	12	0	12	0	12	0	12	0
	Geranium	180	180	180	180	180	180	180	180	180	180	180	180
	Green	3	3	3	3	3	3	3	3	3	3	3	3
NEW PPL	Blue	180	180	180	180	180	180	180	180	180	180	180	180
DLO	Black	150	-	-	150	-	-	150	-	-	150	-	-
	Yellow	162	-	-	162	-	-	162	-	-	162	-	-
	Geranium	145	-	-	145	-	-	145	-	-	145	-	-

4.2.1.4 Adhesives

There are only two grades of adhesives used for production, LA 2882F and LA 5000. The two adhesives are used together with LA 2882F (25 kg) required to mix with LA 5000 (5 kg) in the process of dry lamination. The estimated quantity of adhesives, with the unit of kilogram, required for production of 100 rolls of Product A, B, C and D is demonstrated in Table 4.8. For example, 100 rolls of Product A used approximately 130 kg of LA 2882F and 26 kg of LA 5000 while 100 rolls of Product D used approximately 137 kg of LA 2882F and 27 kg of LA 5000.

Table 4.8: Quantity of adhesives used for production of Product A (100 rolls), Product B (100 rolls), Product C (100 rolls) and Product D (100 rolls) with the unit of kilogram

Adhesive grade	Quantity used for production (kg)	
	Product A, B and C	Product D
LA 2882F	130	137
LA 5000	26	27

Referring to the production plan shown in Table 3.6, the consumption of adhesives in each month could be estimated as illustrated in Table 4.9.

Table 4.9: Consumption of adhesives with the unit of kilogram

Adhesive grade	Quantity used for production (kg)											
	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
LA 2882F	1,711	1,581	1,711	1,581	1,711	1,581	1,711	1,581	1,711	1,581	1,711	1,581
LA 5000	341	315	341	315	341	315	341	315	341	315	341	315

4.2.1.5 Solvents

The solvent could be classified into three grades, Thinner M, Thinner I and EA. The usage of these solvents for production of the five products (100 rolls for Product A, B, C, D and 5 tons for Product E) is demonstrated in Table 4.10. For instance, 316 kg of Thinner M is used in printing process and 196 kg of EA is used in dry laminating process for 100 rolls of Product A. In case of Product E, 290 kg of Thinner I is used in printing for production of 5 tons of Product E.

Table 4.10: Quantity of solvents used for production of Product A (100 rolls), Product B (100 rolls), Product C (100 rolls), Product D (100 rolls) and Product E (5 tons) with the unit of kilogram

Sovent grade	Quantity used for production (kg)				
	Product A	Product B	Product C	Product D	Product E
Thinner M	316	305	324	340	-
Thinner I	-	-	-	-	290
EA	196	196	196	207	-

Therefore, with reference to the production plan presented in Table 3.6, the consumption of solvents demanded in each month could be determined as shown in Table 4.11.

Table 4.11: Consumption of solvents with the unit of kilogram

Solvent grade	Quantity used for production (kg)											
	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
Thinner M	4,144	3,820	4,144	3,820	4,144	3,820	4,144	3,820	4,144	3,820	4,144	3,820
Thinner I	290	-	-	290	-	-	290	-	-	290	-	-
EA	2,581	2,385	2,581	2,385	2,581	2,385	2,581	2,385	2,581	2,385	2,581	2,385

4.2.1.6 Paper cores

There are three sizes of paper cores which have to be ordered, 3" x 445 mm x 15 mm, 6" x 362 mm x 8 mm and 6" x 366 mm x 8 mm. The size of 3" x 445 mm x 15 mm is used with Product E. 6" x 362 mm x 8 mm is used for Product A, B, and C while 6" x 366 mm x 8 mm is used for Product D. Based on the production plan shown in Table 3.6, the consumption of paper cores could be determined as demonstrated in Table 4.12.

Table 4.12: Consumption of paper cores with the unit of piece

Paper core size	Quantity used for production (Pieces)											
	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
3" x 445 mm x 15 mm	173	-	-	173	-	-	173	-	-	173	-	-
6" x 362 mm x 8 mm	1,000	900	1,000	900	1,000	900	1,000	900	1,000	900	1,000	900
6" x 366 mm x 8 mm	300	300	300	300	300	300	300	300	300	300	300	300

4.2.2 Detailed production plan

With reference to the production plan, the detailed plan sequencing production processes in each month could be prepared. The detailed production plan allows the company to easily manage the lot-for-lot policy as it would be considered in determining arrival of raw materials with enough quantity demanded for production. As a result, the right quantity of raw materials could be supplied at the right time to prevent shortage and avoid keeping unnecessary stock in the warehouse.

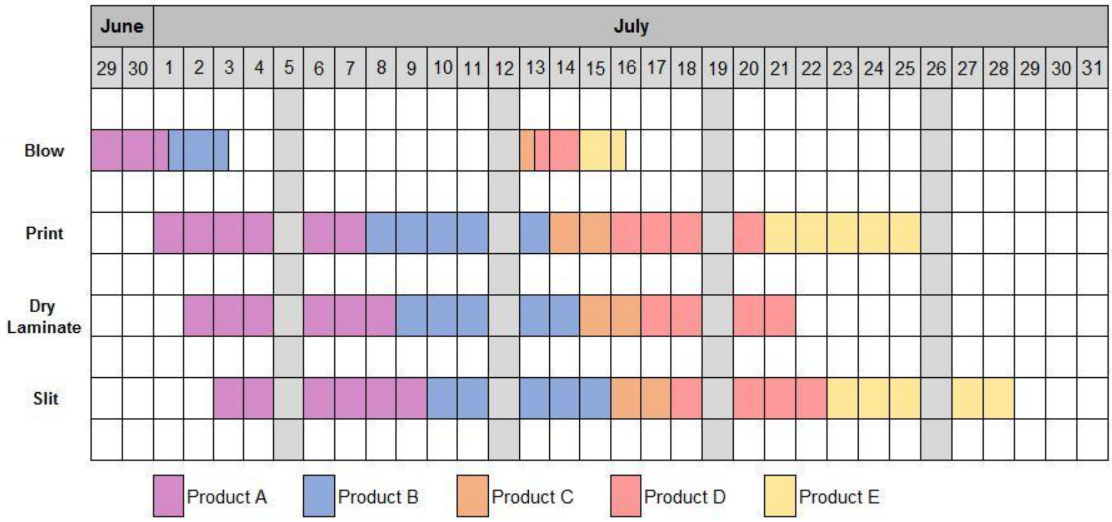
Regarding the production plan illustrated in Table 3.6, the highest production quantity is seen in January and July. Those months with highest production yield 500 rolls of Product A, 400 rolls of Product B, 100 rolls of Product C, 300 rolls of Product D and 5 tons or approximately 173 rolls of Product E. The total production quantity and daily production capacity are aforementioned in Chapter III would be used to outline the detailed production plan in July.

As stated in Chapter III, the production of Product A, B, C and D would pass through four processes including blowing, printing, dry laminating and slitting processes while that of Product E would pass through only three processes; blowing, printing and dry laminating processes. The sequence of production for Product A, B, C and D begins with blowing and printing, to dry laminating, and finishes with slitting. In contrary, the production of Product E begins with blowing and printing, and finishes with slitting. The company currently applies batch production for each product. It should also be noted that printing, dry laminating and slitting processes would operate continuously while the blowing process operates every other week.

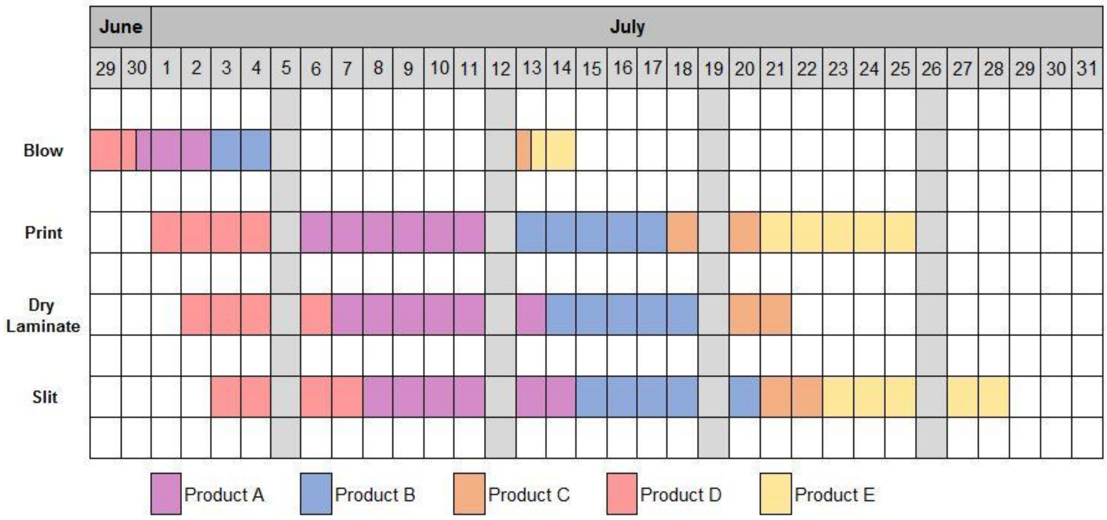
The plan could be adapted to match customer request in case there is any emergency order. Table 4.13 demonstrates the two examples of the detailed production plan in July with dissimilar production sequence, (I) Product A – Product B – Product C – Product D – Product E and (II) Product D – Product A – Product B – Product C – Product E.

Table 4.13: Examples of detailed production plan

(I)



(II)



4.3 Supply of raw materials

The proposed policy regarding inventory control also takes supplier's conditions into consideration including supply condition, MOQ and delivery lead time as described in the following sections.

4.3.1 Supply condition and minimum order quantity (MOQ)

The supply condition and MOQ for each type of raw materials are as follows:

4.3.1.1 Plastic resins and additives

The resins and additives used are purchased from four suppliers, Supplier R_1, Supplier R_2, Supplier R_3 and Supplier R_4; LL 7410A, LL7410D1, LD 2420D, LD 2426K and LD 2426H from Supplier R_1, EL 5220G and EL 5401G from Supplier R_2, SP 2020H from Supplier R_3 and WM from Supplier R_4. Each supplier of plastic resins and additives has different MOQ. The MOQ of resins from Supplier R_1, Supplier R_2, Supplier R_3 and Supplier R_4 are 5,000 kg or 5 tons, 2,500 kg or 2.5 tons, 17,000 kg or 17 tons and 2,500 kg or 2.5 tons, respectively. The order could be a combination of any resin grade offered by the supplier. It should be noted that plastic resins and additives are supplied in a bag with the quantity of 25 kg per bag.

By comparing the consumption of plastic resins and additives presented in Table 4.2 with the MOQ of suppliers, the consumption of resins from Supplier $R_{2,}$

Supplier R_3 and Supplier R_4 is determined to be lower than the MOQ of those suppliers. As a result, the usage quantity of more than one month would be combined to form one purchasing order with the quantity satisfying the MOQ of the suppliers. With reference to the consumption presented in Table 4.2, the order quantity of plastic resins and additives could be determined as illustrated in Table 4.14.

Table 4.14: Order quantity of plastic resins and additives (I) with the unit of kilogram and (II) with the unit of bag

(I)

Item		Order quantity (kg)											
Resin grade	Supplier	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
LL 7410A	Supplier R1	3,825	3,825	3,825	3,825	3,825	3,825	3,825	3,825	3,825	3,825	3,825	3,825
LL 7410D1		20,450	16,650	16,650	20,450	16,650	16,650	20,450	16,650	16,650	20,450	16,650	16,650
LD 2420D		6,975	6,975	6,975	6,975	6,975	6,975	6,975	6,975	6,975	6,975	6,975	6,975
LD 2426H		4,725	2,325	3,000	4,050	3,000	2,325	4,725	2,325	3,000	4,050	3,000	2,325
EL 5220G	Supplier R2	1,500	-	-	-	1,500	-	-	-	1,500	-	-	-
EL 5401G		1,400	-	-	-	1,400	-	-	-	1,400	-	-	-
SP 2020H	Supplier R3	17,000	-	17,000	-	17,000	-	17,000	-	17,000	-	17,000	-
WM	Supplier R4	3,025	-	3,025	-	2,850	-	3,025	-	3,025	-	2,850	-

(II)

Item		Order quantity (Bags)											
Resin grade	Supplier	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
LL 7410A	Supplier R1	153	153	153	153	153	153	153	153	153	153	153	153
LL 7410D1		818	666	666	818	666	666	818	666	666	818	666	666
LD 2420D		279	279	279	279	279	279	279	279	279	279	279	279
LD 2426H		189	93	120	162	120	93	189	93	120	162	120	93
EL 5220G	Supplier R2	60	-	-	-	60	-	-	-	60	-	-	-
EL 5401G		56	-	-	-	56	-	-	-	56	-	-	-
SP 2020H	Supplier R3	680	-	680	-	680	-	680	-	680	-	680	-
WM	Supplier R4	121	-	121	-	114	-	121	-	121	-	114	-

4.3.1.2 Films

Both BOPP P and BOPP HS films purchased from external suppliers are provided as a roll with the length of 12,000 metres per one roll. Currently, there are two suppliers for the BOPP film both Plain and Heat sealable types, Supplier F_1 and Supplier F_2. The decision on purchasing would depend on the price offered by the two suppliers. The order would be placed to the supplier with the lowest price offered. Supplier F_1's MOQ of each type of BOPP film is 8 rolls while that of Supplier F_2 is 11 rolls.

Therefore, with reference to the consumption of BOPP P and BOPP HS films shown in Table 4.5, the order quantity of BOPP film with the unit of roll could be estimated and demonstrated in Table 4.15.

Table 4.15: Order quantity of BOPP P and BOPP HS films with the unit of roll

Film grade	Order quantity (Rolls)											
	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
BOPP P	66	60	66	60	66	60	66	60	66	60	66	60
BOPP HS	21	21	21	21	21	21	21	21	21	21	21	21

4.3.1.3 Printing inks

The ink used in printing process is purchased from two suppliers providing different grades of printing ink. The printing ink of HI-OPP grade is supplied from Supplier I_1 whereas that of NEW PPL and DLO grade is supplied from Supplier I_2.

Printing ink is supplied as a bucket with the quantity of 16 kg (Black, Yellow, Magenta, Medium, Violet, Orange, Geranium, Green and Blue) and 20 kg (White) per bucket. The MOQ offered by Supplier I_1 is 20 buckets while that of Supplier I_2 is 10 buckets. Such MOQ could be included any combined colour of printing ink.

Regarding to the consumption of printing inks shown in Table 4.7, the order quantity of printing ink with the unit of bucket could be approximately estimated and illustrated in Table 4.16.

Table 4.16: Order quantity of printing inks with the unit of bucket

Ink grade	Colour	Order quantity (Buckets)											
		Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
HI-OPP	Black	14	12	14	12	14	12	14	12	14	12	14	12
	Yellow	18	18	18	18	18	18	18	18	18	18	18	18
	Magenta	7	7	7	7	7	7	7	7	7	7	7	7
	Medium	24	22	24	22	24	22	24	22	24	22	24	22
	White	79	79	79	79	79	79	79	79	79	79	79	79
	Violet	18	18	18	18	18	18	18	18	18	18	18	18
	Orange 307	2	2	2	2	2	2	2	2	2	2	2	2
	Orange 303	1	-	1	-	1	-	1	-	1	-	1	-
	Geranium	12	12	12	12	12	12	12	12	12	12	12	12
	Green	1	1	1	1	1	1	1	1	1	1	1	1
NEW PPL	Blue	12	12	12	12	12	12	12	12	12	12	12	12
DLO	Black	10	-	-	10	-	-	10	-	-	10	-	-
	Yellow	11	-	-	11	-	-	11	-	-	11	-	-
	Geranium	10	-	-	10	-	-	10	-	-	10	-	-

4.3.1.4 Adhesives

Currently, the adhesive used in production is purchased from only one supplier, Supplier A. The minimum value of products for one purchase is 10,000 Baht or approximately 3 sets of LA 2882F and LA 5000. Both adhesives of LA 2882F and LA 5000 grades are supplied in buckets with the quantity of 25 kg and 5 kg per bucket, respectively. As a result, referring to the consumption of adhesives presented in Table 4.9, the order quantity of adhesives with the unit of bucket could be determined as shown in Table 4.17.

Table 4.17: Order quantity of adhesives with the unit of bucket

Adhesive grade	Order quantity (Buckets)											
	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
LA 2882F	69	64	69	64	69	64	69	64	69	64	69	64
LA 5000	69	64	69	64	69	64	69	64	69	64	69	64

4.3.1.5 Solvents

There are three choices of suppliers for solvents including Supplier S_1, Supplier S_2 and Supplier S_3. Similar to BOPP films, the decision on selection of supplier would depend on the price offered by them. The supplier offered the lowest price would be selected to receive the order. The solvents are supplied in a form of buckets with the quantity of 180 kg per bucket. The MOQ for solvents of the three suppliers is the same, 8 buckets in combination of any grade of solvent. Based on the consumption of solvents shown in Table 4.11, the order quantity of solvents with the unit of bucket could be estimated as presented in Table 4.18.

Table 4.18: Order quantity of solvents with the unit of bucket

Solvent grade	Order quantity (Buckets)											
	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
Thinner M	24	22	24	22	24	22	24	22	24	22	24	22
Thinner I	2	-	-	2	-	-	2	-	-	2	-	-
EA	15	14	15	14	15	14	15	14	15	14	15	14

4.3.1.6 Paper cores

The paper cores of three sizes are provided from a single supplier, Supplier P. The supplier has the MOQ of 400 pieces in combination of any size of paper cores. The purchasing order quantity of paper cores would include additional 10 percent of the quantity required for production in case the actual production yield is higher than that of planned. As a result, in regard to the consumption of paper cores illustrated in Table 4.12, the order quantity could be determined as presented in Table 4.19.

Table 4.19: Order quantity of paper cores with the unit of piece

Paper core size	Order quantity (Pieces)											
	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
3" x 445 mm x 15 mm	190	-	-	190	-	-	190	-	-	190	-	-
6" x 362 mm x 8 mm	1,100	990	1,100	990	1,100	990	1,100	990	1,100	990	1,100	990
6" x 366 mm x 8 mm	330	330	330	330	330	330	330	330	330	330	330	330

4.3.2 Delivery lead time

The delivery lead time of suppliers depends on whether the supplier has products available on request for prompt delivery or pending production. In case of films and paper cores, the items are made-to-order, and will take time for production following the placed order. Plastic resins and additives vary in delivery lead time depending on the supplier. Supplier $R_{1,}$ R_2 and R_4 are the local providers with production based in Thailand whereas Supplier R_3 is a foreign provider based in Japan. Due to import process, the plastic resins purchased from $Supplier_3$ have longer delivery lead time compared to that of other suppliers of plastic resins and additives.

The other type of raw materials including printing inks, adhesives and solvents has shorter delivery lead time compared to that of the raw materials mentioned above. The suppliers of adhesives and solvents are not the manufacturers but as the trading companies serving products to customers. As a result, they have the ability to deliver products within a relatively short period of time. In contrary, the suppliers of printing ink are both manufacturers and suppliers. However, they normally have products available upon demand as they have stocks ready to serve customer orders.

The delivery lead time for raw materials of each supplier is summarised and demonstrated in Table 4.20.

Table 4.20: Lead time for delivery of raw materials

Type of raw materials	Supplier	Delivery lead time
Plastic resins and additives	Supplier R1	5 - 7 Days
	Supplier R2	7 - 10 Days
	Supplier R3	4 Weeks
	Supplier R4	7 - 10 Days
Films	Supplier F1	3 - 4 Weeks
	Supplier F2	3 - 4 Weeks
Printing inks	Supplier I1	3 - 5 Days
	Supplier I2	5 Days
Adhesives	Supplier A	3 - 5 Days
Solvents	Supplier S1	5 Days
	Supplier S2	3 - 5 Days
	Supplier S3	3 - 5 Days
Paper cores	Supplier P	7 - 10 Days

4.4 Adoption of inventory policy

The adoption of proposed policy would be illustrated in two cases; one in which the company could be prepared for any emergency order from the customers and the other in which the company is be able to certainly plan the production and fix the sequence of products to be produced. The first case is practical when the company expects a chance of receiving any emergency order or facing with situation in which the actual customer order exceeds that of predicted one. In such case, raw materials would be ordered once a month and delivered to the company at the beginning of each month before starting the production. However, in the latter case with fixed production plan, the proposed monthly order of raw materials could be divided into more than one order matching with the sequence of production in order to reduce inventory level. It is noted that inventory control in July would be used as an example for the adoption of the proposed policy.

4.4.1 Case 1: Uncertain customer order with emergency case

By considering the consumption of raw materials on monthly basis, supply condition and MOQ of the suppliers, the monthly order quantity of raw materials could be determined as shown in section 4.3.1. The supplier's delivery lead time would be further considered for decision on date of ordering as well as date of raw materials arrival. In order to be prepared for any emergency order or request of products in quantity exceeding that of predicted, the company have to be able to adjust its production plan to best satisfy the customers. By determining monthly usage of raw materials and ordering the materials in quantity enough to satisfy production in each month, the company would promptly have raw materials available at the beginning of the month and be able to plan the production per the request of customers.

In regard to the first examples of detailed production plan in July shown in Table 4.13 (I), the order quantity in July, order date and delivery date of raw materials are shown in Table 4.21.

Table 4.21: Case 1 - Order of raw materials in July

Type	Grade/ size	Order quantity	Unit	Order date	Delivery date
Plastic resins and additives	LL 7410A	3,825	bags	20th June	27th June
	LL 7410D1	20,450	bags		
	LD 2420D	6,975	bags		
	LD 2426H	4,725	bags		
	SP 2020H	17,000	bags	30th May	
	WM	3,025	bags	17th June	
Purchased films	BOPP P	60	rolls	1st June	30th June
	BOPP HS	21	rolls		
Printing inks	HI-OPP	176	buckets	25th June	30th June
	NEW PPL/ DLO	43	buckets		
Adhesives	LA 2882F	69	buckets	26th June	1st July
	LA 5000	69	buckets		
Solvents	Thinner M	24	buckets	25th June	30th June
	Thinner I	2	buckets		
	EA	15	buckets		
Paper cores	3" x 445 mm x 15 mm	190	pieces	22nd June	2nd July
	6" x 362 mm x 8 mm	1,100	pieces		
	6" x 366 mm x 8 mm	330	pieces		

4.4.2 Case 2: Certain customer order with no emergency case

With certain customer orders, the sequence of production could be fixed and, thus, raw materials could be ordered in small lot size and supplied just before being used in the production. In this second case, one order of raw materials stated in the first case could be split into many orders. With reference to the detailed production plan in July shown in Table 4.13 (I), inventory control could be managed as explained in the following sections.

