Inventory control system improvement in an automotive adhesive company

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A Thesis Submitted in Partial Fulfillment of the Requirements

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นัชชา เนิดน้อย : การปรับปรุงระบบการจัดการพัสดุคงคลังในบริษัทผลิตสารยึดติดสำหรับอุตสาหกรรมรถยนต์ (Inventory control system improvement in an automotive adhesive company) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร. ปวีณา เชาวลิตวงศ์, 117 หน้า.

เป้าหมายของวิทยานิพนธ์นี้คือการปรับปรุงกระบวนการจัดการสินค้าคงคลังเพื่อให้สามารถควบคุมปริมาณของสินค้าคงคลังได้ซึ่งนำไปสู่การลดค่าใช้จ่ายรวมที่เกียวกับการจัดการสินค้าคงคลังวิทยานิพนธ์นี้ได้นำเสนอขั้นตอนทั้งหมด3ขั้นตอนเพื่อการปรับปรุงการจัดการสินค้าคงคลังได้แก่ขั้นตอนการกำหนดปัญหาขั้นตอนการนำเสนอและขั้นตอนการปฏิบัติ

ในขั้นตอนการกำหนดปัญหาได้มีการศึกษาเกี่ยวกับกระบวนการทำงานในการจัดการสินค้าคงคลังในปัจจุบันและมีการร่วมกันคิดวิเคราะห์ปัญหาผลกระทบของปัญหาและสาเหตุของปัญหาซึ่งนำไปสู่การพัฒนาและปรับปรุงนอกจากนั้นยังมีการเก็บข้อมูลและศึกษาปริมาณของสินค้าคงคลังและค่าใช้จ่ายต่างๆที่เกี่ยวกับการจัดการสินค้าคงคลังที่เกิดขึ้นในกระบวนการปัจจุบันเพื่อที่จะสามารถระบุถึงปัญหาและประสิทธิภาพของการจัดการสินค้าคงคลังในปัจจุบันซึ่งเมื่อทราบถึงปัญหาที่เกิดขึ้นจึงนำปัญหานั้นมาเป็นแนวทางในการปรับปรุงและพัฒนากระบวนการจัดการสินค้าคงคลังในขั้นตอนการนำเสนอได้มีการนำเสนอนโยบายการจัดการสินค้าคงคลังและการจัดการคลังสินค้าเพื่อให้บรรลุวัตถุประสงค์ของวิทยานิพนธ์คือปรับปรุงและพัฒนาการจัดการสินค้าคงคลังให้มีประสิทธิภาพมากยิ่งขึ้นโดยได้มีการวิเคราะห์และศึกษาถึงลักษณะและคุณสมบัติของสินค้าคงคลังและรูปแบบของความต้องการของลูกค้าแล้วจึงมีการแบ่งกลุ่มของสินค้าคงคลังเพื่อที่จะมีการกำหนดนโยบายการจัดการสินค้าคงคลังสำหรับสินค้าคงคลลังแต่ละกลุ่มอย่างเหมาะสมนอกจากนั้นยังมีการนำเสนอกระบวนมาตรฐานสำหรับการทำงานที่ เกี่ยวกับการจัดการสินค้าคงคลังและการจัดการคลังสินค้ารวมไปถึงมีการนำเสนอให้มีการใช้เอกสารที่มีมาตรฐานสำหรับขั้นตอนต่างๆในกระบวนการจัดการสินค้าคงคลังและการจัดการคลังสินค้าและมีการนำเสนอการบันทึกและเก็บข้อมูลสินค้าคงคลังผ่านระบบคอมพิวเตอร์ในขั้นตอนการปฏิบัติมีการนำทดสอบวิธีการและนโยบายการจัดการสินค้าคงคลังที่นำเสนอไปโดยทำการทดสอบผ่านโปรแกรมไมโครซอฟเอกเซลล์ข้อมูลที่นำมาใช้ในการทดสอบคือข้อมูลจริงของสินค้าคงคลังรายวันเป็นระยะเวลาทั้งหมด4เดือนโดยการทดสอบได้ทำควบคู่ไปกับการปฏิบัติงานจริงของบริษัท

ผลการทดสอบสามารถสรุปได้ว่านโยบายการจัดการสินค้าคงคลังและการปรับปรุงการดำเนินงานคลังสินค้าสามารถช่วยลดปริมาณของสินค้าคงคลังที่มากเกินความจำเป็นโดยรวมลงได้ร้อยละ46.5ในขณะที่ยังคงสามารถรักษาระดับมาตรฐานการให้บริการกับลูกค้าได้ในระดับเดิมนอกจากนั้นยังมีการลดลงของค่าใช้จ่ายที่เกี่ยวกับการจัดการสินค้าคงคลังที่ลดลงจากเดิมถึง42ล้านบาทจากการทดสอบในระยะเวลา4เดือนซึ่งคิดเป็นร้อยละ45.5ซึ่งจากผลการเปลี่ยนแปลงดังกล่าวที่เกิดขึ้นสามารถสรุปได้ว่ากระบวนการปรับปรุงนโยบายการจัดการสินค้าคงคลังและกระบวนการปรับปรุงการจัดการคลังสินค้าในวิทยานิพนธ์นี้สามารถช่วยเพิ่มประสิทธิภาพในการจัดการสินค้าคงคลังและการจัดการคลังสินค้ารวมไปถึงสามารถนำไปปฏิบัติให้เกิดระโยชน์ได้จริง

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สาขาวิชา การจัดการทางวิศวกรรม ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

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NATTCHA NERDNOI: Inventory control system improvement in an automotive adhesive company. ADVISOR: ASST. PROF. PAVEENA CHAOVALITWONGSE, Ph.D., 117 pp.

The objective of this research is to improve inventory management to be able to control the inventory quantity, which would lead to the minimization of total inventory costs. This research proposes three phase of methodology, which are define, propose phase and implement phase, to improve efficiency of inventory management by control policy and management.

Define phase describes and analyzes current inventory management workflow process. The scope of inventory management in this research consists of three main parts; inventory control policy set up, warehouse activities, such as inbound and outbound activities and inventory recording system. Then, problems and their effects are defined through brainstorming. Cause-and-effect diagrams are created to illustrate key problems, cause of problems and areas for improvement. Additionally, inventory level and cost components of inventory have been studied analyzed and identified at current state to indicate current performance.

In propose phase, characteristic of inventory has been studied, solution for improvement of inventory control process and warehouse process have been developed, proposed and elaborated in order to achieve research objectives with helps of tools and techniques reviewed in literature review chapter. This phase begin with inventory classification and demand pattern analysis. Appropriate inventory control policy are suggested, discussed and calculated for each class of inventory, and then Standard process and workflow of inventory management and warehouse management are outlined, follow by standard documents related and computer based inventory recording system discussion. Warehouse layout and zoning are proposed.