4.4.2.1 Plastic resins and additives

As plastic resins and additives are needed in blowing process, the order quantity and arrival date would be determined by examining production schedule of blowing process demonstrated in Table 4.13 (I). The schedule of blowing process in July is separated into two intervals, Product A - Product B sequence and Product C-Product D-Product E sequence. The consumption of plastic resins and additives as well as MOQ of suppliers would also be taken into account. Based on the order quantity of resins presented in Table 4.21, inventory control of plastic resins and additives in July deals with purchasing of LL 7410A, LL 7410D1, LD 2420D and LD 2426H from Supplier R_1, SP 2020H from Supplier R_3 and WM from Supplier R_4.

In buying resins from Supplier R_3 and R_4, due to the constraint in MOQ, the resins would be purchased as one order to each of the suppliers. However, the purchasing of resins from Supplier R_1 could be separated into two orders delivered upon requirement for production.

Referring to the detailed production plan of July presented in Table 4.13 (I), the first order of resins from Supplier R_1 with quantity enough for production of

Product A and B should be delivered within 27^{th} June while the second order of resins from the supplier with quantity for production of Product C, D and E should be delivered within 11^{st} July. With reference to all the available data, the order of resins in July is summarised in Table 4.22.

Table 4.22: Case 2 - Order of plastic resins and additives in July

Resin grade	First order			Second order		
	Order quantity (kg)	Order date	Delivery date	Order quantity (kg)	Order date	Delivery date
LL 7410A	2,475	20th June	27th June	1,350	4th July	11st July
LL 7410D1	12,600			7,850		
LD 2420D	6,975			-		
LD 2426H	-			4,725		
SP 2020H	17,000	30th May		-	-	-
WM	3,025	17th June		-	-	-

4.4.2.2 Films

As BOPP films ordered from the suppliers are made-to-order and have long delivery lead time of 4 weeks, the order would be placed to the suppliers once a month. Although the films are ordered once a month, the suppliers allow having two delivery dates depending on requirement of customers.

According to the detailed production plan of July presented in Table 4.13 (I), there could be two delivery dates of BOPP films, 30^{th} June and 15^{th}July. BOPP P film for Product A, B and C would be delivered on 30^{th} June whereas BOPP HS film for

Product D would be delivered on 15th July. The order of BOPP films in July is presented in Table 4.23.

Table 4.23: Case 2 - Order of BOPP P and BOPP HS films in July

Film grade	Order quantity (Rolls)	Order date	Delivery date
BOPP P	66	1st June	30th June
BOPP HS	21		15th July

4.4.2.3 Printing inks

Due to short delivery lead time and low MOQ, the total quantity of printing inks required for production in one month could be separated into many orders. In reference to the detailed production plan of July in Table 4.13 (I), there could be four orders of printing inks for four sets of production including Product A, Product B, Product C-Product D and Product E. However, NEW PPL Blue would be ordered once in order to meet the requirement on MOQ of Supplier I_2. The order of printing inks in July is shown in Table 4.24.

Table 4.24: Case 2 - Order of printing inks in July

Ink grade	Colour	First order			Second order			Third order			Forth order		
		Order quantity (Buckets)	Order date	Delivery date	Order quantity (Buckets)	Order date	Delivery date	Order quantity (Buckets)	Order date	Delivery date	Order quantity (Buckets)	Order date	Delivery date
HI-OPP	Black	3	25th June	30th June	8	2nd July	7th July	3	8th July	13rd July	-	15th July	20th July
	Yellow	13			1			4			-		
	Magenta	4			2			1			-		
	Medium	14			7			3			-		
	White	49			-			30			-		
	Violet	18			-			-			-		
	Orange 307	-			2			-			-		
	Orange 303	-			-			1			-		
	Geranium	-			-			12			-		
	Green	-			-			1			-		
NEW PPL	Blue	12			-			-			-		
DLO	Black	-			-			-			10		
	Yellow	-			-			-			11		
	Geranium	-			-			-			10		

4.4.2.4 Adhesives

Similar to printing inks, the purchasing of adhesives could be separated into more than one order. Two orders would be sufficient for the purchase as the quantity of adhesives required for production is relatively lower than that of printing inks. The two orders of adhesives include one for production of Product A and B and the other for production of Product C and D. The order of adhesives in July is demonstrated in Table 4.25.

Table 4.25: Case 2 - Order of adhesives in July

Adhesive grade	First order			Second order		
	Order quantity (Buckets)	Order date	Delivery date	Order quantity (Buckets)	Order date	Delivery date
LA 2882F	47	26th June	1st July	22	9th July	14th July
LA 5000	47			22		

4.4.2.5 Solvents

There would also be two orders of solvents, one for production of Product A and B while the other one for production of Product C, D and E. Although the solvents are used in both printing and dry laminating process, the decision on delivery of the solvents would be based on the schedule of printing which is prior to the dry laminating process. The order of solvents in July is presented in Table 4.26.

Table 4.26: Case 2 - Order of solvents in July

Solvent grade	First order			Second order		
	Order quantity (Buckets)	Order date	Delivery date	Order quantity (Buckets)	Order date	Delivery date
Thinner M	16	25th June	30th June	8	8th July	13rd July
Thinner I	-			2		
EA	10			5		

4.4.2.6 Paper cores

Similarly to printing inks, adhesives and solvents, the purchasing of paper cores would be separated into more than one order. Since paper cores require a relatively wider space for storage compared to other raw materials, it would be better to receive the materials only when it is needed in order to save the storage space. As a result, paper cores would be purchased in three orders with the first order for production of Product A, the second order for production of Product B and C and the third order for production of Product D and E. The order of paper cores in July is summarised in Table 4.27.

Table 4.27: Case 2 - Order of paper cores in July

Paper core size	First order			Second order			Third order		
	Order quantity (Pieces)	Order date	Delivery date	Order quantity (Pieces)	Order date	Delivery date	Order quantity (Pieces)	Order date	Delivery date
3" x 445 mm x 15 mm	-	22nd June	2nd July	-	29th June	9th July	190	7th July	17th July
6" x 362 mm x 8 mm	550			550			-		
6" x 366 mm x 8 mm	-			-			330		

4.5 Conclusion

The design of policy on inventory control of the case study takes both demand and supply of raw materials into consideration. With batch production, the inventory control, thus, based on lot-for-lot policy in which raw materials are ordered in quantity just-enough for each production lot and supplied just when they are required for production. The consumption of raw materials determined from historical record is used to estimate the quantity of demand in each month whereas detailed production plan shown production sequences is considered in planning for timely arrival of raw materials. As a result, the supply of raw materials would be able to satisfy demand for production with enough quantity and in time delivery.

In addition to the demand, the supply of raw materials is considered in terms of suppliers' condition. Supply status and MOQ leads to determination of order quantity. Moreover, delivery lead time and the previously-mentioned detailed production plan are studied so that date of ordering would be properly selected and, thus, shortage of raw materials could be avoided.

The practical adoption of inventory policy are presented in two cases; one for coping with uncertain customer orders and emergency order and the other for steady customer orders with no emergency case. In the first case, raw materials are ordered and supplied into the system once a month. However, the second case allows the company to have more than one order of raw materials delivered more frequently with smaller size of purchase compared that of the first case.

5. CHAPTER V WAREHOUSE MANAGEMENT DESIGN

The existing warehouse management of the case study including layout configuration and warehouse slotting does not promote accessibility of items and ease of warehouse operations especially in terms of put away and order picking processes. The current management is also unable to facilitate FIFO warehouse system, thus, leading to expired raw materials. The current storage poses safety risks as hazardous items are not properly stored in the warehouse. Furthermore, the warehouse of case study lacks efficient supporting tools to facilitate warehouse operations and comfort operations for the workers.

Designing warehouse management is the significant part in warehousing as performance of the warehouse would depend on this phase. The layout configuration and warehouse slotting should be designed to fully exploit space of warehouse, promote operations and support the FIFO warehouse system. Accessibility of the stored items would definitely improve warehouse performance and, thus, productivity of the business as the flow of raw materials into production is uninterrupted. The FIFO warehouse system allows the case study company to less likely incur expired items which could no longer be used in production. The warehouse management of the case study, thus, has to be redesigned to promote efficiency and effectiveness of warehouse operations and FIFO warehouse system.

5.1 Policy on warehouse management

The policy on warehouse management in terms of layout and slotting should be created to increase space utilization and warehousing efficiency, support FIFO warehouse system and reduce safety risks from improper storage of items in the warehouse. The storage space would be designed for full utilization by ensuring that the items stored correctly fit the slot without any wasted horizontal, vertical and ground space.

The inventory would be separated depending on product category and frequency of movement. Warehouse slotting would be processed by defining the quantity of storage in order to reserve locations and determining the placement of items within the warehouse. The quantity of storage is based on policy of inventory management described in Chapter 4 in which order quantity for purchasing of raw materials is mentioned. The adequate storage space would be provided for the incoming inventory prepared for production.

In determining storage location, all items in the warehouse would be ranked based on the frequency of each item picked for an order. The ranking could be determined by sorting in descending order the transaction of picking as requested for production. Following the ranking, warehouse slotting can be designed by considering the distance which the warehouse operator needs to travel to reach to the location and how accessible the location would be once the operator gets there. The warehouse of current case study operates full-pallet picking where a forklift truck operator has a fixed starting point and moves to pick one pallet at a time, then returns to that fixed point. As a result, locations in the warehouse could be ranked by the distance from the starting point. In terms of accessibility, the location which requires forklift truck or ladder to access is considered not easily accessible as compared to one that could be accessed from floor level.

Slotting would assign the fast-moving item to the location toward the front of warehouse for ease of accessibility while the slow-moving item would be slotted toward the back of warehouse. The fast-moving item should also be placed on the low level whereas the slow-moving item could be stored up above in the racks. In addition, the items which are normally requested together should be placed next to each other.

Furthermore, in order to promote FIFO warehouse system, the allocation into storage would also depend on batch number of items. The items of different batch would be segregated and stored separately. The warehouse operators would, therefore, correctly pick the item which is prior received into the system as compared to the others. As a result, it could be assured that FIFO warehouse system is maintained. In terms of safety issue, non-hazardous and hazardous items would be separately stored by providing appropriate location for the latter.

In addition to the redesigning of warehouse operating system, supporting tools including product and batch number labelling as well as product-location records would be introduced to the warehouse to promote ease of operations. Stock card recorded on computer would also be implemented in replacement of the existing paper-based system for better record accuracy.

5.2 Warehouse layout design

The design of the warehouse of case study is adjusted for ease of operations. There would be a new entrance for receiving purpose as the entrance is basically built for receiving of inventory into the warehouse. As a result, a separated zone for receipt area could be introduced. The received items would be temporarily stored at the receipt area for checking process in terms of quantity, physical condition and quality assurance before allocation into respective storage. Other than the receipt area, there is also a separated zone for dispatch where the picked items are temporarily stored before being delivered to the requested department. The receipt area and the dispatch area would be partitioned in order to ensure that items stored would not be mistaken. The proposed warehouse design is illustrated in Figure 5.1.

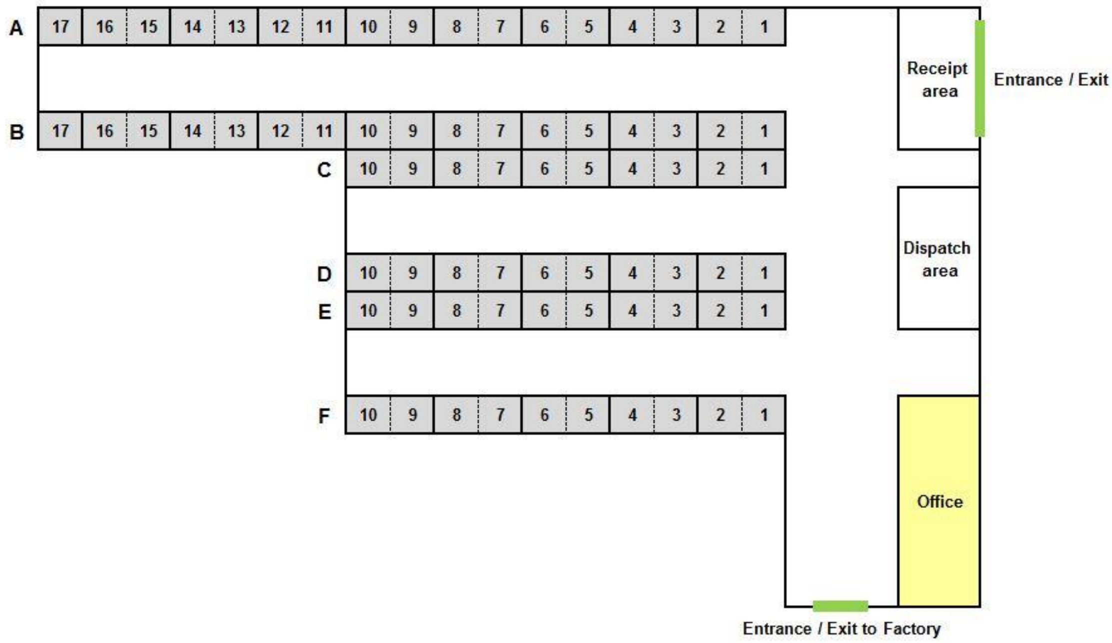


Figure 5.1: Warehouse layout design

5.3 Warehouse slotting design

Warehouse slotting design has to take into account the constraint for storage area for the current case study which is aforementioned in Chapter III. The warehouse has selective racking separated into six zones, A to F. The zoning of warehouse would follow the existing design with the exception of solvents which would be stored separately. With the most available space for storage, Zone A and B is best suitable for resin storage since plastic resins and additives require the most space compared to other raw materials. Following the resins, films require the second most space for storage, thus blown and purchased films would be allocated in Zone C and D. Paper cores would be assigned to Zone E while printing inks and adhesives would be stored together in Zone F as both require minimal space for storage.

The zoning of raw materials is demonstrated in Figure 5.2.

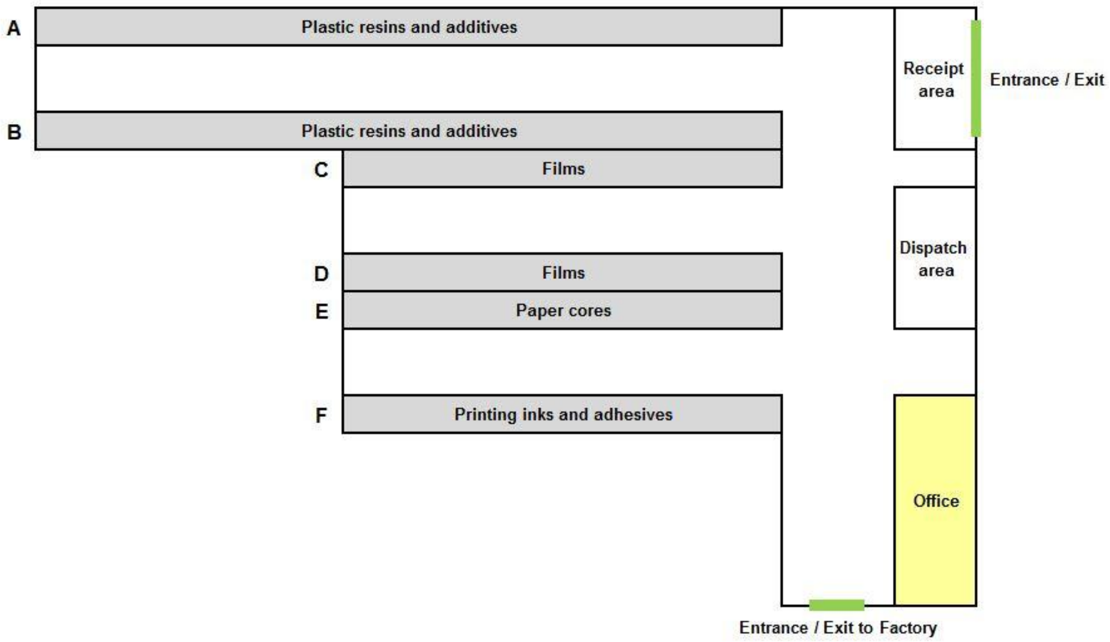


Figure 5.2: Zoning of storage

Referring to the monthly order quantity for raw materials presented in Chapter 4, the data could be summarised as shown in Table 5.1. With reference to Table 5.1, January is the month of maximum order quantity. As a result, the quantity of raw materials ordered in January would be used in calculation for the space required and determining slotting. The storage condition and warehouse slotting for each type of raw materials are clarified in the following sections.

Table 5.1: Summary of order quantity for raw materials

Type	Unit	Order quantity (Unit)											
		Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
Resin	Bag	2,356	1,191	2,019	1,412	2,128	1,191	2,240	1,191	2,135	1,412	2,012	1,191
Film	Roll	87	81	87	81	87	81	87	81	87	81	87	81
Printing ink	Bucket	219	183	188	214	188	183	219	183	188	214	188	183
Adhesive	Bucket	138	128	138	128	138	128	138	128	138	128	138	128
Solvent	Bucket	41	36	39	38	39	36	41	36	39	38	39	36
Paper core	Piece	1,620	1,329	1,430	1,510	1,430	1,320	1,620	1,329	1,430	1,510	1,430	1,320

5.3.1 Plastic resins and additives

As a result of the constraints of the rack, each beam in the upper level could support two pallets with the maximum weight of 500 kg on each pallet. It has been noted in Chapter IV that plastic resins and additives are supplied as a bag with the weight of 25 kg per one bag. One pallet stored at the upper level of the rack, thus, could support 20 bags of resins. However, with no weight constraints at the ground-floor level, two pallets supporting 40 bags each would be located at the ground floor of the rack.

(I) (II)

Figure 5.3: Storage condition of plastic resins and additives (I) 20 bags on pallet (II) 40 bags on pallet

In terms of transaction of items, the frequency of order picking for each grade of plastic resins and additives would be determined from the travel of the order picker. As the warehouse operates order picking of resins as full-pallet picking, the frequency of travel could be identified from the number of pallets to be picked as requested for production. With reference to Table 4.2, the quantity of resins required for the maximum production in both January and July and the approximate number of travel for picking of such quantity are shown with transaction ranking in Table 5.2. It should be noted that the months of January and July with the highest production quantity is selected for calculation.

Table 5.2: Transaction ranking of plastic resins and additives

Transaction ranking	Resin grade	Maximum quantity used for production (Bags)	Frequency of travel for order picking (Times)
1	LL 7410D1	818	41
2	SP 2020H	335	17
3	LD 2420D	279	14
4	LD 2426H	189	10
5	LL 7410A	153	8
6	WM	67	4
7	EL 5220G	30	2
	EL 5401G	28	2

With reference to the order quantity of resins shown in Table 4.14, the quantity of ordered resins in January, the quantity of pallet required for storing such order and transaction ranking are illustrated in Table 5.3. It should be noted that the calculation estimates the packing of 20 bags per one pallet.

Table 5.3: Transaction ranking and quantity of storage for plastic resins and additives

Transaction ranking	Resin grade	Maximum order quantity (Bags)	Quantity of storage (Pallets)
1	LL 7410D1	818	41
2	SP 2020H	680	34
3	LD 2420D	279	14
4	LD 2426H	189	10
5	LL 7410A	153	8
6	WM	121	7
7	EL 5220G	60	3
	EL 5401G	56	3

Warehouse slotting of plastic resins and additives with reference to the transaction ranking and quantity of storage is illustrated in Figure 5.4. The pallets located at the ground floor support 40 bags of resins while those located on the upper level support 20 bags of resins.

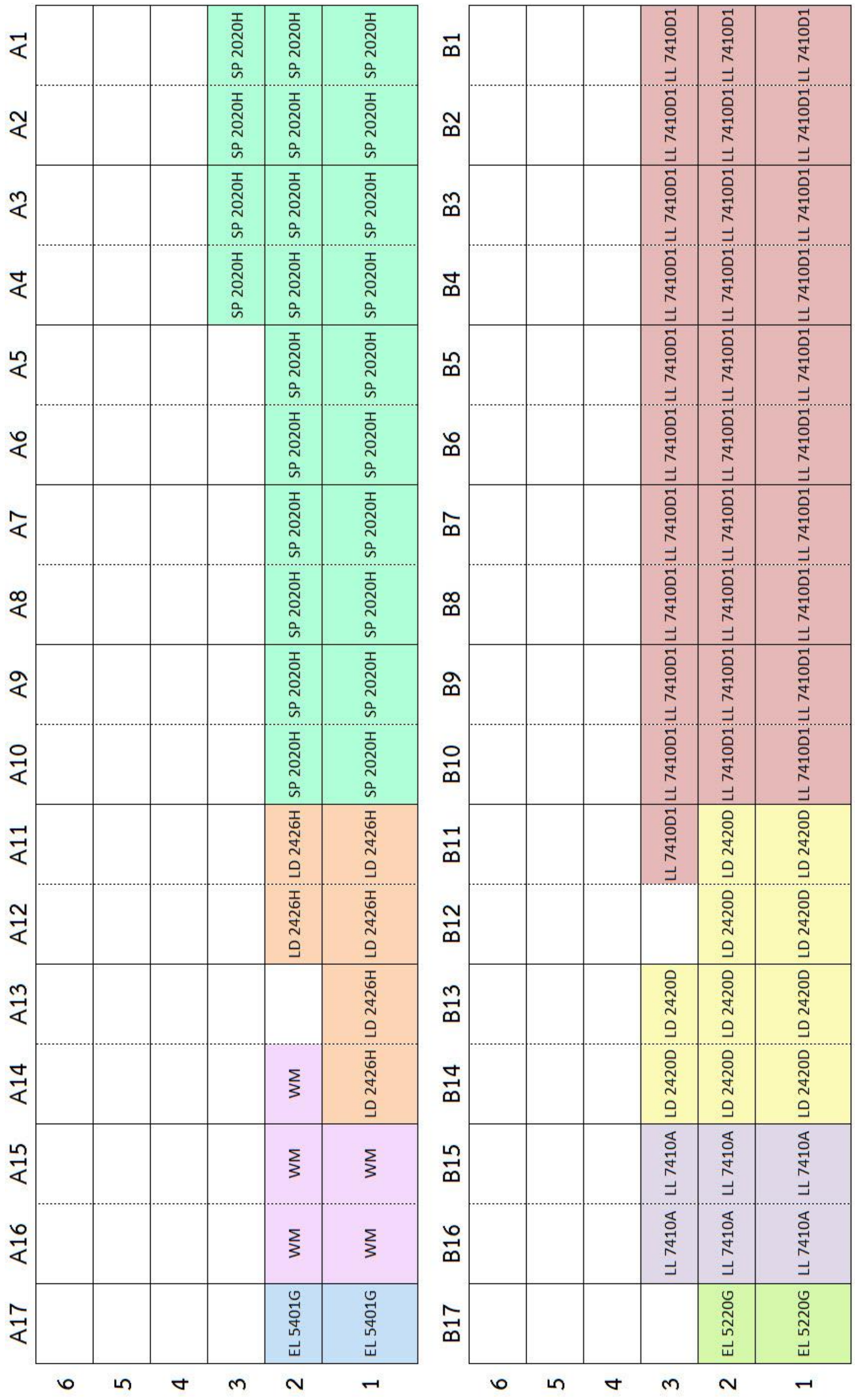


Figure 5.4: Redesigned warehouse slotting of plastic resins and additives (Zone A and B)

5.3.2 Films

The films stored in the warehouse could be separated into two groups, blown film and purchased film. Both groups of films would be placed on pallets before allocation into storage. Due to packaging of the films, one pallet could support two rolls for the purchased film. The blown film has to be placed vertically while the purchased one could be placed horizontally as demonstrated in Figure 5.5. Due to its heavy weight it is unsuitable to place the blown film on the upper level of the rack. Also, in order to promote safety of storage, the blown film should be located at the ground floor of the rack in Zone C, D, E and F.

(I) **(II)**

Figure 5.5: Storage condition of (I) blown film (II) purchased film

Unlike the resins, there are only two grades of the purchased films, making the slotting of the purchased film much simpler. Since BOPP P film would be used more in production compared to BOPP HS film, the transaction rankings of BOPP P and BOPP HS films are 1 and 2, respectively. With reference to the order quantity of films shown in Table 4.15, the quantity of BOPP films ordered in January, the quantity of pallet used for storage and transaction ranking of each grade of film are shown in Table 5.4.

Table 5.4: Transaction ranking and quantity of storage for BOPP P and BOPP HS films

Transaction ranking	Film grade	Maximum order quantity (Rolls)	Quantity of storage (Pallets)
1	BOPP P	66	33
2	BOPP HS	21	11

The slotting of films with reference to transaction ranking and quantity of storage is shown in Figure 5.6.

	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1
6										
5										
4										
3	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P
2	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P
1	Blown film									

	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1
6										
5										
4			BOPP HS					BOPP P	BOPP P	BOPP P
3	BOPP HS	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P
2	BOPP HS	BOPP HS	BOPP HS	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P	BOPP P
1	Blown film									

Figure 5.6: Redesigned warehouse slotting of films (Zone C and D)

5.3.3 Printing inks

Due to constraints in size of printing-ink bucket and pallet for storage, printing ink could be placed on pallet with the maximum quantity of 20 buckets per one pallet. The bucket would not be stacked in order to promote safety of the storage.

The ink with dissimilar colour would be placed on different pallet. The slotting of printing ink would depend on the frequency of transaction for order picking. The basic colours which are normally used in printing of common products would be ranked first and slot in the lower level of the rack while the special colours used rarely would be ranked last and placed in the upper level of the rack. Referring to the quantity of printing inks used for production of each product presented in Table 4.6, the summary of inks used for production and transaction ranking is illustrated in Table 5.5.

Figure 5.7: Storage condition of printing inks

Table 5.5: Transaction ranking of printing inks

Transaction ranking	Ink grade - Colour	Customer product				
		Product A	Product B	Product C	Product D	Product E
1	HI-OPP Black	✓	✓	✓	✓	-
	HI-OPP Yellow	✓	✓	✓	✓	-
	HI-OPP Magenta	✓	✓	✓	✓	-
	HI-OPP Medium	✓	✓	✓	✓	-
2	NEW PPL Blue	✓	✓	-	✓	-
3	HI-OPP White	✓	-	-	✓	-
4	HI-OPP Violet	✓	-	-	-	-
	HI-OPP Orange 307	-	✓	-	-	-
	HI-OPP Orange 303	-	-	✓	-	-
	HI-OPP Geranium	-	-	-	✓	-
	HI-OPP Green	-	-	-	✓	-
	DLO Black	-	-	-	-	✓
	DLO Yellow	-	-	-	-	✓
	DLO Geranium	-	-	-	-	✓

Regarding to the order quantity of printing inks shown in Table 4.16, the quantity of inks ordered in January, the quantity of pallet used for storage and transaction ranking of inks are summarised in Table 5.6.

Table 5.6: Transaction ranking and quantity of storage for printing inks

Transaction ranking	Ink grade - Colour	Maximum order quantity (Buckets)	Quantity of storage (Pallets)
1	HI-OPP Black	14	1
	HI-OPP Yellow	18	1
	HI-OPP Magenta	7	1
	HI-OPP Medium	24	2
2	NEW PPL Blue	12	1
3	HI-OPP White	79	4
4	HI-OPP Violet	18	1
	HI-OPP Orange 307	2	1
	HI-OPP Orange 303	1	1
	HI-OPP Geranium	12	1
	HI-OPP Green	1	1
	DLO Black	10	1
	DLO Yellow	11	1
	DLO Geranium	10	1

Warehouse slotting of printing inks based on the data presented in Table 5.6 is shown in Figure 5.8.

	F10	F9	F8	F7	F6	F5	F4	F3	F2	F1
6										
5										
4					DLO Geranium	DLO Yellow	DLO Black	HI-OPP Green	HI-OPP Orange	HI-OPP Orange
3					HI-OPP Geranium	HI-OPP Violet	HI-OPP White	HI-OPP White	HI-OPP White	HI-OPP White
2					NEW PPL Blue	HI-OPP Medium	HI-OPP Medium	HI-OPP Magenta	HI-OPP Yellow	HI-OPP Black
1	Blown film									

Figure 5.8: Redesigned warehouse slotting of printing inks (Zone F)

5.3.4 Adhesives

There are two grades of adhesives which need to be mixed for dry laminating process, are usually requested together. Therefore, the two grades of adhesives would be allocated together into storage. With the constraint in size of packaging and pallet for storage similar to the printing ink, one pallet is capable to support up to 10 sets of adhesive (10 buckets for each grade of adhesives). The adhesives would also not be stacked as a result of safety issue. In regard to the order quantity of adhesives demonstrated in Table 4.17, the quantities of adhesives ordered in January and pallets for storage is summarised in Table 5.7.

Figure 5.9: Storage condition of adhesives

Table 5.7: Quantity of storage for adhesives

Adhesive grade	Maximum order quantity (Buckets)	Quantity of storage (Pallets)
LA 2882F	69	7
LA 5000	69	

Slotting of adhesives is illustrated in Figure 5.10.

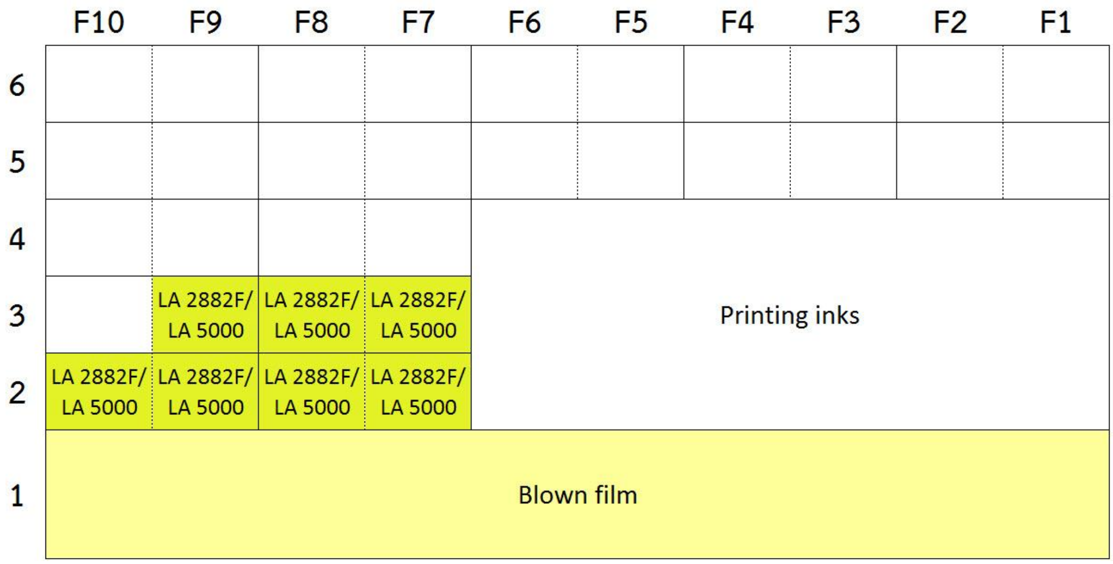


Figure 5.10: Redesigned warehouse slotting of adhesives (Zone F)

5.3.5 Solvents

Since solvent used for production is considered as an inflammable agent, it must be stored separately in a designated space. The location would be away from the warehouse as shown in Figure 5.11. In the designated room for storage, the solvents of different categories would be arranged separately.

Figure 5.11: Designated room for solvent storage

5.3.6 Paper cores

The paper cores of size 3" x 445 mm x 15 mm would be stacked horizontally on pallet with the maximum quantity of 120 rolls per one pallet, while the size of 6" x 362 mm x 8 mm and 6" x 366 mm x 8 mm would be vertically stacked on pallet with the quantity of 108 rolls per one pallet. The maximum quantity is decided by considering the appropriate height of stack since the higher the stack, the more unsafe of storage. The stack of paper cores would be wrapped with plastic in order to avoid falling before allocation into storage.

Figure 5.12: Storage condition of paper cores

The transaction ranking of paper cores would be determined from requirement for production. Since the size 6" x 362 mm x 8 mm is used for most of the products including Product A, B and C, it would be ranked first in transaction ranking. The size 6" x 366 mm x 8 mm should be ranked second as it is used for Product D. Lastly, the size 3" x 445 mm x 15 mm used for Product E would be ranked third since the production of Product E is operated only every three months. Based on the order quantity of paper cores shown in Table 4.19, the quantities of paper cores ordered in January, pallet for storage and transaction ranking is shown in Table 5.8.

Table 5.8: Transaction ranking and quantity of storage for paper cores

Transaction ranking	Paper core size	Maximum order quantity (Pieces)	Quantity of storage (Pallets)
1	6" x 362 mm x 8 mm	1,100	11
2	6" x 366 mm x 8 mm	330	4
3	3" x 445 mm x 15 mm	190	2

Warehouse slotting of paper cores in regard to the quantity of storage and transaction ranking is illustrated in Figure 5.13.

	E10	E9	E8	E7	E6	E5	E4	E3	E2	E1
6										
5										
4										
3			6" x 366 x 8	6" x 366 x 8		6" x 362 x 8	6" x 362 x 8	6" x 362 x 8	6" x 362 x 8	6" x 362 x 8
2	3" x 445 x 15	3" x 445 x 15	6" x 366 x 8	6" x 366 x 8	6" x 362 x 8	6" x 362 x 8	6" x 362 x 8	6" x 362 x 8	6" x 362 x 8	6" x 362 x 8
1	Blown film									

Figure 5.13: Redesigned warehouse slotting of paper cores (Zone E)

5.4 Supporting tool design

The supporting tools including product identification, product-location record and stock card would be designed and introduced to the warehouse of case study. Before allocation into storage, the product identification including material name, specification and batch number would be tagged on pallet. The coloured tape is used to differentiate items of dissimilar batch, thus FIFO warehouse system could be easily managed. In addition, the record identifying location of storage would be created and shown at the racking. Tag of product identification and product-location record are shown in Figures 5.14 and 5.15 respectively.

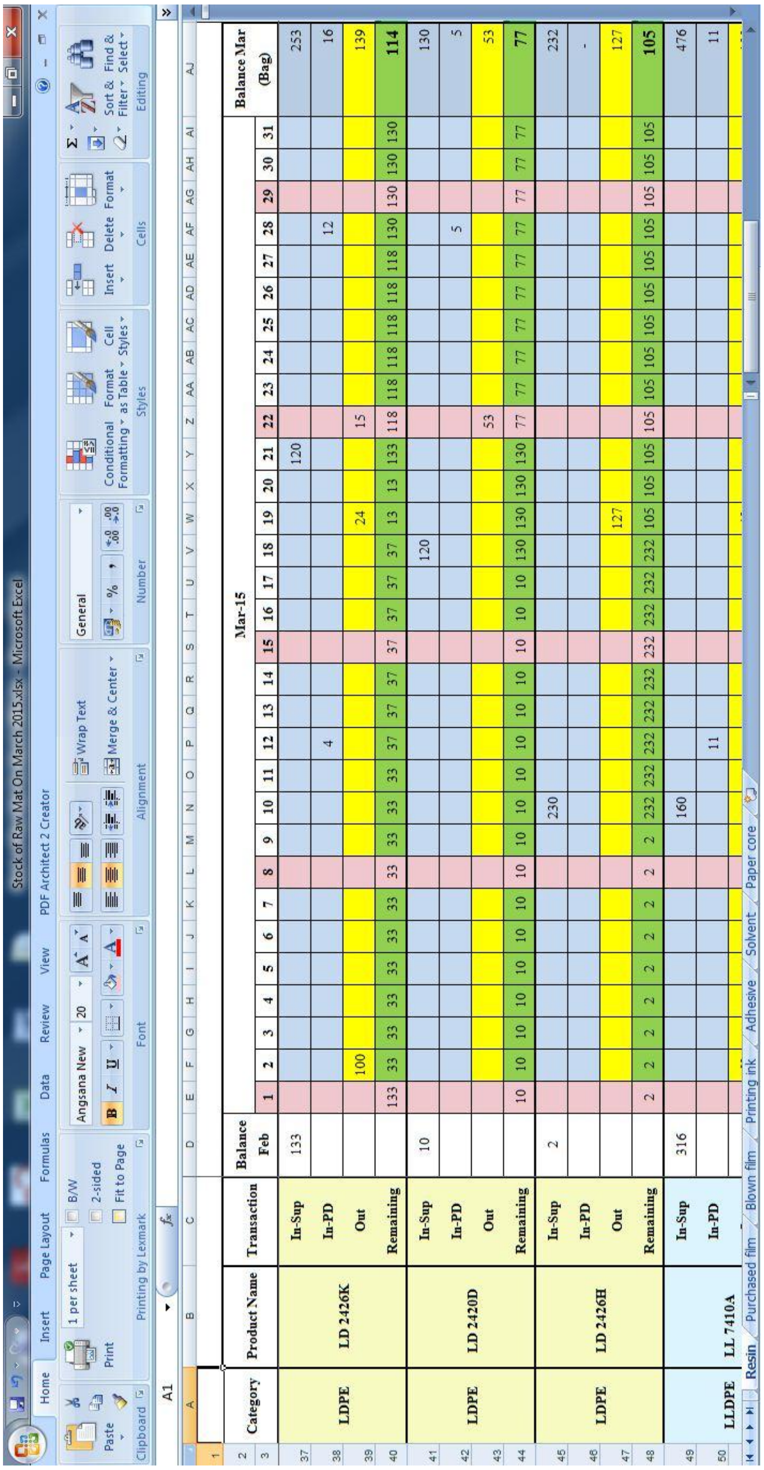
ป้ายชี้บ่งวัตถุดิบ
ชื่อวัตถุดิบ:
ขนาด/ รายละเอียดอื่นๆ:
Lot Number:

Figure 5.14: Product identification

	A2	A1
6		
5		
4		
3		
2		
1		

Figure 5.15: Product-location record

The stock card recorded on Microsoft Office Excel is designed and used instead of manual record with paper-based system. The design of stock card includes record of items moving into and out of the system. The warehouse operator would have to input data regarding quantity of item flowing in and out of the system including receiving from the suppliers and the production or shipping for further processing in production. The record separates items into categories including plastic resins and additives, blown films, purchased films, printing inks, adhesives, solvents and paper cores for ease of searching. It specifies the date in which transaction occurs, the quantity of item in transaction and the daily remaining quantity of items in storage. The design of stock card is illustrated in Figure 5.16.



Category	Product Name	Transaction	Balance Feb	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Balance Mar (Bag)
LDPE	LD 2426K	In-Sup	133																					120											253
		In-PD													4																12				16
		Out			100																	24			15										139
		Remaining		133	33	33	33	33	33	33	33	33	33	33	37	37	37	37	37	37	37	13	13	133	118	118	118	118	118	118	130	130	130	130	114
LDPE	LD 2420D	In-Sup	10																		120														130
		In-PD																													5				5
		Out																							53										53
		Remaining		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	130	130	130	130	77	77	77	77	77	77	77	77	77	77	77
LDPE	LD 2426H	In-Sup	2										230																						232
		In-PD																																	-
		Out																				127													127
		Remaining		2	2	2	2	2	2	2	2	2	232	232	232	232	232	232	232	232	232	105	105	105	105	105	105	105	105	105	105	105	105	105	105
LLDPE	LL 7410A	In-Sup	316										160																						476
		In-PD													11																				11

Figure 5.16: Stock card

5.5 Conclusion

The design of warehouse management focused on layout, slotting and supporting tools with the purpose to increase accessibility of the stored items as well as ease of daily operations. The layout of warehouse is slightly adjusted for ease of warehouse operations. Warehouse slotting is redesigned by considering spaces required for storage and transaction ranking of each material. FIFO warehouse system and safety of storage are also promoted by the redesigned policy. In addition, supporting tools including tags, records and stock card input on computer are introduced to the warehouse to better comfort operations for the workers.

6. CHAPTER VI DESIGN EVALUATION

The evaluation should prove whether the proposed design on inventory policy and warehouse management could better support the case study company in terms of inventory control and warehouse performance in terms of accessibility of the stored items and ease of operations. The evaluation is divided into two parts, inventory policy and warehouse management, presented in the following sections.

6.1 Inventory policy evaluation

The evaluation on the proposed inventory policy focuses on solving the problems involving the existing inventory control. In order to compare the performance of inventory control between the existing and the proposed management, the assessment is performed over the period of 12 months from May 2014 to April 2015 is performed. It should be noted that the redesigned policy on inventory control is introduced to the warehouse of case study since September 2014. The evaluation involves the analysis of shortage as well as inventory level of the six categories of raw materials used for production including plastic resins, films, printing inks, adhesives, solvents and paper cores. Any stock-out occurrence would be recorded for the evaluation on shortage while the stock at the end of month is used for the evaluation on inventory level.

Moreover, the demand of customer during the period of study would also be considered for the evaluation since it poses a significant impact on inventory control. The total customer order for the five main products from May 2014 to April 2015 is shown in Figure 6.1.

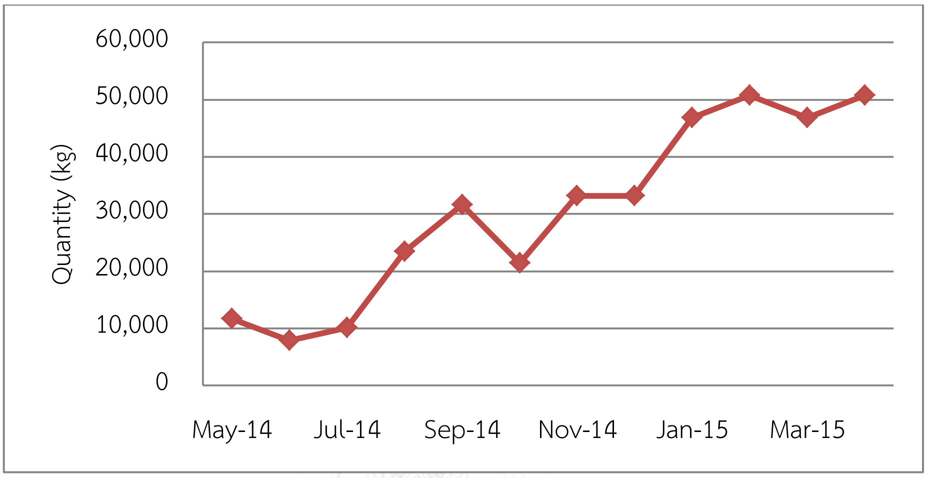


Figure 6.1: Customer order of the five products with the unit of kilogram

Inventory levels of some raw materials over a period of 12 months (May 2014 to April 2015) are presented in Figure 6.2. The data is presented as value of the holding inventory with the unit of Thai Baht. The examples include resins of grade LL 7410D1 and LD 2426H, purchased film of type BOPP P, printing inks of grade HI-OPP Yellow and HI-OPP Magenta, adhesives of grade LA 2882F, solvents of grade EA and paper cores of size 6" x 362 mm x 8 mm. Inventory levels of other raw materials also presented in Appendix C1.