For implement phase, the simulations of the methodology and inventory control policy proposed are simulated through Microsoft Excel. Proposed solutions and method is tested simulation through Microsoft Excel, evaluating with a set of actual four months data from January 2015 – April 2015, while current method is in used. Results show the comparison between proposed method and current method, which can be summarize that the proposed inventory policy and methodology are successful in developing new inventory control policy and managing the inventory, as it can reduce overall inventory value, inventory holding cost and inventory ordering cost, which will result in reduction of total cost related to inventory, while the desired service level is still achieved. The major saving is achieved in reducing the inventory value, captured and compare to the current inventories, there is a saving up to 42 million baht, which is 45.5% during simulated period of four months.

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

Page

Page

Page

Page

Page

List of figures

List of Tables

Chapter 1 : Introduction

1.1 Global Situation and Trend of the automotive industry

During the past 10 years, the trend of global production of automotive has continuously raised. As illustrated in figure 1-1, which shows that the automotive industry is growing. In 2011, the total global production was 80.1 million units, which increased 42% from 2001. The decrease about 12% in year 2009 is subjected to the hamburger crisis. Thailand Automotive Institute also suggests that, for the developed countries, demand is quite saturated, but for the developing countries, the demand is increasing promptly. Because of demand shifting to developing countries, the global automotive manufacturers strategic move are to relocating their manufacturing closer to the market, which will also result in lower production, labour and transportation costs. Thailand is now ranked at no. 10 for total production of motor vehicles in the world with the total production of 2.4 million as figure 1-2 below,

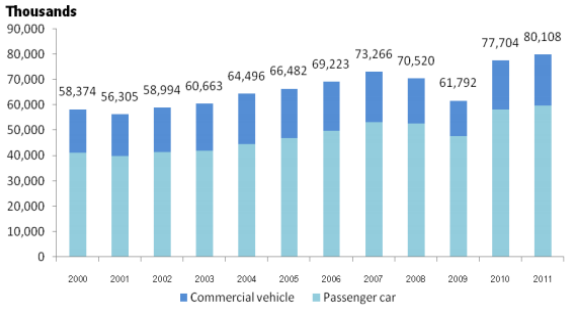


Figure 1-1 : The total demand for sealants and adhesives for each sector

Source : Thailand automotive institute

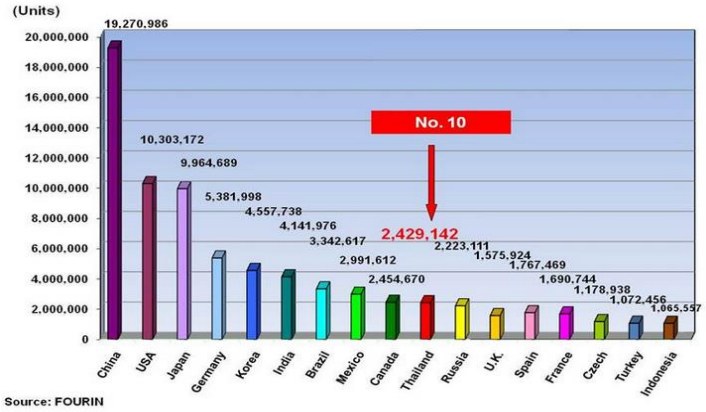


Figure 1-2 : The total demand for sealants and adhesives for each sector

Source : Thailand automotive institute

Focus in Thailand, the production capacity trend is increase continuously follow the global's trend. With significantly decrease point in year 2011 due to the major flood in Thailand.

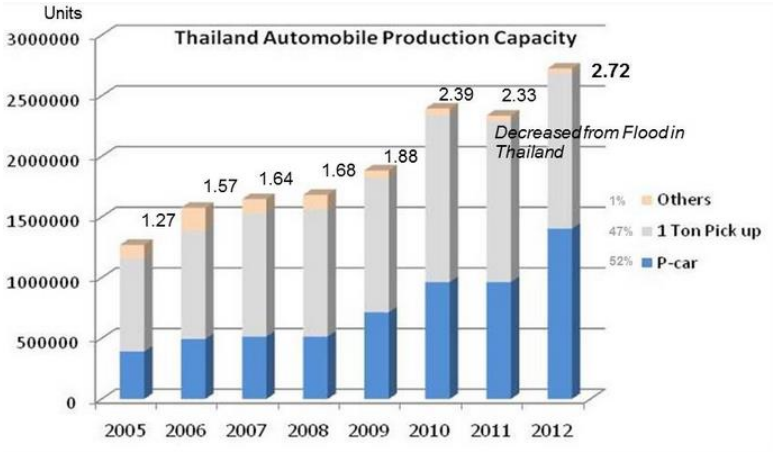


Figure 1-3 : The total demand for sealants and adhesives for each sector
Source : Thailand automotive institute

1.2 Adhesive and sealants

Adhesive and sealants are general term, and in specific contexts may be replaced by designations such as cement, glue, paste, fixative, and bonding agent. (David W., 2013) the adhesive is substance that can of form and maintain a bond between two surfaces, and sealants are substances that used to fill gaps or joints between two materials in order to prevent the liquids, solids or gases that will pass. (David W., 2013)

Adhesives and sealants are formulated by combining the base material with solvents, plasticizers, stabilizers, fillers, pigments and addictive to get the required characteristics. Low to medium performance products are based on natural substances for example, starch and natural rubber or synthetic polymers such as polyvinyl acetate, polyvinyl alcohol, polyesters, acrylics, neoprene, butyl rubber, phenolic or thermoplastic elastomers. High-performance products have enhanced properties including bond strength, elongation capacity, durability or environmental resistance. These products are based on polymers such as epoxy, polysulfide, polyurethane, cyanoacrylate and silicone.

Adhesives and sealants can be classified according to their two major sectors

(Adhesives and Sealants Manufacturers Association, 2012) - industrial sector and consumer sector. The industrial segment is estimated to account for about 80 percent of the market. Major users of adhesives are the packaging, automotive, construction and furniture industries. Sealants are used primarily by the construction, electronics and automotive industries. (Adhesives and Sealants Manufacturers Association, 2012)

The newest applications in on construction industry, this industry represent huge potential markets. Floor systems can bonded by adhesive in order to supporting joists and increased strength Interior wall and panel can join together by adhesively without nail or screw heads. Sealants can be applied to hold a wall panels and insulating panel in place.

The automotive industry, this industry offers substantial potential for new opportunities (Adhesives and Sealants Manufacturers Association, 2012). Many types of adhesive are already used, for example, interior applications for bonding decorative panel, a car floor's carpet and sealing doors and windows. For exterior, starting from the metal body of the car, roof and side moldings. Adhesive has been use widely in order to overcome the corrosion problems of metal, vibration and noise from mechanical fastener and spot welding. Among all the applications, packing, construction industry, durable assembly and transportation sector accounts a major part of adhesives and sealants.