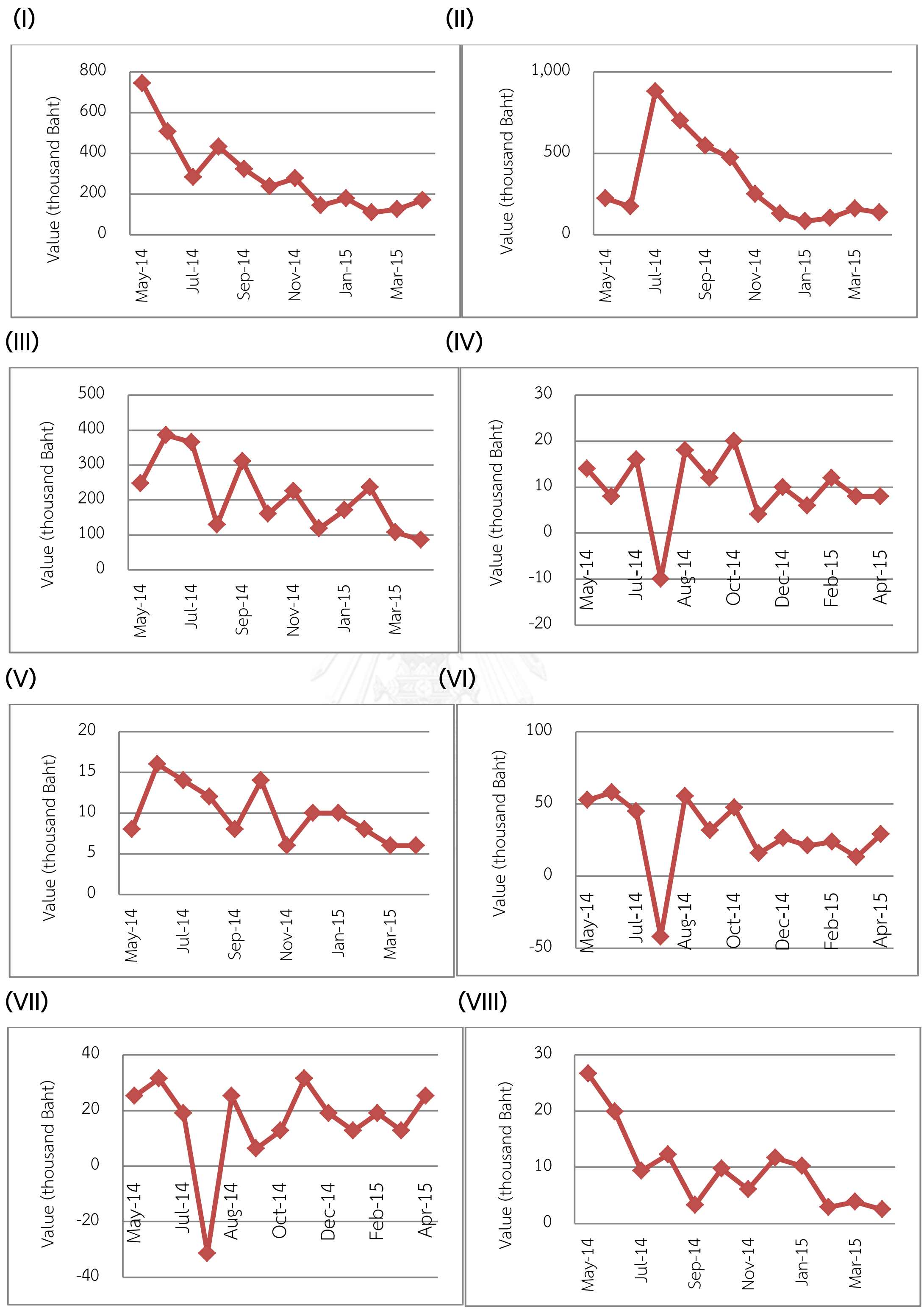


Figure 6.2: Inventory level of (I) LL 7410D1, (II) LD 2426H, (III) BOPP P film, (IV) HI-OPP Yellow, (V) HI-OPP Magenta, (VI) LA 2882F, (VII) EA and (VIII) 6" x 362 mm x 8 mm

A summary of occurrence of shortage and monthly average inventory level of each type of raw materials in both the existing and proposed management is shown in Table 6.1. The detailed records could be found in Appendix C2. The proposed management is divided into two phases; September to December 2014 and January to April 2015. During the first phase of management, the customer orders were still fluctuated and, thus, could not be predicted. Afterwards, in the second phase, the customer orders became more stable so that the company could predetermine the orders and plan the production to support such orders.

Table 6.1: Shortage and inventory level of raw materials in the existing and proposed situations

Type of raw materials	Existing management (May 14 - Aug 14)		Proposed management			
			Phase 1 (Sep 14 - Dec 14)		Phase 2 (Jan 15 - Apr 15)	
	Shortage (occurrences)	Monthly average inventory level (Baht)	Shortage (occurrences)	Monthly average inventory level (Baht)	Shortage (occurrences)	Monthly average inventory level (Baht)
Plastic resins and additives	0	406,121	0	229,375	0	182,084
Purchased films	0	227,391	0	176,963	0	118,388
Printing inks	9	13,541	0	10,899	0	8,540
Adhesives	2	34,250	0	19,694	0	14,128
Solvents	3	27,885	0	17,385	0	18,600
Paper cores	0	11,389	0	4,969	0	2,745
Total	**14**	**720,577**	**0**	**459,285**	**0**	**344,485**
	Saving		261,292 Baht		376,092 Baht	
			36.26%		52.19%	

It could be concluded that the minimum-quantity policy currently employed has led to shortage of raw materials in case of printing inks, adhesives and solvents as the inventory of the materials would always be kept to minimum and could not satisfy demand of the production. The shortage had always occurred whenever there was a high demand of customer as the available raw materials is not enough to support the demand. However, the redesigned policy introduced to the case study in September 2014 would allow the warehouse to avoid the occurrence of stock-outs.

Other than stock outs of raw materials, the existing inventory control also has resulted in overstocking of the materials especially in case of plastic resins and additives, films and paper cores due to large-batch purchasing. According to the monthly average inventory level presented in Table 6.1, it could be noticed that the inventory control of raw materials gradually improved from May 2014 toward April 2015. The overstocking of raw materials during the period of May 2014 to August 2014 is much higher compared to that of September 2014 onward. However, the inventory control during September 2014 to December 2014 is still unstable as a result of fluctuating customer demands. As a result of predetermined customer order, the management of inventory from January 2015 onward shows the best performance with minimum holding stock and highest saving on inventory value.

6.2 Warehouse management evaluation

The evaluation on warehouse management could be separated into two parts including warehouse layout and slotting evaluation and supporting tool evaluation described in the following sections.

6.2.1 Warehouse layout and slotting evaluation

The evaluation on warehouse slotting is performed by assessing the accessibility of items stored in the warehouse both in case of the existing and redesigned slotting. The indicator used is Pallets x m which could be calculated by multiplying volume of storage by travel distance to the storage location as shown in Equation 6.1. The picking lists of items normally requested by the production to process the main customer products would be used for the evaluation. It is assumed that, in picking of the same items, the centre of storage location would be the point used in determining the travel distance.

$$\text{Pallets x m} = \text{Volume of storage (pallets)} \times \text{Travel distance (m)}$$

Where

$$\text{Travel distance} = \text{Horizontal distance (m)} + [\text{Vertical distance (m)} \times \text{Level weight}]$$

and

$$\text{Level weight} = \begin{cases} 1 & \text{if at the ground floor} \\ 1.25 & \text{if at the } 2^{nd} \text{ beam} \\ 1.5 & \text{if in between the } 2^{nd} \text{ and the } 3^{rd} \text{ beams} \\ 1.75 & \text{if at the } 3^{rd} \text{ beam} \\ 2 & \text{if in between the } 3^{rd} \text{ and the } 4^{th} \text{ beams} \\ 2.25 & \text{if at the } 4^{th} \text{ beam} \\ 2.5 & \text{if in between the } 4^{th} \text{ and the } 5^{th} \text{ beams} \end{cases}$$

Equation 6.1: Pallets x m indicator

The volume of storage is determined based on storage condition of each type of raw materials aforementioned in Chapter IV. The travel distance is measured from the same starting point for order picking to the destination of storage. In case of picking on the upper level of racks, the distance toward the upper level would be determined from the height of destination multiplied by level weight as specified in Equation 6.1. The detailed dimension of warehouse used in calculation for travel distance is presented in Figure 6.3. In addition, as stated in Chapter III, the height of the ground floor of racks is 2 metres while that of the upper level is 1.2 metres.

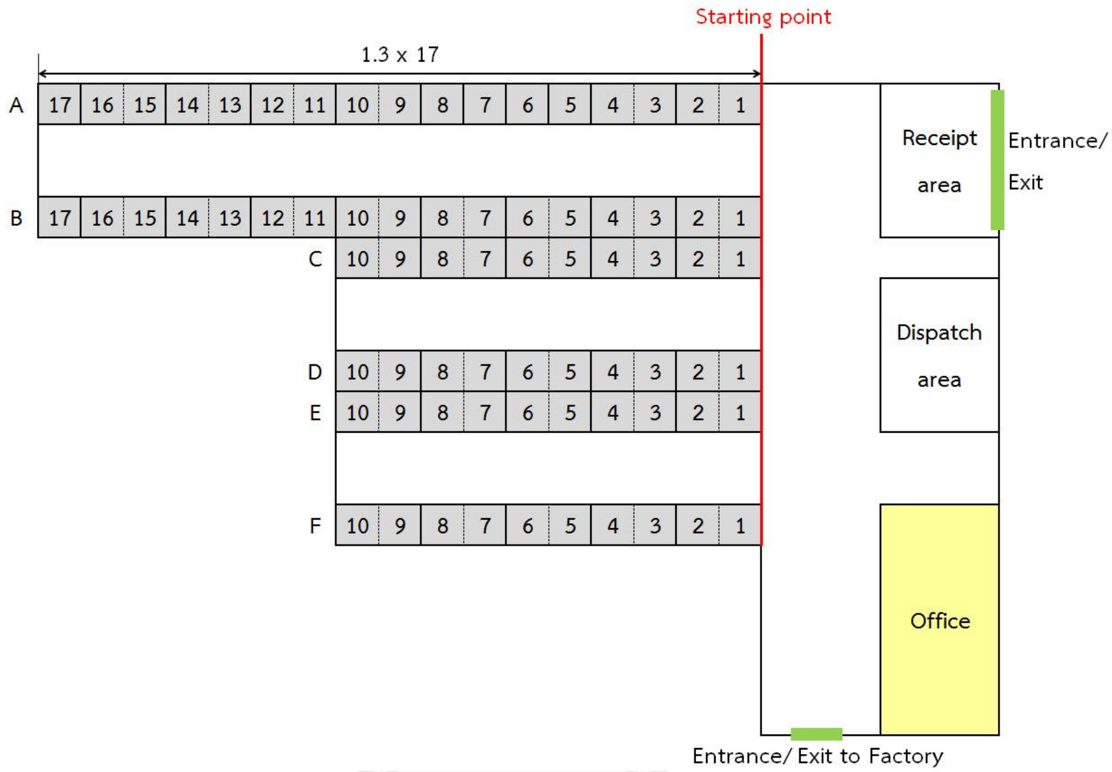


Figure 6.3: Detailed dimension of warehouse used in calculation for travel distance

Per the picking list for production of 500 rolls of Product A shown in Table 6.2, the destinations for order picking of each raw material could be determined and demonstrated in Figure 6.4, 6.5 and 6.6.

Table 6.2: Picking list for production of Product A

Picking list (Product A 500 rolls)			
Type	**Grade/ Size**	**Quantity**	**Unit**
Plastic resins and additives	LL 7410A	55	Bag
	LL 7410D1	280	Bag
	LD 2420D	155	Bag
	SP 2020H	130	Bag
	WM	30	Bag
Purchased films	BOPP P	35	Roll
Printing inks	HI-OPP Black	3	Bucket
	HI-OPP Yellow	13	Bucket
	HI-OPP Magenta	4	Bucket
	HI-OPP Medium	14	Bucket
	HI-OPP White	49	Bucket
	HI-OPP Violet	18	Bucket
	NEW PPL Blue	9	Bucket
Adhesives	LA 2882F	26	Bucket
	LA 5000	26	Bucket
Paper cores	6" x 362 mm x 8 mm	500	Piece

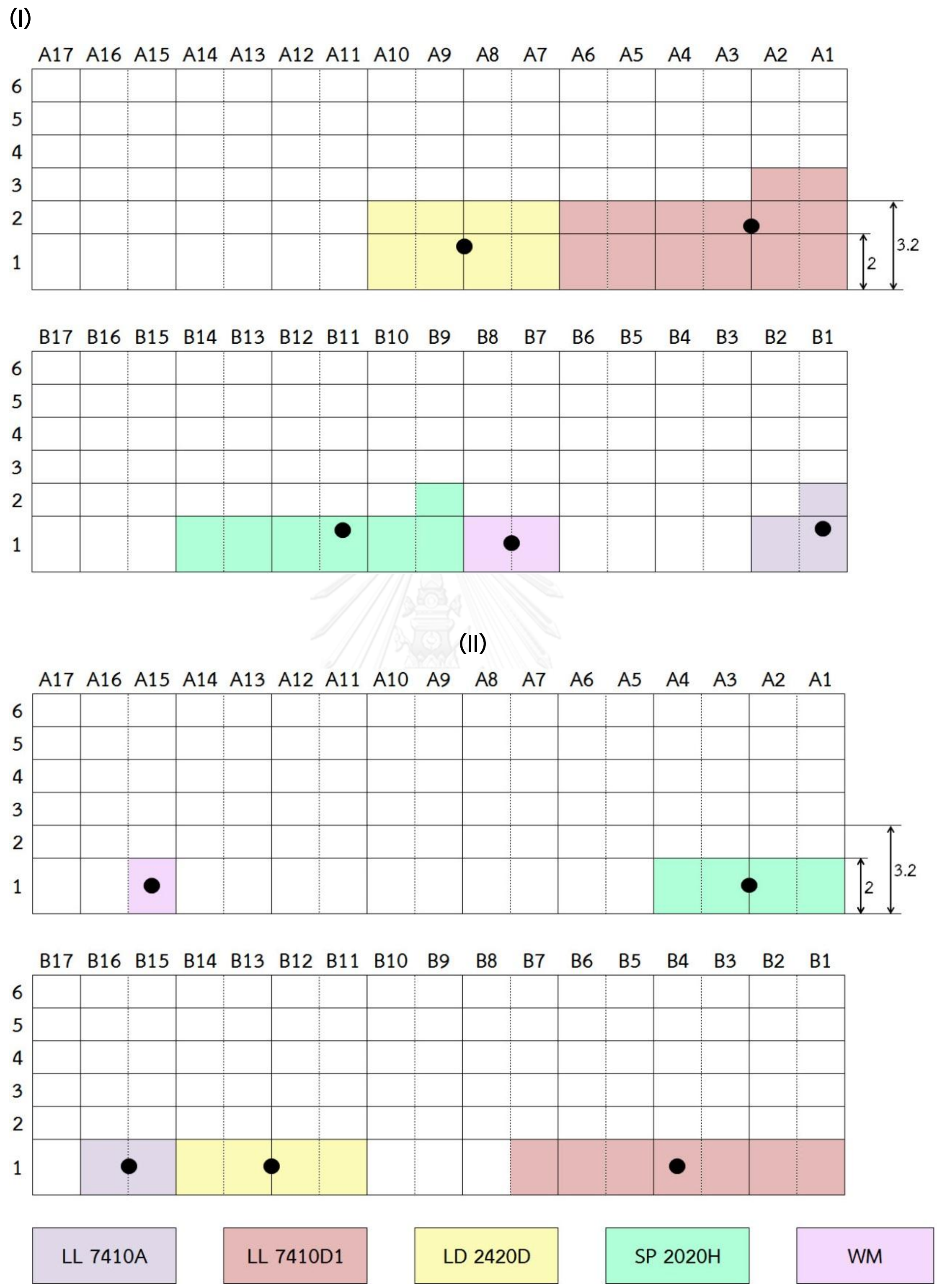


Figure 6.4: Storage location of plastic resins and additives required for production of Product A in case of (I) existing slotting and (II) redesigned slotting

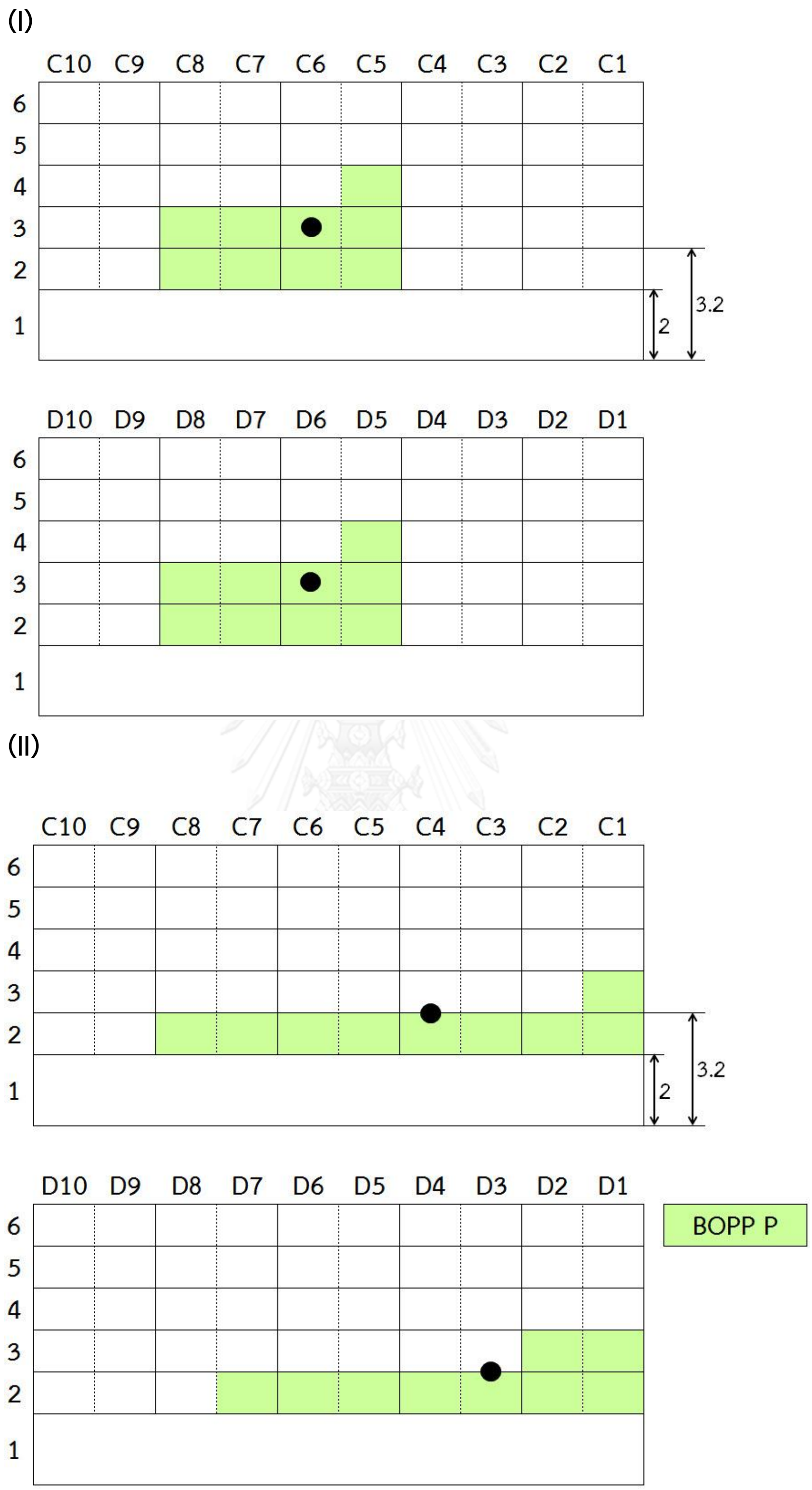


Figure 6.5: Storage location of films required for production of Product A in case of (I) existing slotting and (II) redesigned slotting

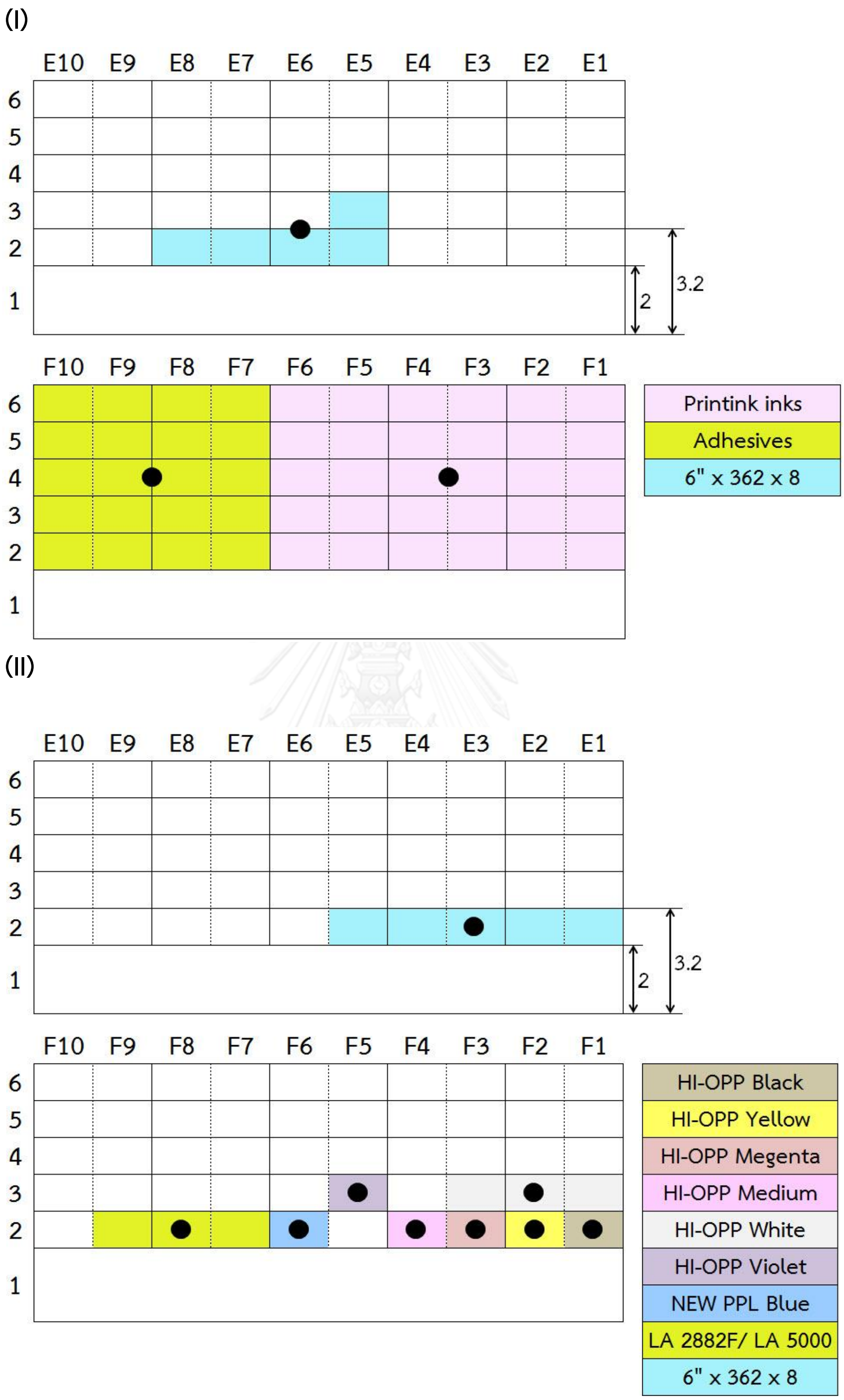


Figure 6.6: Storage location of printing inks, adhesives and paper cores required for production of Product A in case of (A) existing slotting and (B) redesigned slotting

Regarding the storage locations of the raw materials presented in Figure 6.4, 6.5 and 6.6, the Pallets x m of both existing and redesigned slotting for picking list of Product A could be calculated as illustrated in Table 6.3 and 6.4, respectively. The calculation of Pallets x m for picking lists of Product B, C, D and E are presented in Appendix D1, D2, D3 and D4, respectively. In summary, the comparison of the total Pallets x m for all picking lists operated in the existing and redesigned situations is presented in Table 6.5.

Table 6.3: Accessibility evaluation of the existing slotting

Picking list (Product A 500 rolls)				Accessibility evaluation of existing slotting				
Type	Grade/ Size	Quantity	Unit	Pallets	Horizontal distance (m)	Vertical distance (m) x Level weight	Total travel distance (m)	Pallets x m
Plastic resins and additives	LL 7410A	55	Bag	3	0.65	1.6	2.25	6.75
	LL 7410D1	280	Bag	14	2.6	3.3	5.9	82.6
	LD 2420D	155	Bag	8	10.4	1.6	12	96
	SP 2020H	130	Bag	7	13.65	1.6	15.25	106.75
	WM	30	Bag	2	9.1	1	10.1	20.2
Purchased films	BOPP P	35	Roll	18	7.15	7.6	14.75	265.5
Printing inks	HI-OPP Black	3	Bucket	1	3.9	14	17.9	17.9
	HI-OPP Yellow	13	Bucket	1				17.9
	HI-OPP Magenta	4	Bucket	1				17.9
	HI-OPP Medium	14	Bucket	1				17.9
	HI-OPP White	49	Bucket	3				53.7
	HI-OPP Violet	18	Bucket	1				17.9
	NEW PPL Blue	9	Bucket	1				17.9
Adhesives	LA 2882F	26	Bucket	3	10.4	14	24.4	73.2
	LA 5000	26	Bucket					
Paper cores	6" x 362 mm x 8 mm	500	Piece	5	7.55	5.6	13.15	65.75
				Total Pallets x m				**877.85**

Table 6.4: Accessibility evaluation of the redesigned slotting

Picking list (Product A 500 rolls)				Accessibility evaluation of redesigned slotting				
Type	Grade/ Size	Quantity	Unit	Pallets	Horizontal distance (m)	Vertical distance (m) x Level weight	Total travel distance (m)	Pallets x m
Plastic resins and additives	LL 7410A	55	Bag	2	19.5	1	20.5	41
	LL 7410D1	280	Bag	7	4.55	1	5.55	38.85
	LD 2420D	155	Bag	4	15.6	1	16.6	66.4
	SP 2020H	130	Bag	4	2.6	1	3.6	14.4
	WM	30	Bag	1	18.85	1	19.85	19.85
Purchased films	BOPP P	35	Roll	9	4.55	5.6	10.15	91.35
				9	3.25	5.6	8.85	79.65
Printing inks	HI-OPP Black	3	Bucket	1	0.65	3.9	4.55	4.55
	HI-OPP Yellow	13	Bucket	1	1.95	3.9	5.85	5.85
	HI-OPP Magenta	4	Bucket	1	3.25	3.9	7.15	7.15
	HI-OPP Medium	14	Bucket	1	4.55	3.9	8.45	8.45
	HI-OPP White	49	Bucket	3	1.95	7.6	9.55	28.65
	HI-OPP Violet	18	Bucket	1	5.85	7.6	13.45	13.45
	NEW PPL Blue	9	Bucket	1	7.15	3.9	11.05	11.05
Adhesives	LA 2882F	26	Bucket	3	9.75	3.9	13.65	40.95
	LA 5000	26	Bucket					
Paper cores	6" x 362 mm x 8 mm	500	Piece	5	3.25	3.9	7.15	35.75
				Total Pallets x m				507.35

Table 6.5: Comparison of the Pallets x m in the existing and redesigned situations

Monthly picking list	Total Pallets x m	
	Existing slotting	Redesigned slotting
Product A	877.85	507.35
Product B	653.45	388.60
Product C	247.50	164.40
Product D	596.35	463.40
Product E	128.45	108.45
Total	**2,503.60**	**1,632.20**
	Saving	**871.40**
		34.80%

As illustrated in Table 6.5, the Pallets x m of the redesigned slotting is reduced by 34.80 % compared to that of the existing situation. The high value of Pallets x m in the existing case is a result of inappropriate storage policy in which the fast-moving item is stored toward the back of warehouse as well as on the high level of racking while the slow-moving one are assigned to location toward the front of warehouse. In contrast to the existing case, the redesigned slotting facilitates the operation of order picking by providing ease of accessibility especially for the items having high frequency of movement. Furthermore, in case of plastic resins and additives, the redesigned slotting assigned the storage of 40 bags of resins on pallet at the ground-floor level, thus the operator is able to pick 40 bags in a single travel. While one travel of the redesigned case allows picking of 40 bags of resins, that of the existing case enables only 20 bags of resins. All of the implemented modification in the redesigned slotting resulting in lesser Pallets x m indicator compared to that of the existing case, and, therefore, a significant improvement in accessibility of the items stored in the case study warehouse.

6.2.2 Supporting tool evaluation

The supporting tools including product identification and product-location record significantly support daily warehouse operations. The operation with no supporting tools is quite difficult since the warehouse operators would have to totally memorise the items stored in the warehouse as well as the corresponding location of storage. Such working method has a high chance of inaccuracy that could impede smooth operations of the warehouse or eventually damage the production. By the introduction of supporting tools, instead of memorising, the warehouse operators could clearly identify product identification from a tag on pallet located at the ground floor or even at the upper level of the racking. The product-location record is also useful as it would identify all the location of storage. The operators could promptly identify storage location in the racking by checking with the list of items attached. The introduction of supporting tools would apparently promote ease of the warehouse operations.

Furthermore, the stock card implemented in Microsoft Office Excel would enable the accuracy of data recorded. The reliability of stock record is critical since the record is essential for warehouse management. The designed stock card would also promote better user satisfaction as the operator could easily record data by computer instead of using the paper-based system.

6.3 Conclusion

The evaluation is designed to prove whether the proposed management would results in better performance of inventory control and warehouse management compared to that of the existing one. In terms of inventory policy evaluation, inventory level of raw materials during May 2014 to April 2015 is recorded and presented for comparison. The inventory control in existing management is compared to the proposed management which could be divided into two phases; one with fluctuated customer orders and the other with predictable orders. Regarding the comparison, inventory control is gradually improved from the existing phase, to the first phase and to the second phase. The increased performance results in absence of shortage as well as lower stocks of raw materials.

In addition to inventory policy evaluation, warehouse management evaluation is performed by assessing accessibility of items in the warehouse. The indicator used is Pallets x m calculated from volume of storage and the corresponding travel distance to the location of storage. The picking lists usually requested by the production are studied and used for the calculation. Per the evaluation, the redesigned slotting shows increased accessibility of items with reduced Pallets x m value. Moreover, the supporting tools introduced to the warehouse could well support daily operation of the workers.

7. CHAPTER VII CONCLUSION AND RECOMMENDATION

7.1 Conclusion

The plastic packaging industry in Thailand is expected to continually maintain high market growth in the year ahead. The country is considered as a leading hub for plastic manufacture due to highly skilled as well as affordable workforce. The company of case study is a manufacturer of plastic packaging first established in December 2009. As a new participant, the company understands competitive threats and need to heighten business performance and reduce costs especially in terms of inventory control and warehouse management.

The case study company encountered problems regarding inventory control of raw materials as well as warehouse management. The inventory policy results in inefficient inventory control posing problems regarding shortage of raw materials in the warehouse. In addition to inventory control, the current warehouse management, including layout and slotting, does not adequately support accessibility of items and, thus, the daily operations. The storage policy also impedes management of FIFO warehouse system. Moreover, the warehouse lacks supporting tools for promoting effective operations. As a result, both inventory control and warehouse management of the case study have to be improved for better performance of the business.

The study begins with analysis of current performance of both inventory control and warehouse management and reviewing related literatures in the topic of interest. The existing situation is, then, studied in order to look for opportunities of improvement. The case study company is now serving five main products with different specification to the customers. Since demand in the year 2015 is predetermined, the production plan could be outlined to satisfy the customer orders. The study also shows that the current production capacity is sufficient to serve the predetermined demand of customers.

In terms of the warehouse design, there are six categories of raw materials stocked within the available area. The selective racking system is employed for storage of such inventory. The design of warehouse is separated into six zones in which each category of raw material is assigned to a specific zone. The resins, films and paper cores have a fix assigned location while the others are stored randomly within the provided zones. The raw materials, once arrived to the warehouse, would be allocated into the available space for storage adjacent to the similar item. In addition, the warehouse does not have records on identification of product and location of storage to facilitate daily operations. Only a paper-based system exists for recording items moving in and out of the warehouse. The existing inventory control operated by warehouse supervisor is based on minimum-quantity policy set by engineers. With reference to the existing situation study, inventory control design, warehouse management design and evaluation of the designs are summarised as follows:

7.1.1 Inventory control design

The design of inventory policy takes into account the demand of raw materials for production as well as suppliers' conditions in terms of supply status, MOQ and delivery lead time. Since the case study company applies batch production, the lot-for-lot policy is best suitable for inventory control. The policy also conforms to JIT technique allowing the right material in the right amount is delivered at the right time.

In order to capable to satisfy demand for production with enough quantity, with reference to the production plan, the monthly consumption of raw materials is estimated according to historical data of production. Timely arrival of the materials is also significant in order to be able to satisfy the demand. As a result, the detailed production plan scheduling sequence and step of the production has to be outlined in accordance with the production plan. Moreover, supply of raw materials is studied regarding supply condition, MOQ and delivery lead time. The supply condition and MOQ take part in determining order quantity on monthly basis while the delivery lead time and detailed production plan are significant factors in regulating date of ordering and delivery.

The adoption of the proposed policy is demonstrated in two cases. The first case enables the company to best deal with emergency order as raw materials would be promptly available before starting production in each month. The second case, in contrast, is suitable for dealing with certain customer orders which have no emergency case. As the monthly order would be divided to be delivered separately, smaller size of purchase with frequent delivery would be achieved.

7.1.2 Warehouse management design

The warehouse management design is divided into three parts; layout design, slotting design and supporting tool design. The design is aimed at increasing accessibility of items and warehousing efficiency, supporting FIFO warehouse system and promoting safety of storage. The layout design poses some changes to the existing design including new entrance and receipt area for receiving operation as well as dispatch area for items waiting to be delivered for production.

In terms of warehouse slotting design, the items are separately stored with reference to product category. The slotting takes into consideration the quantity of storage as well as frequency of movement. The quantity of storage is determined by the order quantity of each item so that the storage space could be provided sufficiently for the inventory ordered for production. The frequency of movement is also identified in order to list transaction ranking within each product category.

According to the ranking, the fast-moving item is assigned to the location toward the front of warehouse as well as at the low level of racking whereas the slow-moving one is located toward the back of warehouse and at the upper level of racking. The items that are usually requested together are closely located in storage. The FIFO warehouse system is also promoted by separating items in storage according to batch number which is normally specified on product label. Furthermore, a separate space is provided for storage of hazardous items.

Lastly, the supporting tools are designed to facilitate daily warehouse operations as well as increasing user satisfaction. The tools introduced to the warehouse include product-identification tag and location record which would facilitate searching. The computer based stock card is also implemented in replacement of paper-based system for better accuracy and ease of recording.

7.1.3 Design evaluation

The design evaluation consists of two parts, inventory policy and warehouse management. The evaluation on inventory policy emphasises on ability of the design to solve problem regarding stock-outs of raw materials encountered by the existing management. The warehouse management is assessed by determining whether the design can better support warehouse operations compared to that of the existing design.

The inventory policy evaluation is performed by comparing the performance of inventory control between the existing and redesigned management. The level of stock of raw materials during the 12 month period is recorded and plotted on a graph presenting for comparison. According to the evaluation, the existing inventory policy leads to shortage of raw materials and high inventory level while the redesigned management has better control of the inventory with no shortage and reduced holding stock.

The evaluation on warehouse management regarding layout and slotting is done by assessing the accessibility of items. The Pallets x m is used as an indicator determined from volume of storage and the corresponding travel distance. The calculated values are, then, compared to analyse the accessibility of stored items between existing and redesigned slotting. It could be concluded that items stored per the redesigned slotting are more easily accessible compared to those of the existing slotting.

In case of supporting tool evaluation, both product identification and location record show benefits to the daily warehouse operations. The tools could well replace the existing working method resulting in better warehouse performance. Furthermore, the designed stock card also leads to increased accuracy of the record and better user satisfaction.

7.2 Recommendation

The recommendations are listed as follows:

7.2.1 The study involves inventory control and warehouse management designed for manufacturing plastic packaging, the designs of which could be applied to other items in the same business or any company requiring similar management.

7.2.2 The company of case study could support more customer demand since the current operation is still less than production capacity. The overtime and shift production could be applied to *increase manufacturing yield* and satisfy higher customer order. Moreover, the warehouse still has available space to support higher inventory required to feed the increased production.

7.2.3 The proposed design is practical when the company is situated in static and deterministic environment. In other words, the customer demand has to be predictable with limited allowance for uncertainty. In case the demand becomes more highly uncertain, the proposed design of both inventory control and warehouse management has to be adjusted so that the company could best deal with the changed situation.

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APPENDIX

Appendix A – Detailed calculation of daily production capacity

- Daily production capacity of Product A, B, C and D

Regarding Equation 3.1;

In case of blowing machine, production yield of machine (Y) is 80 m/min and actual working duration (T) is 22 hours or 1,320 minutes as a result of production shifts.

Thus,

$$C\ (m) = 80\ (m/min) \times 1{,}320\ (min)$$

$$= 105{,}600\ (m)$$

As a result, the blowing machine is capable of yielding a film (2 columns) of 105,600 meters or approximately 200 rolls of finished goods (1 column of length 1,050 m) per one day.

In case of printing machine, production yield of machine (Y) is 160 m/min and actual working duration (T) is 5 hours or 300 minutes.

Thus,

$$C\ (m) = 160\ (m/min) \times 300\ (min)$$

$$= 48{,}000\ (m)$$

As a result, the printing machine is capable to yield film (2 columns) of 48,000 meters or approximately 91 rolls of finished goods (1 column of length 1,050 m) per one day.

In case of dry laminating machine, production yield of machine (Y) is 120 m/min and actual working duration (T) is 7 hours or 420 minutes.

Thus,

$$C\ (m) = 120\ (m/min) \times 420\ (min)$$

$$= 50{,}400\ (m)$$

As a result, the dry laminating machine is capable of yielding a film (2 columns) of 50,400 meters or approximately 96 rolls of finished goods (1 column of length 1,050 m) per one day.

In case of slitting machine, production yield of machine (Y) is 150 m/min and actual working duration (T) is 5 hours or 300 minutes.

Thus,

$$C\ (m) = 150\ (m/min) \times 300\ (min)$$

$$= 45{,}000\ (m)$$

As a result, the slitting machine is capable of yielding a film (2 columns) of 45,000 meters or approximately 85 rolls of finished goods (1 column of length 1,050 m) per one day.

- Daily production capacity of Product E

Regarding Equation 3.1;

In case of blowing machine, production yield of machine (Y) is 60 m/min and actual working duration (T) is 22 hours or 1,320 minutes as a result of production shifts.

Thus,

$$C\ (m) = 60\ (m/min) \times 1{,}320\ (min)$$

$$= 79{,}200\ (m)$$

As a result, the blowing machine is capable of yielding a film (2 columns) of 79,200 meters or approximately 158 rolls of finished goods (1 column of length 1,000 m) per one day.

In case of printing and slitting machines, production yield of machine (Y) is 60 m/min and actual working duration (T) is 5 hours or 300 minutes.

Thus,

$$C\ (m) = 60\ (m/min) \times 300\ (min)$$

$$= 18{,}000\ (m)$$

As a result, the printing and slitting machines are capable to yield film (2 columns) of 18,000 meters or approximately 36 rolls of finished goods (1 column of length 1,000 m) per one day.

Appendix B – Detailed calculation of total BOPP films required for production

With reference to Equation 4.1 and the data shown in Table 4.3;

For 500 rolls of Product A,

$$\text{Total BOPP P film used} = \frac{1.6 \times 500 \times 1{,}050}{2}$$

$$= 420{,}000 \text{ m}$$

As a result, production of 500 rolls of Product A requires 420,000 meters of BOPP P film.

For 400 rolls of Product B,

$$\text{Total BOPP P film used} = \frac{1.4 \times 400 \times 1{,}050}{2}$$

$$= 294{,}000 \text{ m}$$

As a result, production of 400 rolls of Product B requires 294,000 meters of BOPP P film.

For 100 rolls of Product C,

$$\text{Total BOPP P film used} = \frac{1.4 \times 100 \times 1{,}050}{2}$$

$$= 73{,}500 \text{ m}$$

As a result, production of 100 rolls of Product C requires 73,500 meters of BOPP P film.

For 300 rolls of Product D,

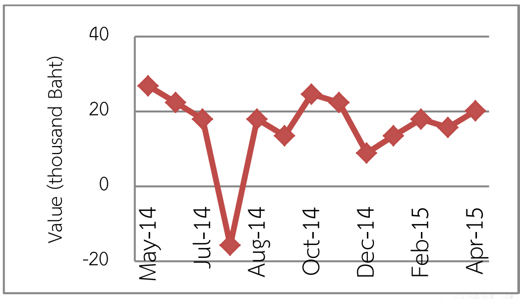
$$\text{Total BOPP HS film used} = \frac{1.6 \times 300 \times 1{,}050}{2}$$

$$= 252{,}000 \text{ m}$$

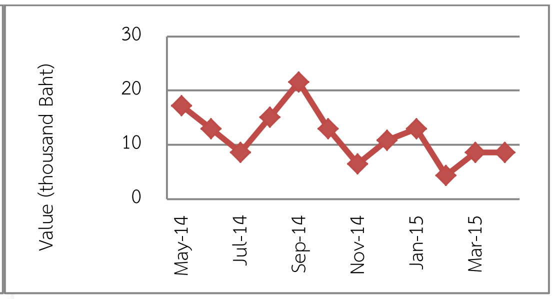
As a result, production of 300 rolls of Product D requires 252,000 meters of BOPP HS film.