The global adhesives and sealants market is likely to be driven by the Asia Pacific markets (Global Adhesives & Sealants Market Report, 2014), twisted trends in the US transportation sector and increasing demand for more environment friendly products. According to the study, the total demand for sealants and adhesives in the Asia–Pacific region is expected to grow by 3.6% a year through to 2013 (Sealing Technology, September 2013)

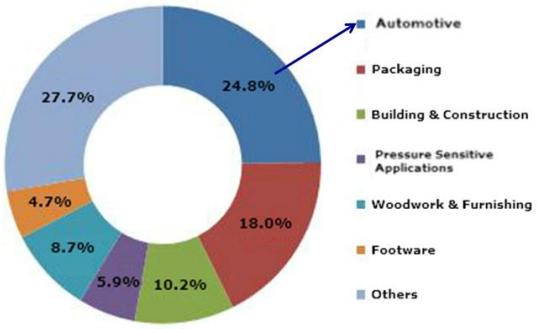


Figure 1-4 : The total demand for sealants and adhesives for each sector
Source : Global Adhesives & Sealants Market Report, 2014

1.3 Background of the studied company

The case study company, namely, CMD (Thailand) CO., LTD. made an entrance into the Thai market just 30 years ago as a distributor of adhesive and sealants from its head quarter company in Japan, CMD Thailand is a manufacturer of a quality adhesive and sealant, which include consumer grade adhesives, though it's focus is on industrial applications - automotive, construction and manufacture. CMD soon became a byword for top quality adhesive, and sealant, which are indispensable elements in the making of automobiles. However, as industrialization picked up speed, existing supply began to fall short of demand. The situation called for a CMD local production base that would better provide to the growing needs of the heavy industries.

In 1981, CMD (Thailand) CO., LTD. was formed as a joint venture with Japan's CMD CO., LTD. The manufacturing starts as a family business, the factory of CMD located in Bangpoo industrial estate in Thailand with area of 4.2 Rai. CMD operate as a manufacturer of adhesive and sealants for automotive industry and the new set-up was warmly welcomed because it guaranteed a stable supply and reasonable prices for manufacturers. Over the three decades, CMD (Thailand) CO., LTD. has gained tremendous recognition in supplying multinational automobile makers and smaller local companies alike.

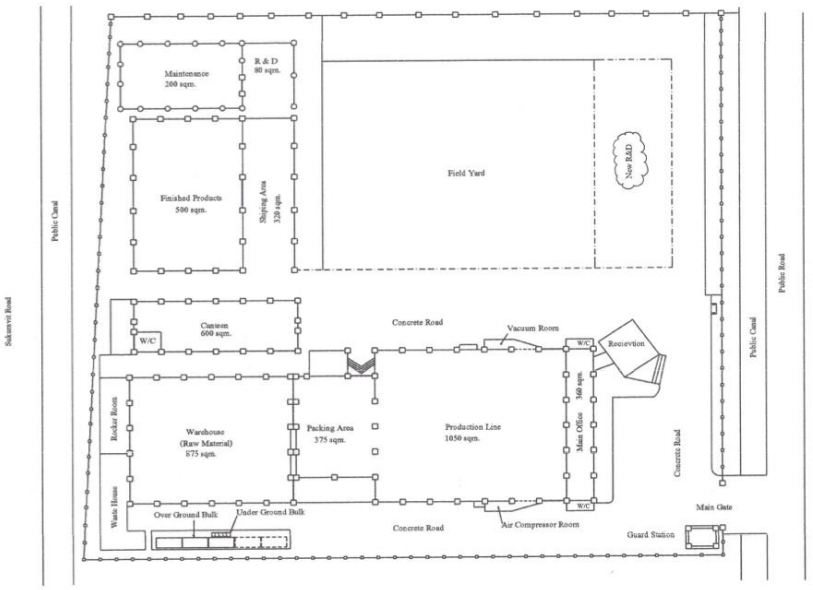


Figure 1-5 : Layout of the case study factory

Source : CMD Company's Document

The scope of the uses of CMD adhesives is wide with each passing year adding more usage. The emphasis for CMD is on the automotive industry, CMD has been a major player in Thailand's growing automotive industry because that CMD offers a comprehensive range of auto related adhesives. Utilization of CMD adhesives is found in more than 15 areas within car manufacturing. CMD adhesives are found in almost every parts of automotive manufacturing as figure 1-6 and 1-7 below.

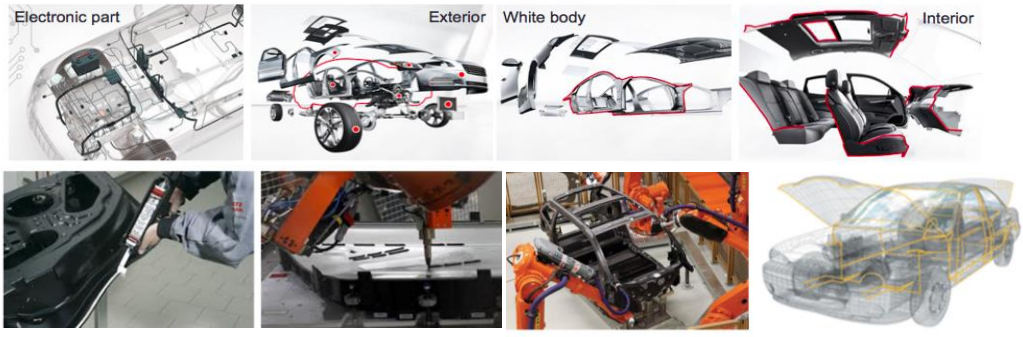


Figure 1-6 : Application in car manufacturing

Source : CMD Company's Document

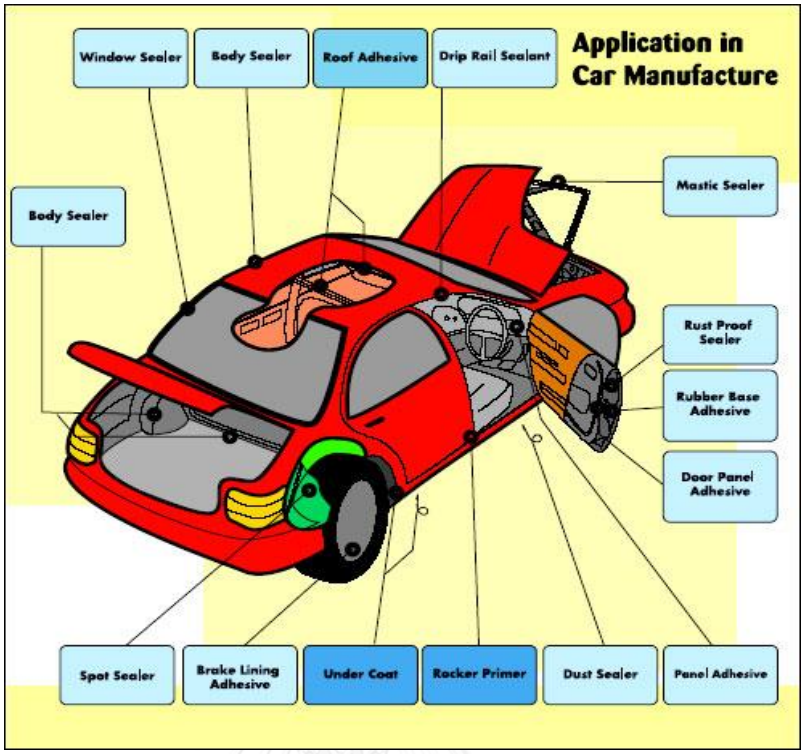


Figure 1-7 : Application in car manufacturing

Source : CMD company document

1.3.1 Current workflow

As mentioned earlier, CMD first established as a sole distributor of CMD Japan in order to only distribute products within Thailand but then the business went very well that the expansion is needed. CMD transform itself into manufacturer and start the manufacturing as a family business. So, the workflow of the company is relatively simple as follows.

Customers	• Yearly demand provided once a year at the beginning of the year • 3 month in advance demand provided every quarter – by E-mail
Production	• Production manager convert forecast to production plan • Production manager translate forecast into raw material requirement – follow each type's formula • Production staffs forward requirement to warehouse – by paper and hand written
Warehouse	• Received requirements from production staff – paper • Walking inside warehouse to check the location and quantity of ordered raw materials • Warehouse manager make a decision on ordering raw material to fulfilled inventory – based on experience • Write requested quantity for purchase – by paper and hand written
Purchase	• Received information from warehouse staff – paper • Issue order to suppliers – quantity adjusted due to suppliers limitation and policy
Warehouse	• Warehouse staffs received physical raw materials from suppliers • Warehouse staffs putaway raw materials received – into random, free space inside the warehouse
Production	• Production staffs issue withdraw form of raw materials to use in production process – paper and hand written • Return unused raw material back to warehouse

Figure 1-8 : Current workflow process of CMD

1.3.2 Product portfolio

CMD offer wide range of adhesive and sealants, around 80 permanent types of adhesive available for customer to choose and variety of customization for customers to order. This wide range of products resulted in more than 150 types of raw materials to be stock in order to support production process.The finish goods : there are a variety of product range and categories offer, which can separate into 2 main sectors, consumers and industrial. The finish goods available in variety of package size as illustrated in figure 1-4 and 1-5

Figure 1-9 : Sample products of CMD (Thailand) company for consumer sector

Figure 1-10 : Products and package size of CMD (Thailand) company for industrial sector

1.3.3 The supply chain

As a manufacturing company, CMD, as mentioned earlier, offer wide ranges of adhesive but mostly focus on automotive sector. For the suppliers side, CMD have both local and import raw materials. The diagram below illustrates the relationship of suppliers and customers of CMD (Thailand). Raw materials are about 30% imported and 70% from local suppliers. As for the customers, 70% are automotive sector and 30% are retail & consumer sector.

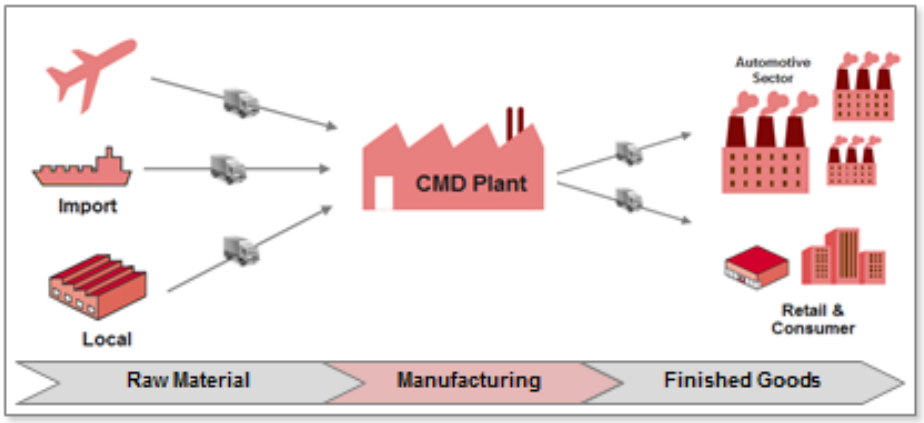


Figure 1-11 : Supply chain of CMD (Thailand) Co., Ltd.

In total, CMD Thailand is supplied by 35 companies locally and 10 companies internationally, mainly from Japan. Imported goods are coming in by sea freight and air freight. The lead time of sea freight shipments are between 45 to 120 days depends on the goods ordered and location of suppliers. CMD supplies around 10 customers who contribute large main volume from automotive sector and 15 customers, medium to small size from retail & consumer sector.

1.3.4 Organizational structure

Currently, CMD employed approximately 300 employees in the company. Figure xx shows the organization structure of CMD.

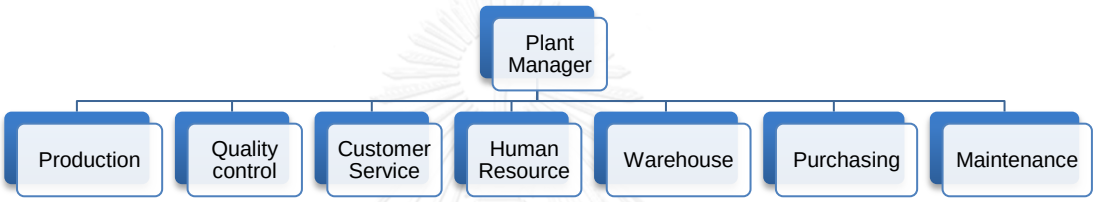


Figure 1-12 : Organization chart of CMD Thailand Company Limited

1.4 Statement of problems

As mentioned in the introduction, automotive sector in Thailand is now growing strongly (Thailand automotive institution, 2012) but now the company is facing financial problem, the company is now operating with loss, which is totally contradict to our main sector trend. The management team is now concern on the performance of the factory due to financial problems. The company also gets pressure from customer policy that the sell price has to reduce by 5% every 3 years, this main driver lead the company to face the problems of operating with loss. From those issues, a closer observation is needed.

Consequently, by just walking into the warehouse, excess inventories is the most significant issue. There are many items of raw material ordered have no place to store and are place on the floor of the warehouse, without label and unidentified quantity. The warehouse, which normally have enough space are now full and newly ordered raw materials are place outside the warehouse and the amounts continue to increase.

Figure 1-13 : inventory inside CMD Company warehouse – November, 2014

According to *Norm S., 2014, if there is* a trend in the increased use of outside storage space, then this can indicate an ongoing inventory management issue. To confirm what have been seen, the quantitative data of inventory have been collected, the record of total 150 types of raw material quantity was collected. The studied is based on period of April, 2013 to December 2014. The figure 1-8 below has shown that the quantity of inventory has been increase about 16% from April, 2013 to December, 2014., which is about 95,000 kilograms of raw materials increased during those period.