Appendix C1 – Inventory level of raw materials during May 2014 to April 2015

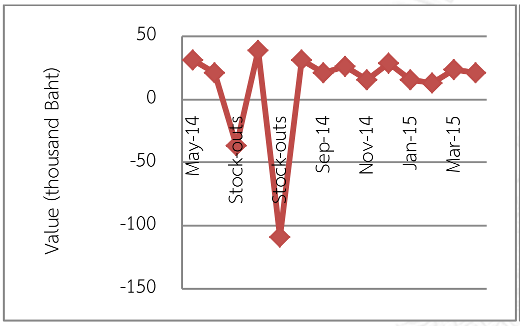
HI-OPP Medium



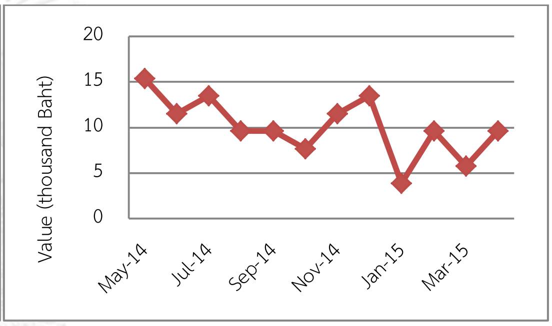
HI-OPP Black



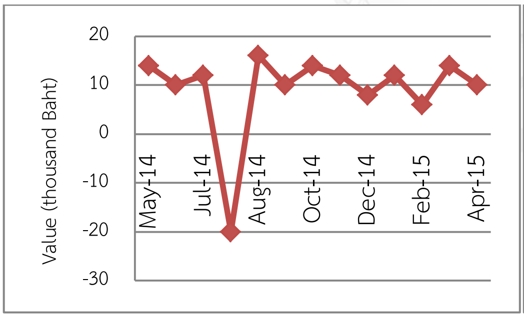
HI-OPP White



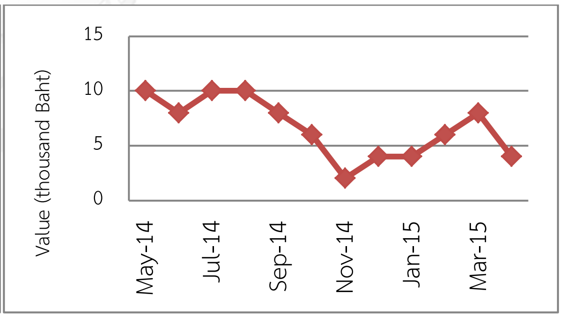
NEW PPL Blue



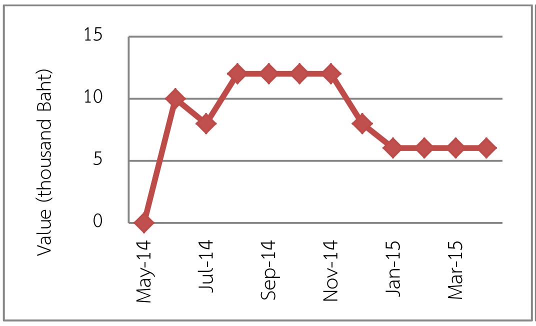
HI-OPP Violet



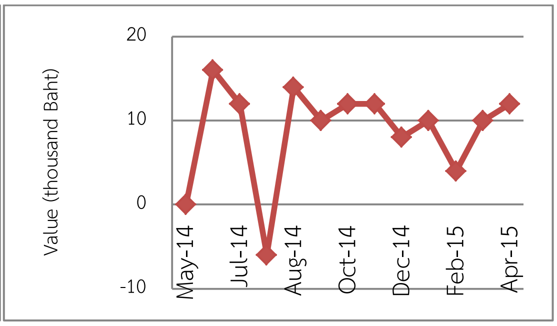
HI-OPP Orange 307



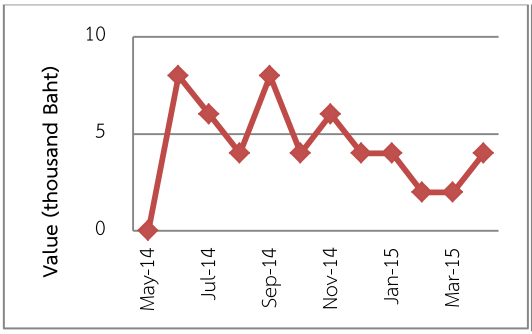
HI-OPP Orange 303



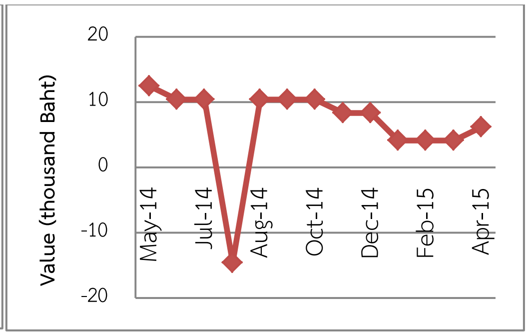
HI-OPP Geranium



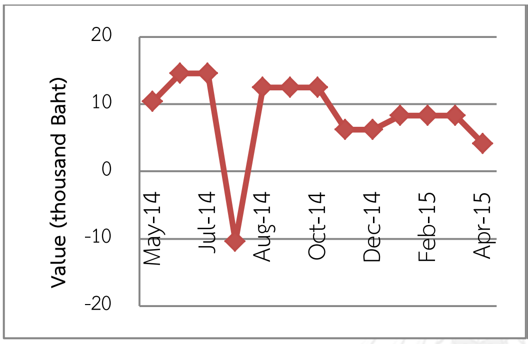
HI-OPP Green



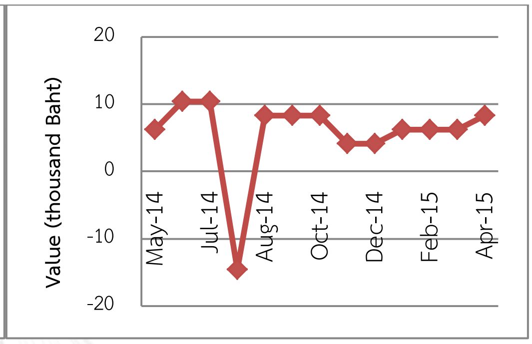
DLO Black



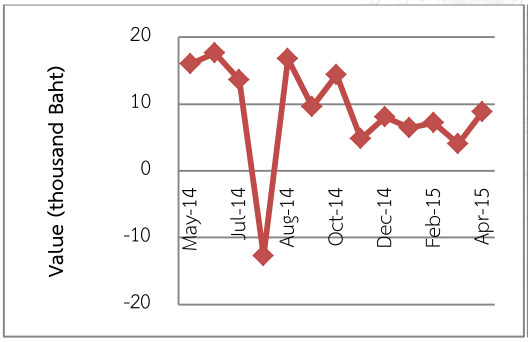
DLO Yellow



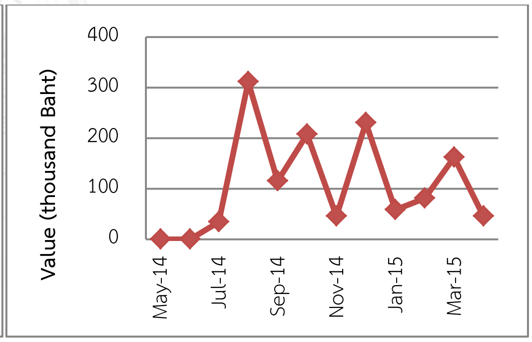
DLO Geranium



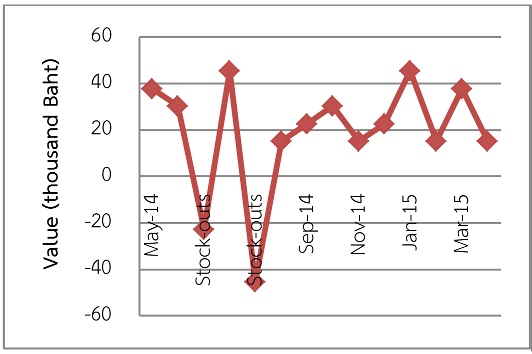
LA 5000



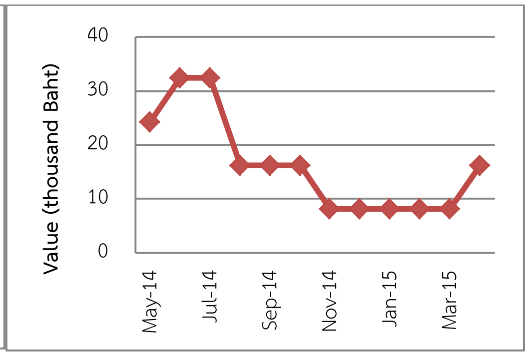
BOPP HS



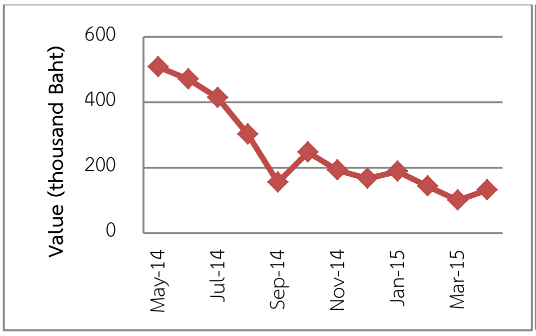
Thinner M



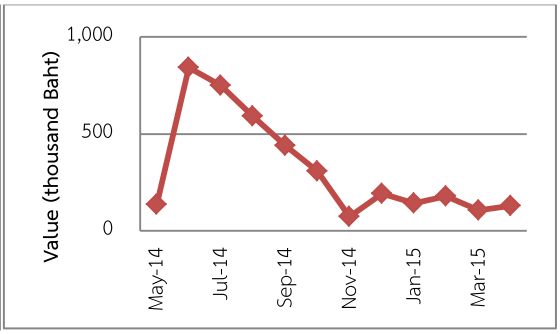
Thinner I



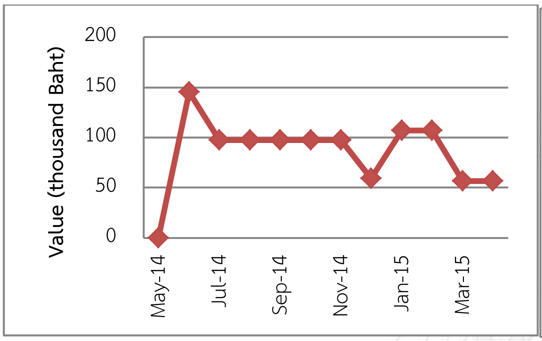
LL 7410A



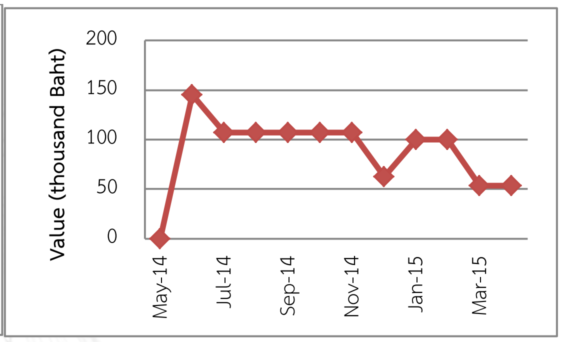
LD 2420D



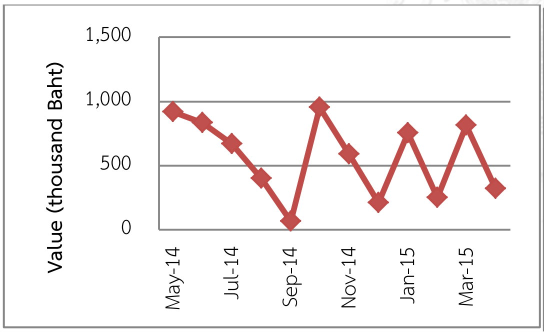
EL 5220G



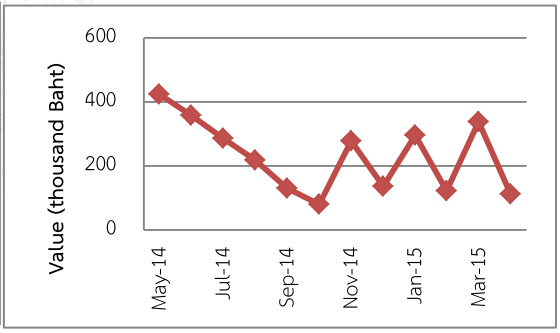
EL 5401G



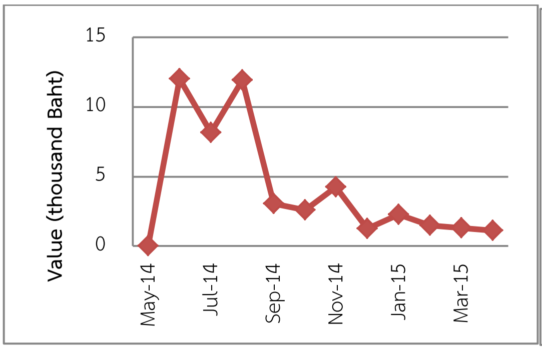
SP 2020H



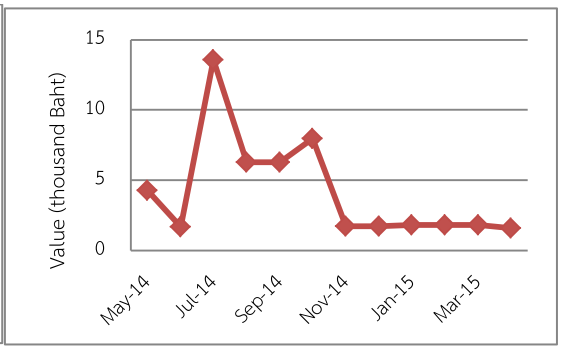
WM



6" x 366 mm x 8 mm



3" x 445 mm x 15 mm



Appendix C2 – Occurrence of shortage and monthly average inventory level of raw materials in both the existing and proposed inventory control

Item	Existing management (May 14 - Aug 14)		Proposed management			
			Phase 1 (Sep 14 - Dec 14)		Phase 2 (Jan 15 - Apr 15)	
	Shortage (Occurrences)	Monthly average inventory level (Baht)	Shortage (Occurrences)	Monthly average inventory level (Baht)	Shortage (Occurrences)	Monthly average inventory level (Baht)
LL 7410A	0	423,156	0	189,750	0	140,250
LL 7410D1	0	491,219	0	245,094	0	145,750
LD 2420D	0	580,450	0	253,500	0	138,775
LD 2426H	0	493,675	0	350,025	0	120,900
EL 5220G	0	113,100	0	87,725	0	81,925
EL 5401G	0	119,867	0	96,063	0	76,850
SP 2020H	0	704,844	0	455,813	0	535,031
WM	0	322,656	0	157,031	0	217,188
BOPP P	0	281,531	0	203,775	0	150,150
BOPP HS	0	173,250	0	150,150	0	86,625
HI-OPP Black	0	13,500	0	12,960	0	8,640
HI-OPP Yellow	1	14,000	0	11,500	0	8,500
HI-OPP Magenta	0	12,500	0	9,500	0	7,500
HI-OPP Medium	1	21,280	0	17,360	0	16,800
HI-OPP White	2	30,550	0	22,750	0	18,200
HI-OPP Violet	1	13,000	0	11,000	0	10,500
HI-OPP Orange 307	0	9,500	0	5,000	0	5,500
HI-OPP Orange 303	0	10,000	0	11,000	0	6,000
HI-OPP Geranium	1	14,000	0	10,500	0	9,000
HI-OPP Green	0	6,000	0	5,500	0	3,000
NEW PPL Blue	0	12,480	0	10,560	0	7,200
DLO Black	1	10,920	0	9,360	0	4,680
DLO Yellow	1	13,000	0	9,360	0	7,280
DLO Geranium	1	8,840	0	6,240	0	6,760
LA 2882F	1	52,500	0	30,188	0	21,656
LA 5000	1	16,000	0	9,200	0	6,600
Thinner M	2	32,130	0	22,680	0	28,350
Thinner I	0	26,325	0	12,150	0	10,125
EA	1	25,200	0	17,325	0	17,325
3" x 445 mm x 15 mm	0	6,452	0	4,437	0	1,777
6" x 362 mm x 8 mm	0	17,025	0	7,680	0	4,898
6" x 366 mm x 8 mm	0	10,690	0	2,790	0	1,560

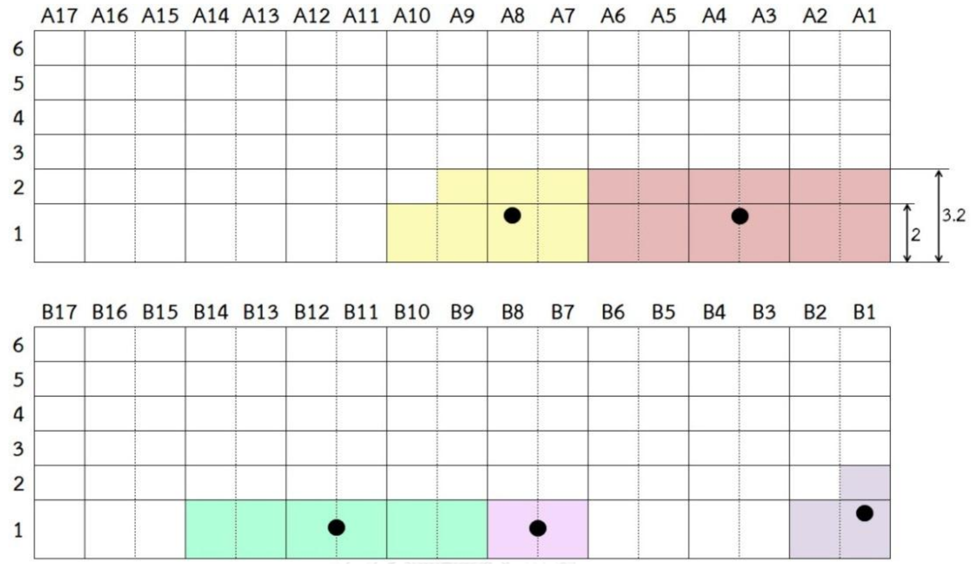
Appendix D1 – Calculation of Pallets x m for picking lists of Product B

According to picking list for production of 400 rolls of Product B shown below, the destinations for order picking could be determined and, thus, accessibility evaluation of the existing and redesigned slotting could be performed.

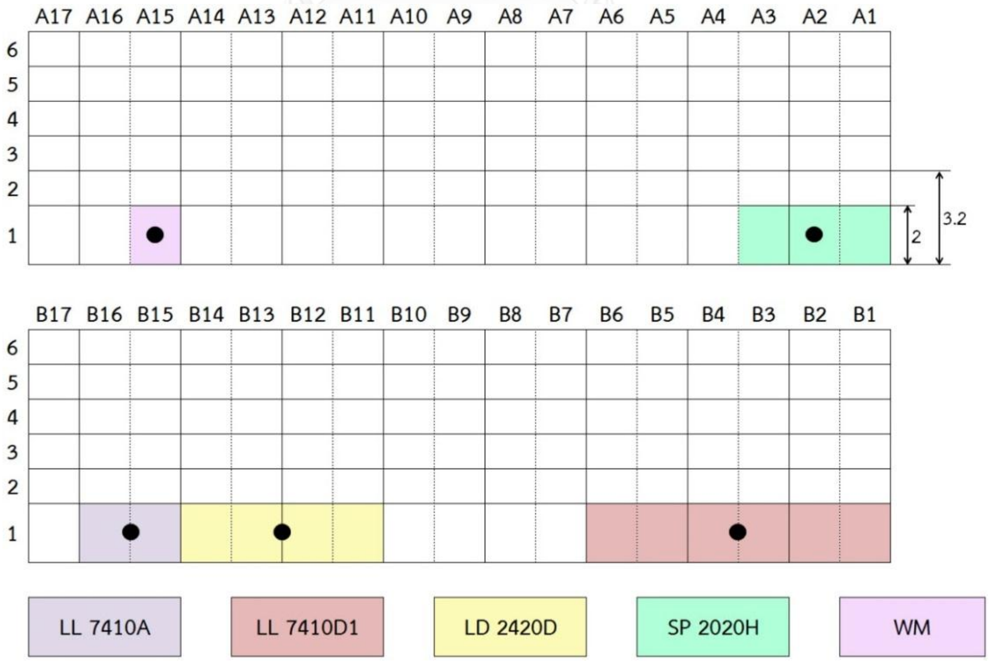
Picking list (Product B 400 rolls)			
Type	**Grade/ Size**	**Quantity**	**Unit**
Plastic resins and additives	LL 7410A	44	Bag
	LL 7410D1	224	Bag
	LD 2420D	124	Bag
	SP 2020H	104	Bag
	WM	24	Bag
Purchased films	BOPP Plain	25	Roll
Printing inks	HI-OPP Black	8	Bucket
	HI-OPP Yellow	1	Bucket
	HI-OPP Magenta	2	Bucket
	HI-OPP Medium	7	Bucket
	HI-OPP Orange 307	2	Bucket
	NEW PPL Blue	3	Bucket
Adhesives	LA 2882F	21	Bucket
	LA 5000	21	Bucket
Paper cores	6" x 362 mm x 8 mm	400	Piece

- Storage location of plastic resins and additives required for production of Product B

Existing slotting

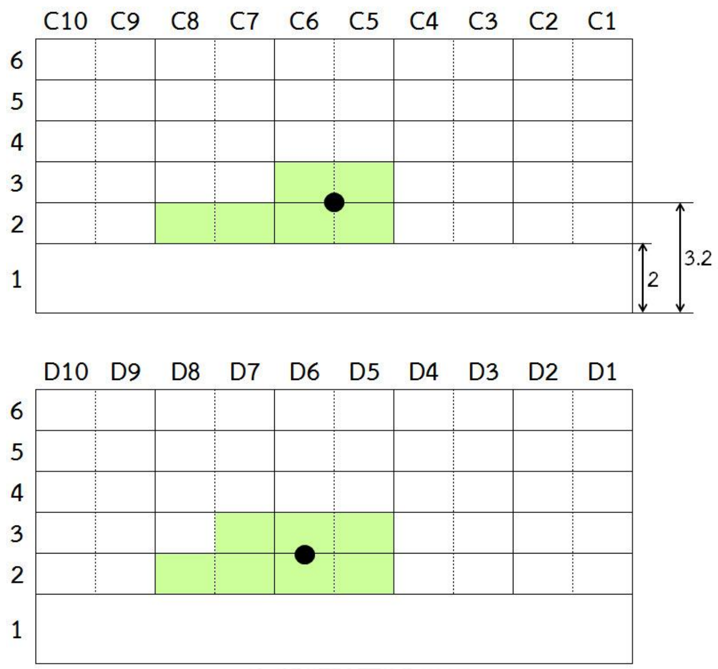


Redesigned slotting

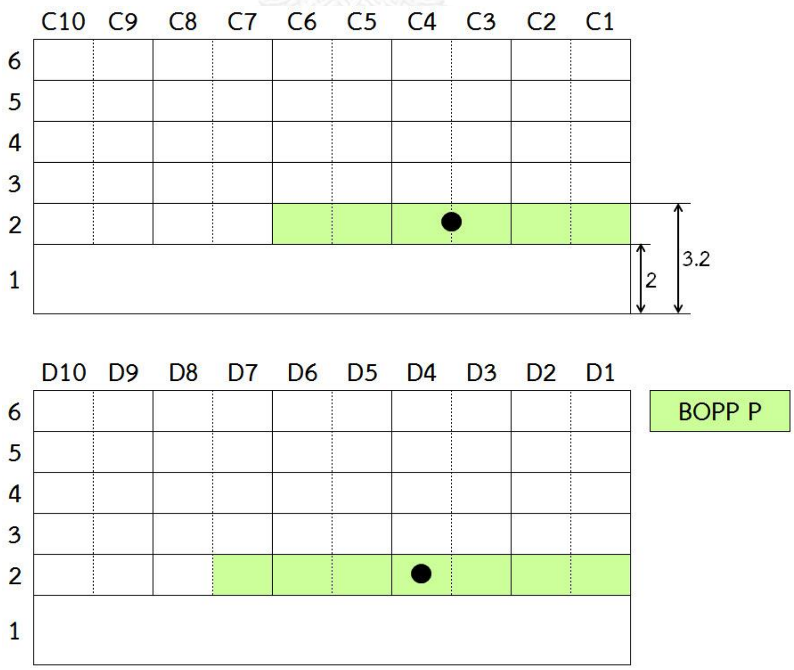


- Storage location of films required for production of Product B

Existing slotting

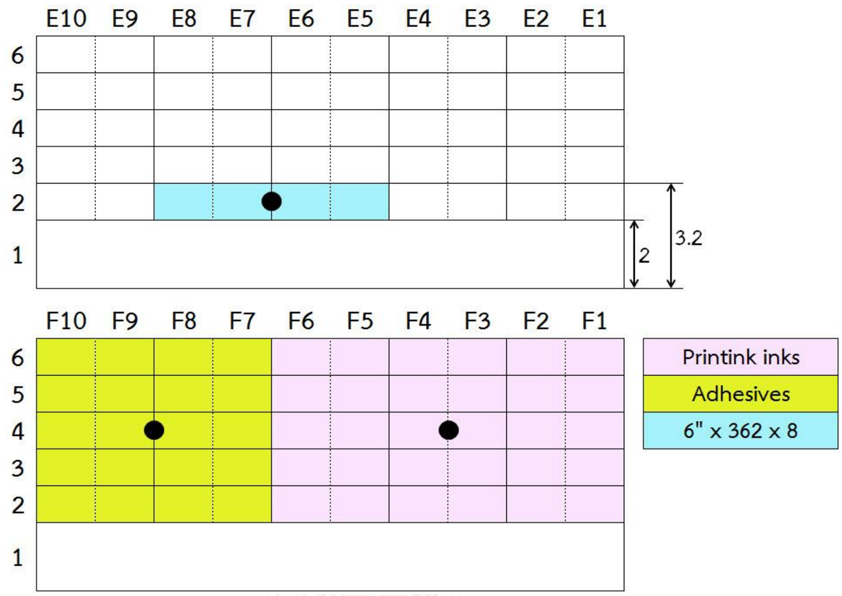


Redesigned slotting

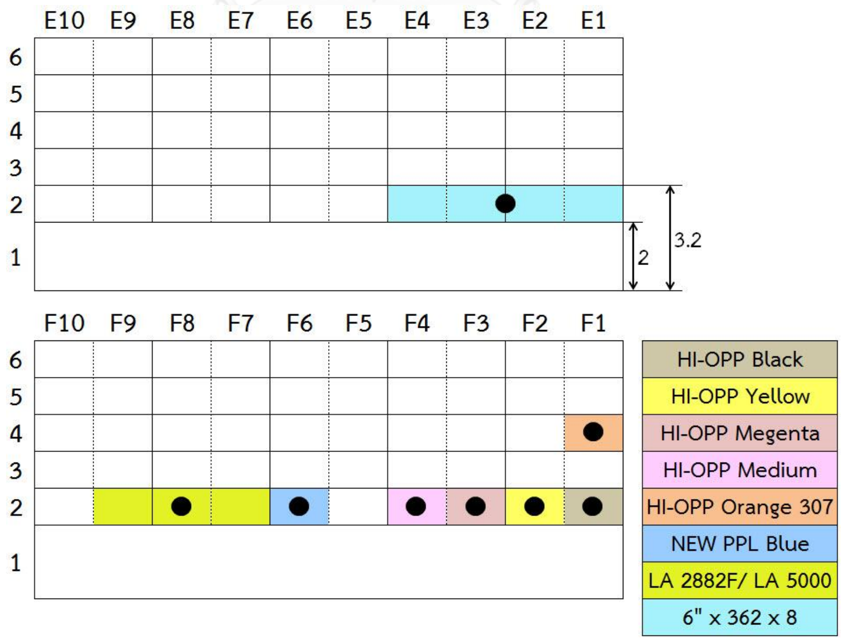


- Storage location of printing inks, adhesives and paper cores required for production of Product B