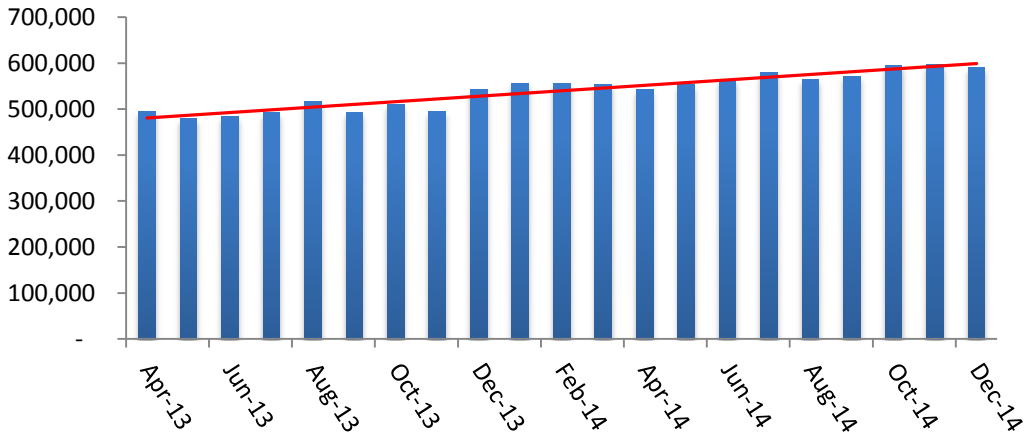


Figure 1-14 : Monthly quantity of raw material on hand during Apr 2013 – Dec 2014

Nevertheless, the higher inventory quantity did not always interpret that there is a problem with inventory. Because if the inventory gets higher and the finish goods get higher too, that would mean the company is growing or expanding. To investigate more, the researcher collects more data from company's financial records to confirm the primary observation; value of inventory and finished goods sold was collected and explore as below, Figure 1-9 illustrates the value of inventory and finished goods sold during April, 2013 to December, 2014. The inventory value increases dramatically from the beginning of year 2014, while the finished goods sold value remains just about the same. This situation positively reflexes the problem, since the inventory represents a sizable investment of company funds and often where the biggest budgets are hidden (Harrington, 1996). Larger inventories mean higher cost.

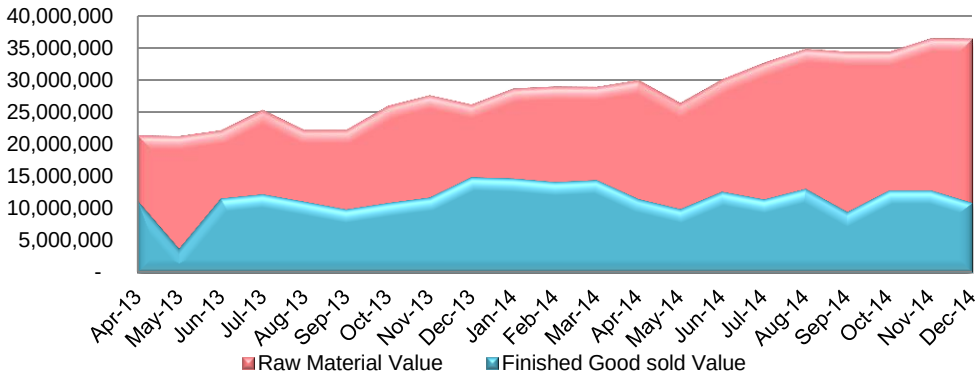


Figure 1-15 : Inventory value and Finished goods sold during Apr 2013 – Dec 2014

Additionally the effects from company's main customer's automotive sector policy, to decrease price by 5% at the end of year 2013, is the average price per unit sold fall considerably from THB 58 to THB 55.1 from December 2013 to January 2014 as shown in figure 1-10. In contrast, from CMD collected data and cost study, the cost per unit shown the opposite trend, increasing gradually over the same time period. This is evidently states that CMD is operating with loss since the starting of year 2014.

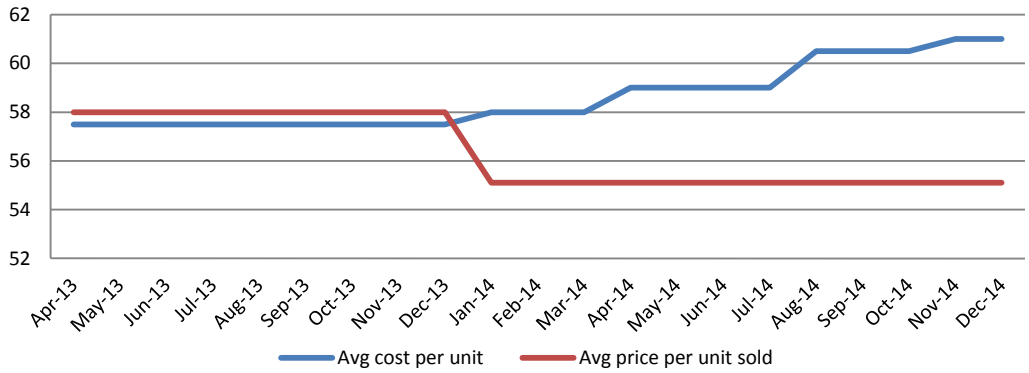


Figure 1-16 : Average cost/unit vs Average price/unit sold during Apr 2013 – Dec 2014

From overall investigation and observation, the problems are listed below

- The company is now operating with loss due to the customer's policy of price reduction for 5% every 3 years.
- The excess inventory that cannot store in warehouse and the quantity of raw materials that continuously increases over time.
- The significant increasing in raw material value, which show dissimilar trend to finished goods sold value

A part from data analysis of CMD Company, a hearing session is conducted. The author interviews relevant persons who involve in the process, the process, workflow and problems occurred in the area of raw material and inventory management are concluded and explain as follows. In general, CMD Company plans it production operation according to the projected demand pattern during the year given by the customer in a period of every three months. Based on the past experience, the projected demands by customers come in ranges, for example 200 -300 drums per month. The production department then translate this demand into raw material quantity requirement by calculation follows the formula of each type. In general, the demand from customer is higher than the installed capacity of the factory; hence to satisfy all demand at current operating level without extra investment to expand the capacity, the factory adopted stock building policy. However, this stock building policy only ensures the satisfaction of the demand, without taking account of inventory cost incurred and the level of the over stock built. The main policy is to always over.

Furthermore, this structure is substantial relying on human interpolation, which makes it helpless to have the mistakes and errors. The determination of the over stock level of both finish goods and raw material are purely subjected to human judgment. There has not been a tool to help the factory reliably and flexibly determine the appropriate level of both raw material inventory level and finish goods level.

The plan developed by production serves only as the benchmark for warehouse. The information flow from production department to warehouse came in traditional way, the paper and pen. At the moment the factory is almost fully rely on its staff skills of recording information. The warehouse staffs were always having problems in order to keep track of the raw materials and also finish goods coming in, going out of the warehouse and the remaining of both. Almost all the time that items in the warehouse are misplace and causing error when the staffs trying to check the quantity. Warehouse manager now make the decision based on approximation method, experiences and personal judgment due to unreliable information.

The big problem with the traditional way of information flow, paper, is that, they are inaccurate and easily missing. Many times, problem occurs when several involved person need to see the same information recorded.

1.5 Research Objectives

The objectives of this study is to critically assess current process of inventory control and inventory policy and focus on improving CMD's inventory management, which is to propose, design and develop a new inventory control policy in order to be able to control the inventory quantity, which would lead to the minimization of total inventory costs through simulation analysis.

1.6 Scope of research

This research will focus on the improvement of CMD's inventory control policy by analyzing the relevant historical data. The scope will be as follows:

- Analysis of the present business position, current process and policy
- Redesign and develop process of inventory management and warehouse management
    - For the inventory control policy set up, historical data are collected for

analyzed and then appropriate policy is proposed

- For warehouse process and inventory record system will be improved by redesign warehouse process

- Implement of proposed policy, results discussion and future plan

1.7 Expected benefits

- Reduce excess inventory quantity
- More synchronize and integrated work flow within the company
- A new policy for better inventory control
- Reduce overall inventory cost to stay competitive and meet customer's requirement, policy and achieve expected service level.

1.8 Research methodology and structure

As the background of the studied company, research problems, research objectives and scope of research have been presented. This part will explain shortly of the outline of each chapter within this thesis. The propose methodology for this thesis can be explain as following,

Phase	Objective	Outcome	Chapter
Introduction	To present and give an overview of the background of the studied company, research problems, research objectives and scope of research.	Understanding of business environment, current problems and objectives of research	Chapter 1
Literature Review	To review theoretical consideration involves academic materials that relate to the research. Information on tools and techniques used in this research.	Understanding of acadamic theory, tools and techniques related to this research	Chapter 2
Define Phase	To studied, analyzed and clearly define current operation, process and data which will lead to problem identification. Cause of problems will be determined by creating cause-and-effect diagram to elaborate each factor and identify its important and suggest area to improve. Moreover, the measurement parameter will be proposed in order to measure the result of solution proposed.	Understand of current process, problems, causes of problem and effects of problems clearly. Pinpoint and clarification of problems	Chapter 3
Propose Phase	To develop and propose solution for improvement of inventory control process and warehouse process to achieve research objectives with helps of tools and techniques review in chapter 2	Raw materials' classification, proposed inventory policy are suggested and discussed, proposed stock record process are outlined and propose solutions for improve warehouse issues	Chapter 4
Implement phase	To test proposed solutions and methodology from propose phase and compare results with current method	Demonstration of simulation of the methodology and inventory control policy proposed. Results of proposed solutions compare to current method are shown	Chapter 5

Table 1-1 : Overview of research methodology

Chapter 2 : Literature Review

The related topic of literature will be conducted and explored, which are in the area of inventory management and policies, inventory related cost, Economics Order Quantity (EOQ) and storage management in warehouse.

Chapter 3 : Define phase

This chapter will focus on current process; historical data will be collected, details of the research problem will be critically assessed and discussed. Parameter of inventory cost will be studied and analyzed. Problems and areas for improvement will be identified and solution to those will be proposed.

Chapter 4 : Proposed phase

Proposed method will be explained in more detail by involving the knowledge from literature review in chapter 2. Raw material characteristic will be studied and discussed and then, will be categorized by ABC analysis method, Inventory policies will be set up for each category, the step by step calculation of example raw material will be presented and explained, the simulation of inventory policy will be shown, the computerized stock keeping record system will be proposed and the visual management system example will be illustrated.

Chapter 5 : Implementation phase and result discussion

The solutions have been proposed in chapter 4 will be validated. Proposed method will be test on the set of prepared data (during 4 months period; January 2015 – April 2015), assessed and reviewed. Detail of simulation result will be discussed and evaluated in relation to the current implemented process. The key findings of research will be summarized and the suggestion for further research will be stated.

Chapter 2 : Literature review

Theoretical consideration involves academic materials that relate to the research. Information on tools and techniques used in this research will be present and review within this chapter.

2.1 Supply chain and logistics management

The aim of supply chain is to make available the right product, at the right time on the right location (Heck 2009). Supply chain management is an integrated approach of planning and control of both physical materials and information flows between suppliers and customers, or between departments within the company (Nenes, Panagiotidou et al. 2010) Supply chain management is involved in the strategic, tactic and operational level of a company (Badell et al., 2006). The descriptions of each level are as the following

1. Strategic Level – focusing on long term planning, which is about locations of facilities and capacity
2. Tactical Level: focusing on policy, which is about operation policy, inventory policy and etc,.
3. Operational Level: focusing on daily working process, for example, operations, production planning or delivery scheduling.

The objective is to manage the material flow, information and financial flows in a cost efficiently way, however still focus on customers' satisfaction (Heck 2009)

2.2 Inventory management

Inventory and stock are often used interchangeably (Beutel and Minner 2012) But when talk about inventory management, it somewhat difference to stock management. For the word stock, it is normally mean the amount of goods that being held at a specific place, for example, in a warehouse, which can be refer as inventory. Inventory management is normally means to identify the amount and location of the stocked goods, that done at different locations in order to protect

against uncertainty and protect the production from running out of raw materials to produce finished goods.(Krittanathip, Cha-um et al. 2013)
Inventory management has larger scope than stock management. Coyle, 2003 state that inventory management is about managing the material flow and other activity related, such as inventory forecast, visibility of inventory, inventory lead time control, cost related to inventory and space for inventory (COYLE J J and J)

Inventories are amount of raw materials(RM), components, WIP (work in process), and finished goods(FG) that exist at several points throughout a company's production and logistics channel (Ballou 2004) In the past, high inventory quantity gave an advantage and viewed positively (Thummalapalli 2010) when time passed, inventory are now viewed as a necessary evil due to its related cost such as, carrying costs. Thummalapalli, 2010 suggest that annual inventory holding costs can range between 20% and 40% of material costs.

According to Nanthan S., 2014, Inventory management is a field of highest importance for successful operation and supply chain management as per the inventory costs represent the second largest asset group in manufacturing companies, next to only investment in plant and equipments. The proportion of inventories to total asset varies between 15 to 30%(Nenes, Panagiotidou et al. 2010). So, the important of inventory management should be emphasized. Higher the inventory, higher the cash blocked and higher space needed. On the other hand, lower inventory may lead to trouble in production or unsatisfied customers, that's why inventory management is very important aspect for every organization (Ambastha, 2012).

In small business, the investment in inventory takes up a big percentage of the total budget, however inventory management is one of the most abandoned and mistreated management areas (Ying Zhong, Lining Bai et al. 2008) Many small business have an high amount cash locked up to excessive inventory because of the loose inventory management and failure to manage inventory in an efficiently manner (Ying Zhong, Lining Bai et al. 2008) Poor inventory management resulted directly on a company's cash flow.

Inventory management is challenging (Jammernegg W., 2006) because it directly impacts both cost and service. Uncertain demand, uncertain supply and production cycle times make it necessary to hold inventory at certain level. The challenge in managing inventory is to balance the supply of inventory with demand (COYLE J J and J)A company would preferably want to have enough inventories to satisfy the demands of its customers, no loss sale due to inventory stock outs, while does not want to have too much inventory on hand because of the cost of carrying inventory(COYLE J J and J). Enough but not too much is the crucial objective for every company Many companies have saved millions of dollars in costs and decreased inventories while improving efficiency and customer satisfaction through various inventory management techniques (Chhajed and Lowe 2008) Within most organizations inventory exists in a variety of places, and in a variety of forms, and for a variety of reasons (3520 2013) Although these inventories represent a substantial cost investment, in some cases as much as 50% of total capital invested, they are necessary in order to provide a required level of service to customers. The objective of inventory management is to strike a balance between inventory investment and customer service.