Existing slotting



Redesigned slotting



- Accessibility evaluation of the existing slotting

Picking list (Product B 400 rolls)				Accessibility evaluation of existing slotting				
Type	Grade/ Size	Quantity	Unit	Pallets	Horizontal distance (m)	Vertical distance (m) x Level weight	Total travel distance (m)	Pallets x m
Plastic resins and additives	LL 7410A	44	Bag	3	0.65	1.6	2.25	6.75
	LL 7410D1	224	Bag	12	3.9	1.6	5.5	66
	LD 2420D	124	Bag	7	9.75	1.6	11.35	79.45
	SP 2020H	104	Bag	6	14.3	1	15.3	91.8
	WM	24	Bag	2	9.1	1	10.1	20.2
Purchased films	BOPP Plain	25	Roll	6	6.5	5.6	12.1	72.6
				7	7.15	5.6	12.75	89.25
Printing inks	HI-OPP Black	8	Bucket	1	3.9	14	17.9	17.9
	HI-OPP Yellow	1	Bucket	1				17.9
	HI-OPP Magenta	2	Bucket	1				17.9
	HI-OPP Medium	7	Bucket	1				17.9
	HI-OPP Orange 307	2	Bucket	1				17.9
	NEW PPL Blue	3	Bucket	1				17.9
Adhesives	LA 2882F	21	Bucket	3	10.4	14	24.4	73.2
	LA 5000	21	Bucket					
Paper cores	6" x 362 mm x 8 mm	400	Piece	4	7.8	3.9	11.7	46.8
				Total Pallets x m				653.45

- Accessibility evaluation of the redesigned slotting

Picking list (Product B 400 rolls)				Accessibility evaluation of redesigned slotting				
Type	Grade/ Size	Quantity	Unit	Pallets	Horizontal distance (m)	Vertical distance (m) x Level weight	Total travel distance (m)	Pallets x m
Plastic resins and additives	LL 7410A	44	Bag	2	19.5	1	20.5	41
	LL 7410D1	224	Bag	6	3.9	1	4.9	29.4
	LD 2420D	124	Bag	4	15.6	1	16.6	66.4
	SP 2020H	104	Bag	3	1.95	1	2.95	8.85
	WM	24	Bag	1	18.85	1	19.85	19.85
Purchased films	BOPP Plain	25	Roll	6	3.9	3.9	7.8	46.8
				7	4.55	3.9	8.45	59.15
Printing inks	HI-OPP Black	8	Bucket	1	0.65	3.9	4.55	4.55
	HI-OPP Yellow	1	Bucket	1	1.95	3.9	5.85	5.85
	HI-OPP Magenta	2	Bucket	1	3.25	3.9	7.15	7.15
	HI-OPP Medium	7	Bucket	1	4.55	3.9	8.45	8.45
	HI-OPP Orange 307	2	Bucket	1	0.65	12.5	13.15	13.15
	NEW PPL Blue	3	Bucket	1	7.15	3.9	11.05	11.05
Adhesives	LA 2882F	21	Bucket	3	9.75	3.9	13.65	40.95
	LA 5000	21	Bucket					
Paper cores	6" x 362 mm x 8 mm	400	Piece	4	2.6	3.9	6.5	26
				Total Pallets x m				388.6

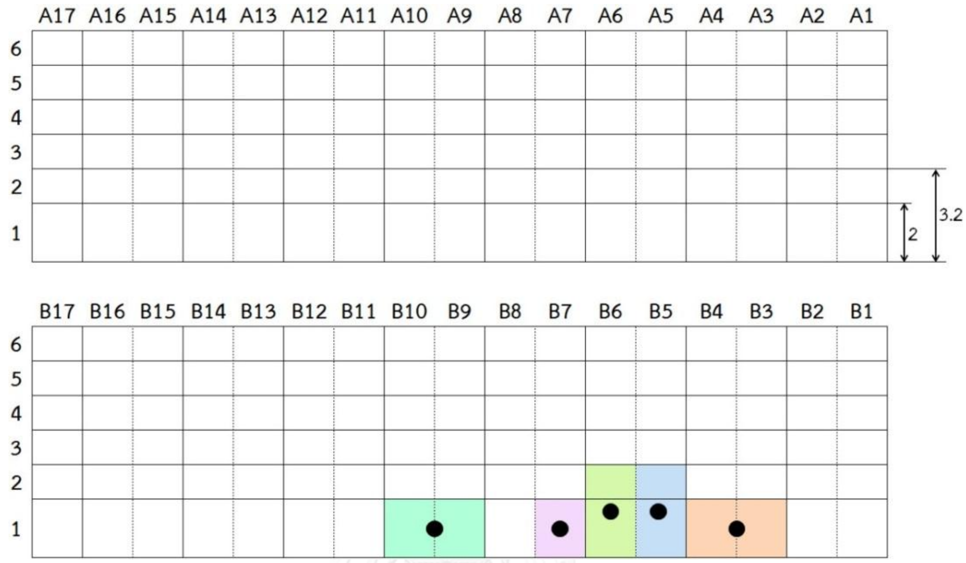
Appendix D2 – Calculation of Pallets x m for picking lists of Product C

According to picking list for production of 100 rolls of Product C shown below, the destinations for order picking could be determined and, thus, accessibility evaluation of the existing and redesigned slotting could be performed.

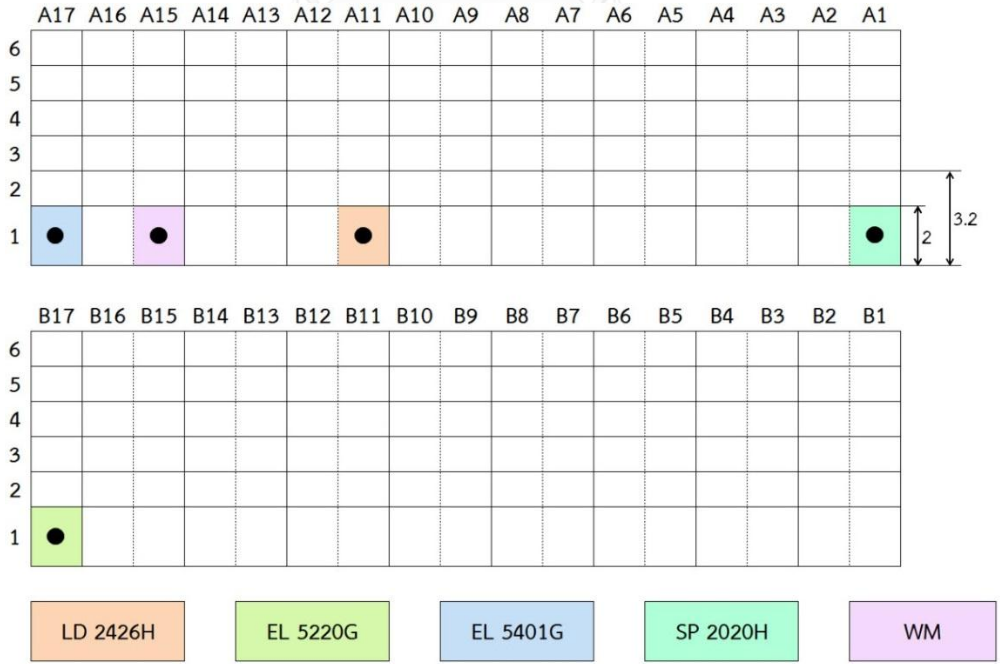
Picking list (Product C 100 rolls)			
Type	**Grade/ Size**	**Quantity**	**Unit**
Plastic resins and additives	LD 2426H	27	Bag
	EL 5220G	30	Bag
	EL 5401G	28	Bag
	SP 2020H	23	Bag
	WM	6	Bag
Purchased films	BOPP Plain	7	Roll
Printing inks	HI-OPP Black	2	Bucket
	HI-OPP Yellow	1	Bucket
	HI-OPP Magenta	1	Bucket
	HI-OPP Medium	2	Bucket
	HI-OPP Orange 303	1	Bucket
Adhesives	LA 2882F	6	Bucket
	LA 5000	6	Bucket
Paper cores	6" x 362 mm x 8 mm	100	Piece

- Storage location of plastic resins and additives required for production of Product C

Existing slotting

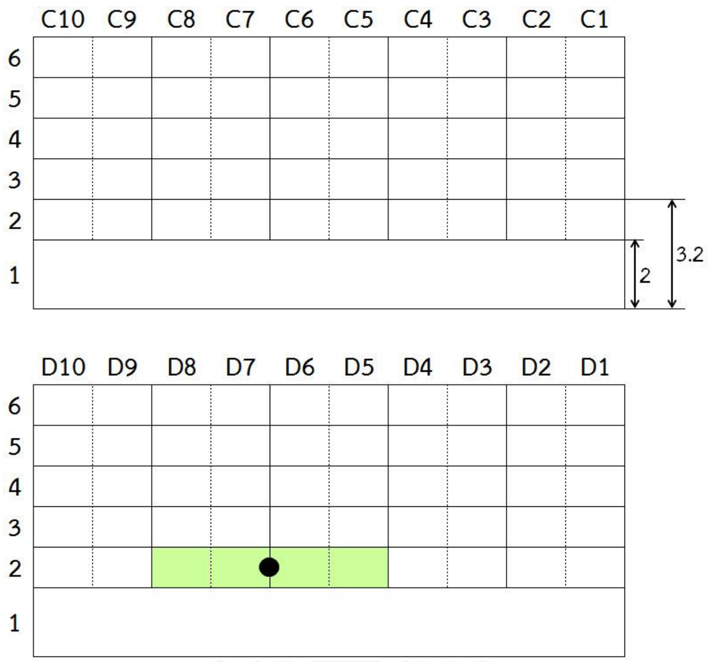


Redesigned slotting

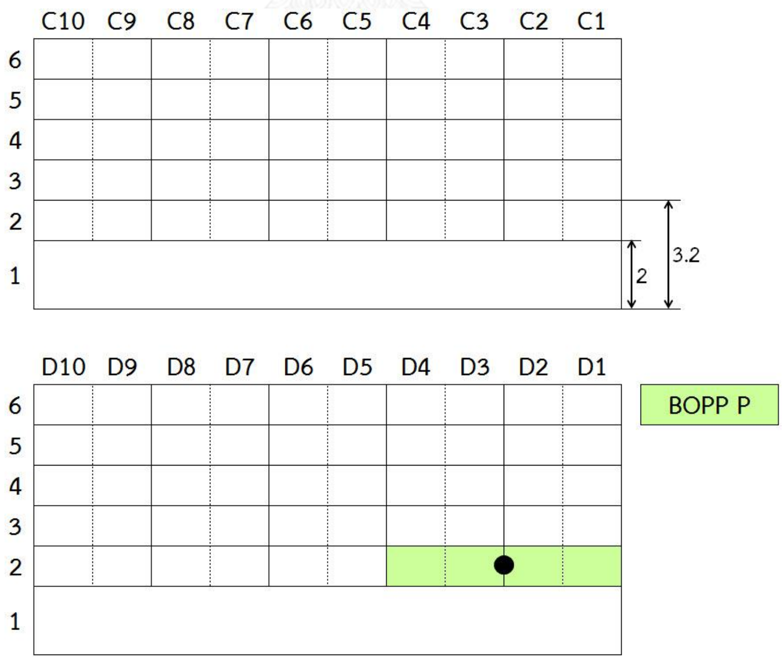


- Storage location of films required for production of Product C

Existing slotting

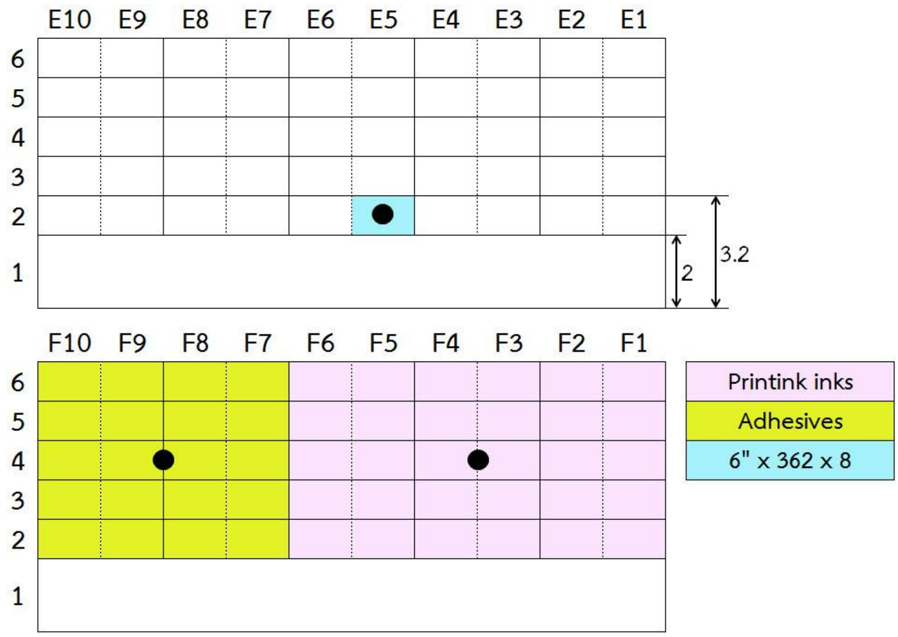


Redesigned slotting

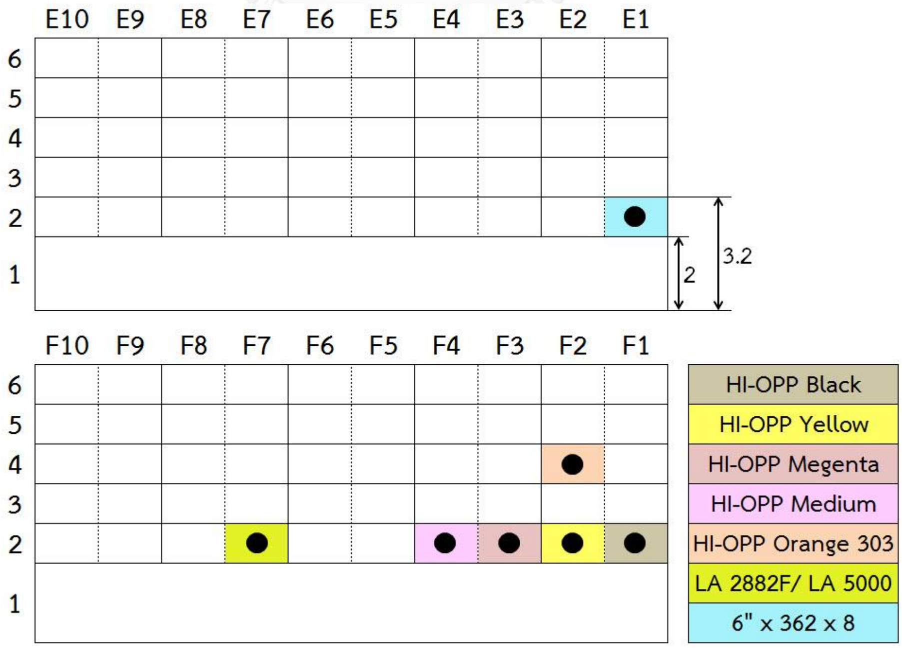


- Storage location of printing inks, adhesives and paper cores required for production of Product C

Existing slotting



Redesigned slotting



- Accessibility evaluation of the existing slotting

Picking list (Product C 100 rolls)				Accessibility evaluation of existing slotting				
Type	Grade/ Size	Quantity	Unit	Pallets	Horizontal distance (m)	Vertical distance (m) x Level weight	Total travel distance (m)	Pallets x m
Plastic resins and additives	LD 2426H	27	Bag	2	3.9	1	4.9	9.8
	EL 5220G	30	Bag	2	7.15	1.6	8.75	17.5
	EL 5401G	28	Bag	2	5.85	1.6	7.45	14.9
	SP 2020H	23	Bag	2	11.7	1	12.7	25.4
	WM	6	Bag	1	8.45	1	9.45	9.45
Purchased films	BOPP Plain	7	Roll	4	7.8	3.9	11.7	46.8
Printing inks	HI-OPP Black	2	Bucket	1	3.9	14	17.9	17.9
	HI-OPP Yellow	1	Bucket	1				17.9
	HI-OPP Magenta	1	Bucket	1				17.9
	HI-OPP Medium	2	Bucket	1				17.9
	HI-OPP Orange 303	1	Bucket	1				17.9
Adhesives	LA 2882F	6	Bucket	1	10.4	14	24.4	24.4
	LA 5000	6	Bucket					
Paper cores	6" x 362 mm x 8 mm	100	Piece	1	5.85	3.9	9.75	9.75
					Total Pallets x m			**247.5**

- Accessibility evaluation of the redesigned slotting

Picking list (Product C 100 rolls)				Accessibility evaluation of redesigned slotting				
Type	Grade/ Size	Quantity	Unit	Pallets	Horizontal distance (m)	Vertical distance (m) x Level weight	Total travel distance (m)	Pallets x m
Plastic resins and additives	LD 2426H	27	Bag	1	13.65	1	14.65	14.65
	EL 5220G	30	Bag	1	21.45	1	22.45	22.45
	EL 5401G	28	Bag	1	21.45	1	22.45	22.45
	SP 2020H	23	Bag	1	0.65	1	1.65	1.65
	WM	6	Bag	1	18.85	1	19.85	19.85
Purchased films	BOPP Plain	7	Roll	4	2.6	3.9	6.5	26
Printing inks	HI-OPP Black	2	Bucket	1	0.65	3.9	4.55	4.55
	HI-OPP Yellow	1	Bucket	1	1.95	3.9	5.85	5.85
	HI-OPP Magenta	1	Bucket	1	3.25	3.9	7.15	7.15
	HI-OPP Medium	2	Bucket	1	4.55	3.9	8.45	8.45
	HI-OPP Orange 303	1	Bucket	1	1.95	12.5	14.45	14.45
Adhesives	LA 2882F	6	Bucket	1	8.45	3.9	12.35	12.35
	LA 5000	6	Bucket					
Paper cores	6" x 362 mm x 8 mm	100	Piece	1	0.65	3.9	4.55	4.55
				Total Pallets x m				**164.4**

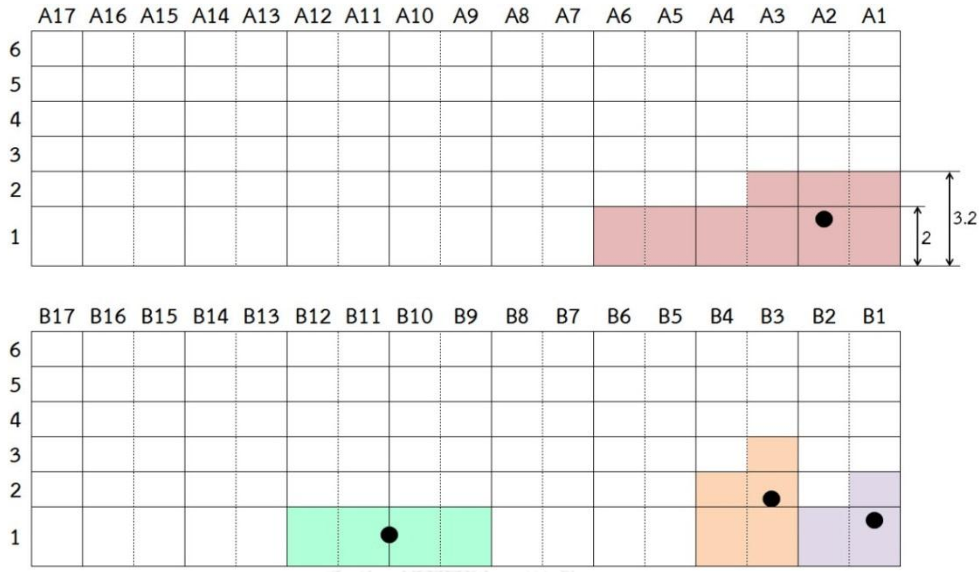
Appendix D3 – Calculation of Pallets x m for picking lists of Product D

According to picking list for production of 300 rolls of Product D shown below, the destinations for order picking could be determined and, thus, accessibility evaluation of the existing and redesigned slotting could be performed.