2.2.1 Demand forecast and pattern

2.2.1.1 Demand forecasting

Demand forecasting is essential for every manufactures, suppliers or retailers. Forecasted demand will normally determine the quantities of products that should be produced, purchased or shipped. Forecasting is necessary, due to process of transfer raw materials from suppliers, then manufacture and deliver finished goods to customers take time . Mostly, the company cannot respond immediately to customers demand. So, many manufacturing company adopt policy of make to stock, rather than make to order.(Walters 2003) Since, generally the customers are not willing the wait that long for the whole process to be complete; the company starts from order raw material from suppliers, which can take weeks or months, manufacture the product and lastly shipped the product to them. The company usually plans and uses experience in guessing the demand ahead, manufactured and then kept it as inventory, once, the customer demand occurred, the company can now respond to those demands immediately. Company that offer fast delivery to their customers tend

to force competitors in the market to keep finished goods inventories in order to provide faster or at least the same order cycle times. As a consequence, almost every company involved needs to manufacture or at least order raw materials based on a forecast of future demand. So, the ability of forecasting accurately enhances the company opportunities to plan for efficient logistic operation, which for example include production up to efficiently quantity, order raw material up to the economy of scale and optimize the transportation (Walters 2003) Accordingly, more accurate demand forecast normally lead to more efficient operations and higher service level for customers. In contrast, less accurate forecasts will unavoidably lead to inefficient, high cost operations or poor service levels for customers. Improving the quality of demand forecast can resulted in more efficiency and more effective supply chain.

Most of the time, in general retailers, the demand to be forecasted is based on company's customers. Demand is up to customers, who able to order whatever and whenever they want. But for the manufacturing company, it might not be the same. For example, the studied company, CMD, has a plan to manufacture 2,000 Kilograms of certain type of adhesive, each type of raw material quantity requirements are known from the formula. Knowing each supplier's lead time, the total quantity of raw material requirement can be determined through a structured analysis of the product's formula and manufacturing process. Forecasts from customer demand for the product are not relevant to this analysis anymore. The CMD may not in fact sell all the 2,000 kilograms of adhesive, but that is not a concern issue due to CMD have already promised to manufacture 2,000 kilograms, following the production schedule. This type of demand is described as dependent demand due to it depends on production schedule requirement. When demand is converted in to raw materials requirement through some system, it creates a deterministic demand for raw materials. This is difference from independent demand, which directly arise from customers' orders. An example is shown in Figure 2-1. Item A is the independent demand item. All the other items are dependent demand. The quantities that go into the final item are shown in parentheses. Notice that two units of C are combined with one unit of B to make the final product. Similarly, two units of D and one unit of E are combined to make one unit of B.

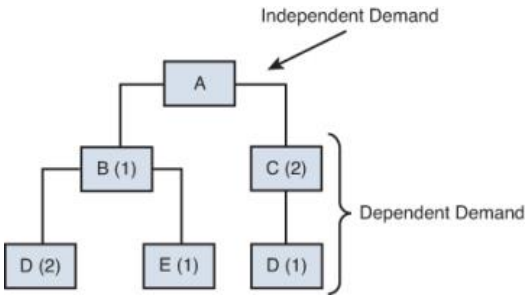


Figure 2-1 : Independent demand and dependent demand
Source : Nada R. S., 2013

2.2.1.2 Demand pattern

According to Jeff, 2004, there are 4 types of demands that forecast reflect. 3 of them behave in a pattern, which are trend, cycles and seasonal, the other called random or irregular way. The figure 2-2 below, illustrate the example of different type of demand patterns.

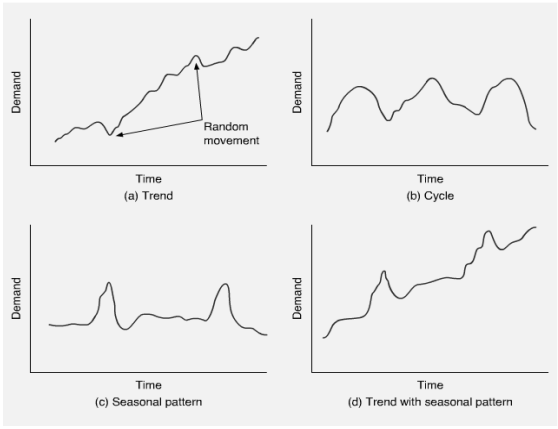


Figure 2-2 : Types of demand (Jeff, 2004)

A trend is a movement of long term that can be up or down. Figure 2-2(a) shown example of trend pattern of demand which should be the upward movement.

A cycle is demand patterns that move up and down, which repeated through long time period, generally through a year or more than. Automobile sale also follow this cycle pattern of demand. Figure 2-2 (b) shown the behaviors of cycle demand

A seasonal pattern is a similar movement of demand over time that happened repeatedly, but happened in shorter time period than a cycle pattern. This usually involves weather, for example, Christmas tree sale increase during December on Christmas holidays. Seasonal pattern can be based on daily or weekly, for example, the department store usually has higher demand during weekend. Figure 2-2 (c), shows seasonal pattern.

When demand behavior exhibitions no pattern, it referred as Irregular or random variations, which the movement is unpredicted. Moreover demand pattern normally show several pattern concurrently. Figure 2-2 (d) illustrates the combination of two demand patterns, a trend with a seasonal pattern.

2.2.2 Inventory classification

Types of inventory

In general, there are three main types of inventories (Kilgore J., 2004):

1. Raw material – it is the products which serve as a beginning part of production, no actions have been done to the items yet.
2. Work in process (WIP) – it is the state of raw material that partly converted to product to be sold.
3. Finished product – it is the products that ready for sale, so can be used as a buffer against irregular demand and seasonal changes.

As Figure 2-3 shows, a material flow, which illustrate inventories in several forms.

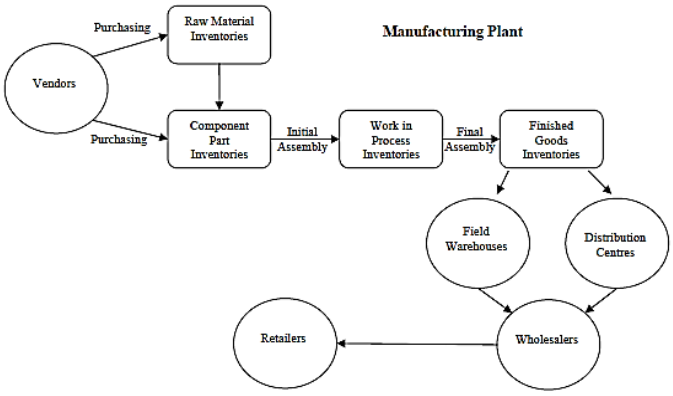


Figure 2-3 : forms of inventories
Source : INDUSTRIAL STATISTICS AND OPERATIONAL MANAGEMENT, Ravi M.