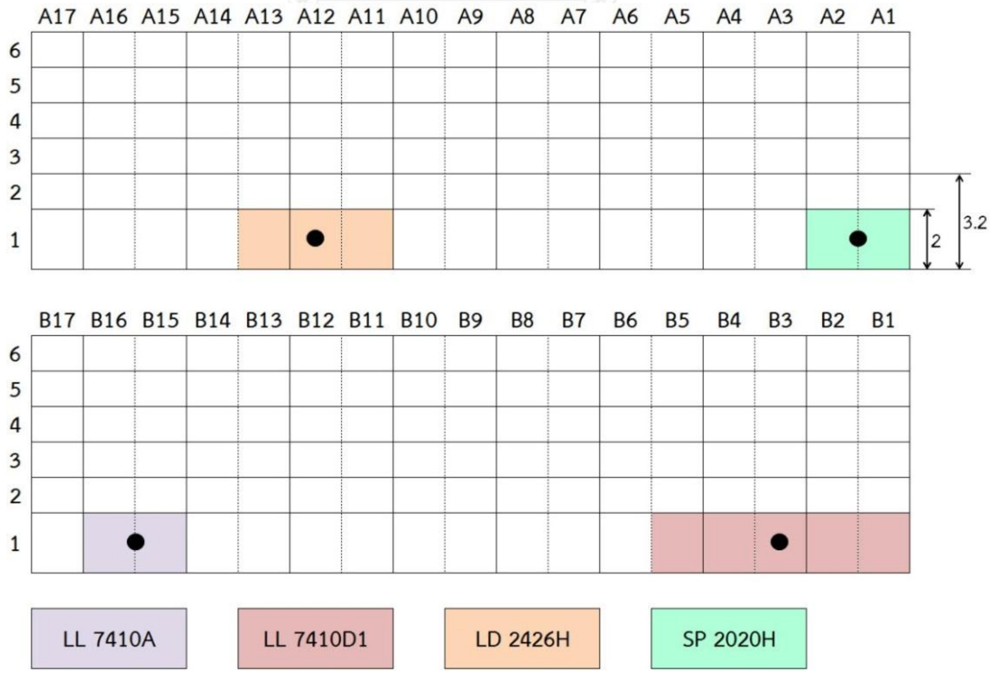
Picking list (Product D 300 rolls)			
Type	**Grade/ Size**	**Quantity**	**Unit**
Plastic resins and additives	LL 7410A	54	Bag
	LL 7410D1	162	Bag
	LD 2426H	93	Bag
	SP 2020H	78	Bag
Purchased films	BOPP HS	21	Roll
Printing inks	HI-OPP Black	2	Bucket
	HI-OPP Yellow	5	Bucket
	HI-OPP Magenta	2	Bucket
	HI-OPP Medium	2	Bucket
	HI-OPP White	30	Bucket
	HI-OPP Geranium	12	Bucket
	HI-OPP Green	1	Bucket
	NEW PPL Blue	1	Bucket
Adhesives	LA 2882F	17	Bucket
	LA 5000	17	Bucket
Paper cores	6" x 366 mm x 8 mm	300	Piece

- Storage location of plastic resins and additives required for production of Product D

Existing slotting

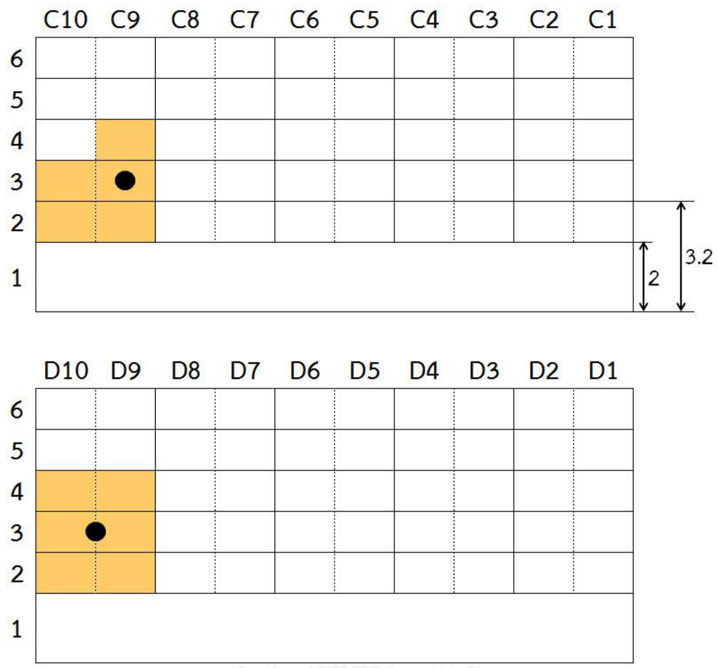


Redesigned slotting

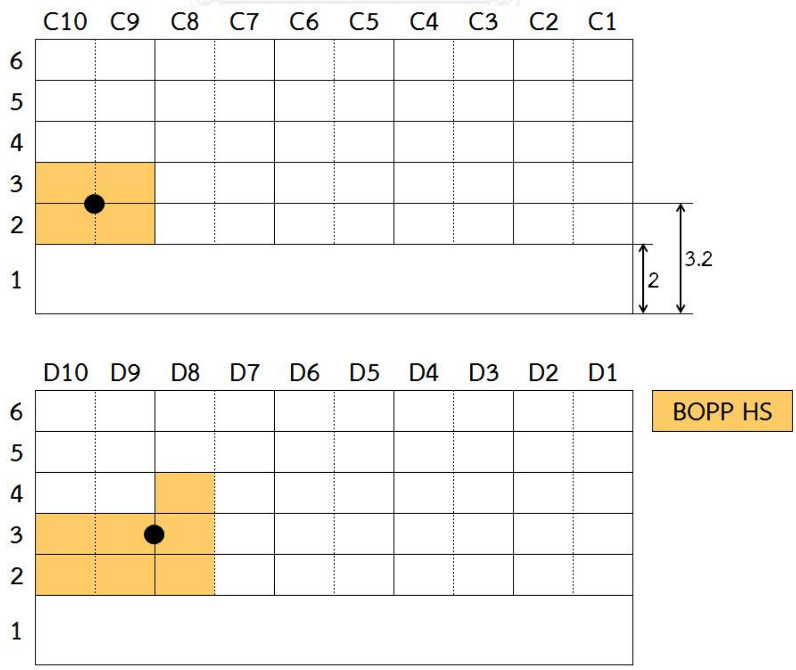


- Storage location of films required for production of Product D

Existing slotting

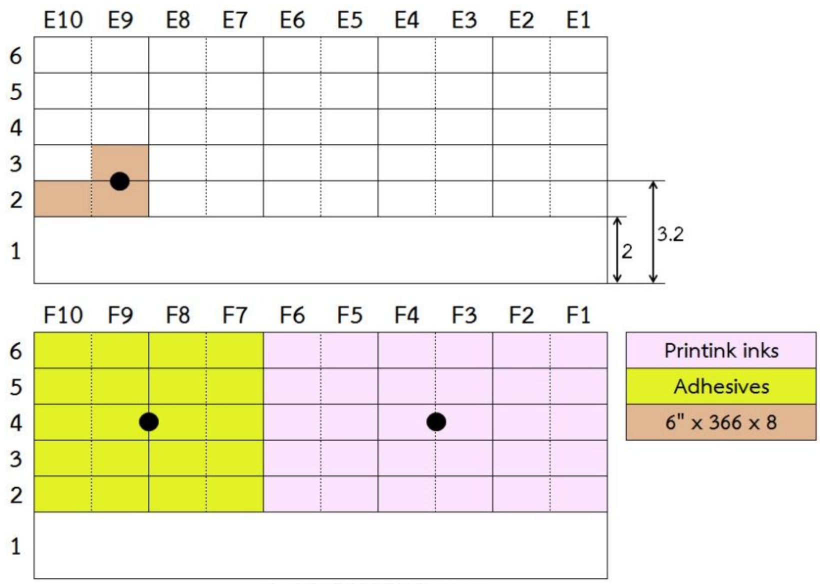


Redesigned slotting

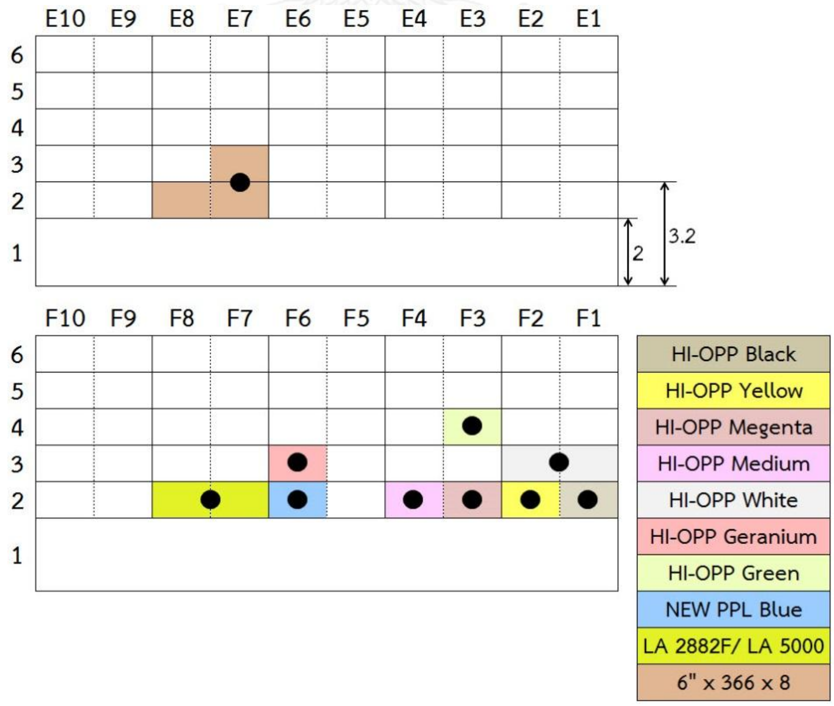


- Storage location of printing inks, adhesives and paper cores required for production of Product D

Existing slotting



Redesigned slotting



- Accessibility evaluation of the existing slotting

Picking list (Product D 300 rolls)				Accessibility evaluation of existing slotting				
Type	Grade/ Size	Quantity	Unit	Pallets	Horizontal distance (m)	Vertical distance (m) x Level weight	Total travel distance (m)	Pallets x m
Plastic resins and additives	LL 7410A	54	Bag	3	0.65	1.6	2.25	6.75
	LL 7410D1	162	Bag	9	1.95	1.6	3.55	31.95
	LD 2426H	93	Bag	5	3.25	3.3	6.55	32.75
	SP 2020H	78	Bag	4	13	1	14	56
Purchased films	BOPP HS	21	Roll	5	11.05	7.6	18.65	93.25
				6	11.7	7.6	19.3	115.8
Printing inks	HI-OPP Black	2	Bucket	1	3.9	14	17.9	17.9
	HI-OPP Yellow	5	Bucket	1				17.9
	HI-OPP Magenta	2	Bucket	1				17.9
	HI-OPP Medium	2	Bucket	1				17.9
	HI-OPP White	30	Bucket	2				35.8
	HI-OPP Geranium	12	Bucket	1				17.9
	HI-OPP Green	1	Bucket	1				17.9
	NEW PPL Blue	1	Bucket	1				17.9
Adhesives	LA 2882F	17	Bucket	2	10.4	14	24.4	48.8
	LA 5000	17	Bucket					
Paper cores	6" x 366 mm x 8 mm	300	Piece	3	11.05	5.6	16.65	49.95
				Total Pallets x m				**596.35**

- Accessibility evaluation of the redesigned slotting

Picking list (Product D 300 rolls)				Accessibility evaluation of redesigned slotting				
Type	Grade/ Size	Quantity	Unit	Pallets	Horizontal distance (m)	Vertical distance (m) x Level weight	Total travel distance (m)	Pallets x m
Plastic resins and additives	LL 7410A	54	Bag	2	19.5	1	20.5	41
	LL 7410D1	162	Bag	5	3.25	1	4.25	21.25
	LD 2426H	93	Bag	3	14.95	1	15.95	47.85
	SP 2020H	78	Bag	2	1.3	1	2.3	4.6
Purchased films	BOPP HS	21	Roll	4	11.7	5.6	17.3	69.2
				7	10.4	7.6	18	126
Printing inks	HI-OPP Black	2	Bucket	1	0.65	3.9	4.55	4.55
	HI-OPP Yellow	5	Bucket	1	1.95	3.9	5.85	5.85
	HI-OPP Magenta	2	Bucket	1	3.25	3.9	7.15	7.15
	HI-OPP Medium	2	Bucket	1	4.55	3.9	8.45	8.45
	HI-OPP White	30	Bucket	2	1.3	7.6	8.9	17.8
	HI-OPP Geranium	12	Bucket	1	7.15	7.6	14.75	14.75
	HI-OPP Green	1	Bucket	1	3.25	12.5	15.75	15.75
	NEW PPL Blue	1	Bucket	1	7.15	3.9	11.05	11.05
Adhesives	LA 2882F	17	Bucket	2	9.1	3.9	13	26
	LA 5000	17	Bucket					
Paper cores	6" x 366 mm x 8 mm	300	Piece	3	8.45	5.6	14.05	42.15
				Total Pallets x m				**463.4**

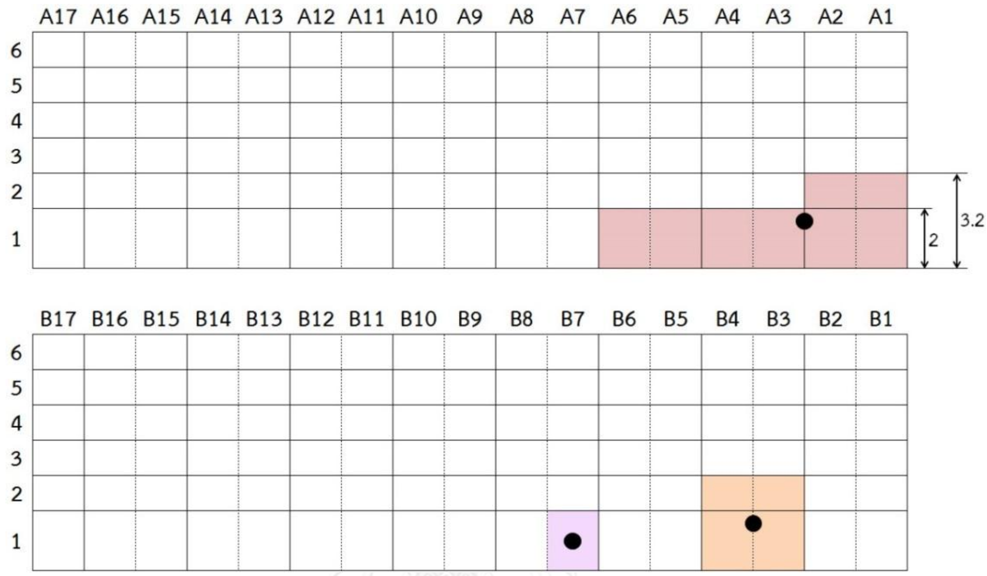
Appendix D4 – Calculation of Pallets x m for picking lists of Product E

According to picking list for production of 5 tons of Product E shown below, the destinations for order picking could be determined and, thus, accessibility evaluation of the existing and redesigned slotting could be performed.

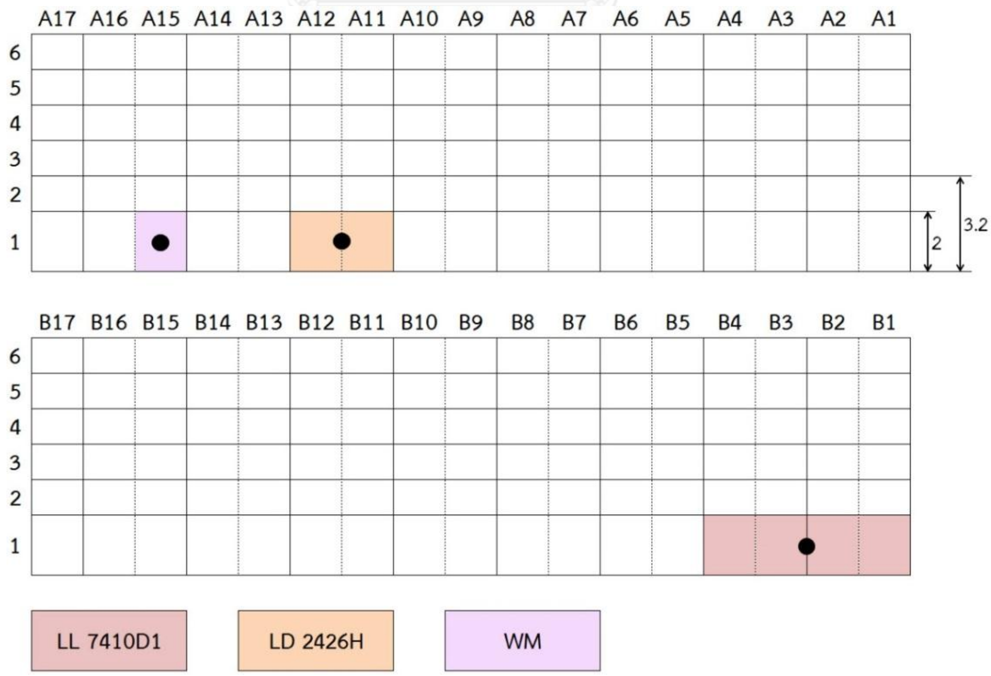
Picking list (Product E 5 tons)			
Type	**Grade/ Size**	**Quantity**	**Unit**
Plastic resins and additives	LL 7410D1	152	Bag
	LD 2426H	69	Bag
	WM	7	Bag
Printing inks	DLO Black	10	Bucket
	DLO Yellow	11	Bucket
	DLO Geranium	10	Bucket
Paper cores	3" x 445 mm x 15 mm	173	Piece

- Storage location of plastic resins and additives required for production of Product E

Existing slotting

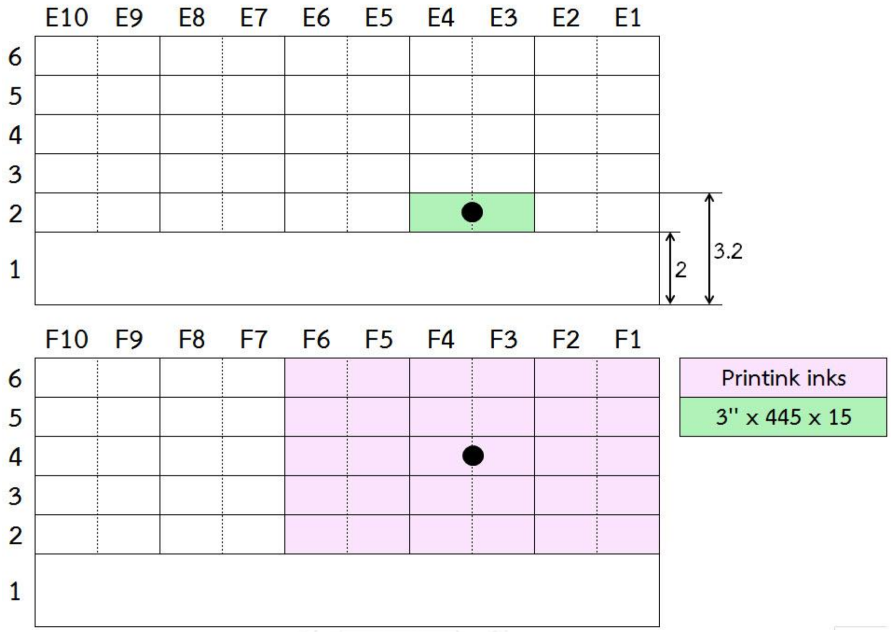


Redesigned slotting

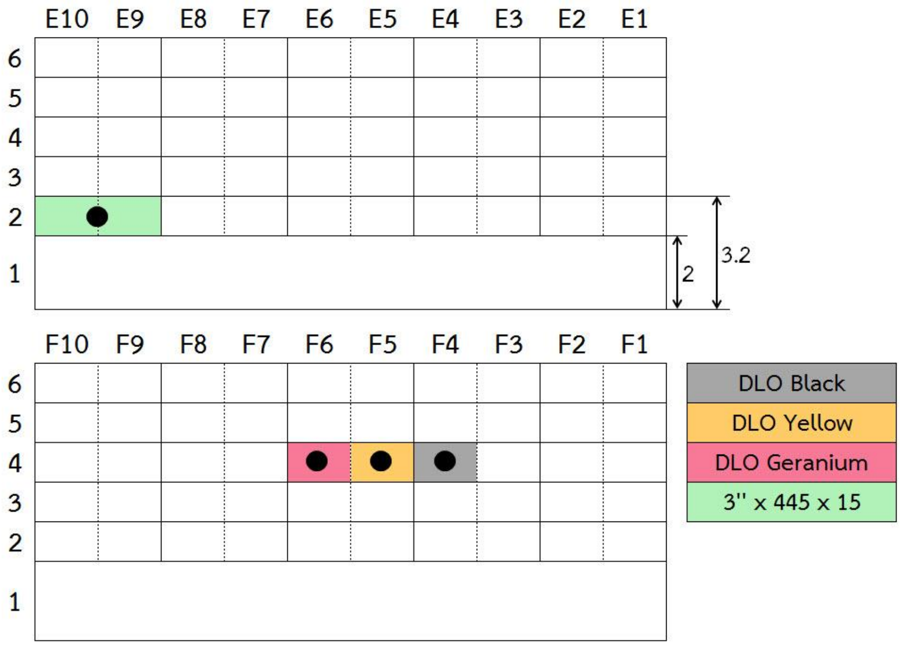


- Storage location of printing inks, adhesives and paper cores required for production of Product E

Existing slotting



Redesigned slotting



- Accessibility evaluation of the existing slotting

Picking list (Product E 5 tons)				Accessibility evaluation of existing slotting				
Type	Grade/ Size	Quantity	Unit	Pallets	Horizontal distance (m)	Vertical distance (m) x Level weight	Total travel distance (m)	Pallets x m
Plastic resins and additives	LL 7410D1	152	Bag	8	0.65	1.6	2.25	18
	LD 2426H	69	Bag	4	3.9	1.6	5.5	22
	WM	7	Bag	1	9.75	1.6	11.35	11.35
Printing inks	DLO Black	10	Bucket	1	3.9	14	17.9	17.9
	DLO Yellow	11	Bucket	1				17.9
	DLO Geranium	10	Bucket	1				17.9
Paper cores	3" x 445 mm x 15	173	Piece	2	7.8	3.9	11.7	23.4
				Total Pallets x m				**128.45**

- Accessibility evaluation of the redesigned slotting

Picking list (Product E 5 tons)				Accessibility evaluation of redesigned slotting				
Type	Grade/ Size	Quantity	Unit	Pallets	Horizontal distance (m)	Vertical distance (m) x Level weight	Total travel distance (m)	Pallets x m
Plastic resins and additives	LL 7410D1	152	Bag	4	0.65	1.6	2.25	9
	LD 2426H	69	Bag	2	3.9	1.6	5.5	11
	WM	7	Bag	1	9.75	1.6	11.35	11.35
Printing inks	DLO Black	10	Bucket	1	3.9	14	17.9	17.9
	DLO Yellow	11	Bucket	1				17.9
	DLO Geranium	10	Bucket	1				17.9
Paper cores	3" x 445 mm x 15	173	Piece	2	7.8	3.9	11.7	23.4
				Total Pallets x m				**108.45**

VITA

Miss Kwanrat Pruekwatana was born on 22th May 1989 in Bangkok, Thailand. She gained her Bachelor’s degree in Nano-engineering from Chulalongkorn University in 2011. After graduation, she started working as a warehouse and logistics supervisor at the case study company, a plastic packaging manufacture as well as continued her study as a part-time student for Master’s degrees in Engineering Management and Supply Chain and Logistics Management at Regional Centre for Manufacturing Systems Engineering, Chulalongkorn University in Thailand jointed with University of Warwick in the United Kingdom.