2.2.3 ABC analysis

A manufacturer often keeps inventory of various raw materials and components to meet production needs. Inventory classification is a necessary application and most common techniques (Joffrey Collignon and Vermorel 2012) to manage a large number of inventory items. It is based on the Pareto's principle, which states that a small percentage of items accounts for a large percentage of value. This value can ranges from sales value, profits, or other measure as appropriate. Roughly 10% to 20% of inventory items account for 70 % to 80 % of inventory value. These highly valuable items are classified as "A Class" inventory items. Standard value items account for nearly 30% of inventory items and account for around 35 percent of the total. They are called "B Class". Lastly, approximately 50% of the items only account for 10% of total inventory value. These are called "C Class" items and are the least important.

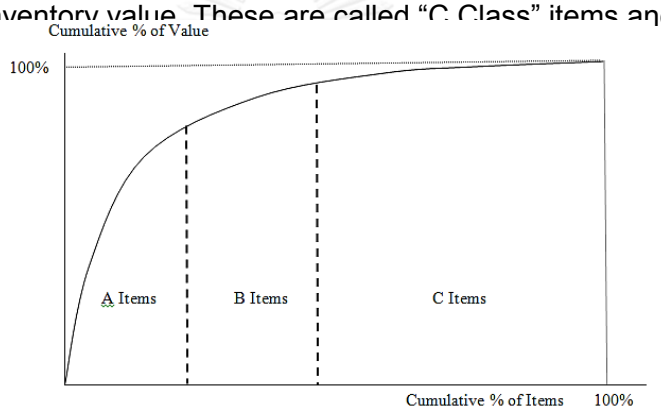


Figure 2-4 : Pareto's diagram of inventory classification (Joffrey Collignon and Vermorel 2012)

The total inventory value is calculate by multiply the quantity of each types of material by its unit price. Figure 2-5 displays the relation of the value to the percentage of ABC classification.

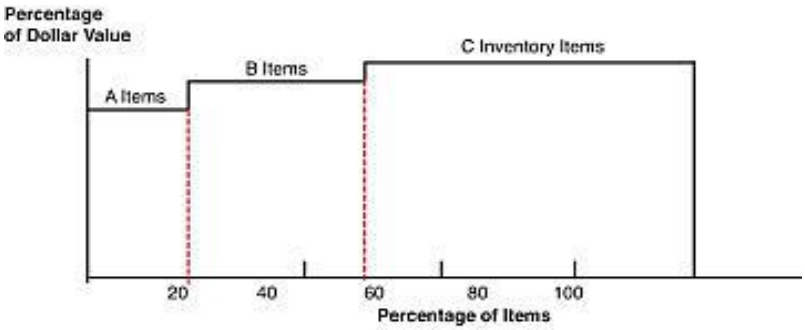


Figure 2-5 : Relation of value to percentage of ABC Classification (Chen, 2011)

In conclusion each class of items are listed as following,

Class A – 5% to 10% of the items represent 70% to 75% of the money

Class B – 15% to 20% of the items represent 15% to 20% of the money.

Class C – The remaining items, which represent 5% -10% of the money

Accordingly, Class A items, which contribute to highest portion of value should be under the most strict and maximum control, follows by class B and class C respectively (Balaji and Kumar 2014).

Particulars	A item	B item	C item
Control	Tight	Moderate	Loose
Requirement	Exact	Exact	Estimated
Check	Close	Some	Little
Expenditure	Regular	Some	No
Posting	Industrial	Individual	Group/none
Safety Stock	Low	Medium	Lare

Figure 2-6 : level of control for each class of inventory (Balaji and Kumar 2014)

Advantages of ABC Analysis (Joffrey Collignon and Vermorel 2012)

1. It ensures a closer and a more strict control over such items, which are having a sizable investment in there.
2. It releases working capital, which would otherwise have been locked up for a more profitable channel of investment.
3. It reduces inventory-carrying cost.
4. It enables the relaxation of control for the class C item and thus makes it possible for sufficient buffer stock to be created.
5. It enables the maintenance of high inventory turnover rate.

2.2.4 Inventory related cost

The costs play an important role in making decision about the inventory in the organization. Barfield et al, 2003 explain costs related with inventory management as follows,

1. Ordering Cost

Ordering costs, which is a variable costs that incur when perform the ordering process, which normally include all costs that directly related to ordering process and depends on the amount of orders placed, without concern on the ordered quantity (Jonsson & Mattsson, 2009). Ordering costs have to define to perform the Economic Order Quantities (EOQ) calculation. From the fact that individual item has a specific ordering cost, which would be too complex. The way to simplified that is to average out the ordering cost for every individual inventory items. The component of ordering cost are listed in the table 2-7

Request for quotation	Goods reception
Supplier negotiation	Inspection
Selection of supplier	Put away in stock
Purchase order/order proposal	Delivery reporting
Purchase order processing	Internal transportation
Delivery monitoring	Invoice check
Other supplier contracts	Payment
External transportation	

Figure 2-7 : Component of ordering cost (Jonsson & Mattsson, 2009).

In order to calculate the ordering cost, two approaches are presented, by top-down and bottom-up methods. A top-down approach will use the total amount of variable ordering costs, for example, the total cost of time spent on material planning, purchasing process and order handling, is divided by the total amount of order lines, see equation 2-1 and 2-2 (Jonsson & Mattsson, 2009).

$$Top-down = \frac{Total\ amount\ of\ variable\ ordering\ costs}{Number\ of\ order\ lines} \quad \text{Eq. 2-}$$

$$Bottom-up = Hourly\ rate \times Time\ per\ order\ line\ for \begin{cases} Place\ order + \\ Send\ invoice + \\ Goods\ reception + \\ Inspection + \cdots \\ (full\ list\ in\ Appendix\ 3) \end{cases} \quad \text{Eq. 2-}$$

Whereas, for the bottom-up approach, the calculation should be done over a longer period of time, for example, 1 – 2 years, in order to protect against variations. In the same way, when using top-down approach, fluctuations and variations occurred, but the effect is less due to the overall capacity included in consideration (Jonsson and Mattsson (2009).

2. Inventory Holding Cost :

The holding, sometimes refer as carrying or storage cost, is the cost associated with maintaining an inventory until it is used or sold. It involved the cost of storage facilities, ex. Warehouse rental, facilities maintenance, bank charge or taxes, costs related to obsolescence, and capital cost ties up to the inventory. The capital cost tied up to inventories can be called “the opportunity cost”, which is the main portion of the holding cost and difficult to identify. Normally, the company estimates that its inventory holding cost is approximately 13 – 15% of the price of its total inventories (Barfield et al, 2003).

3. Shortage Cost :

The shortage cost or stock out cost occurs when demand exceeds supply. In practical, it is very hard to determine, due to the main portion of shortage cost is implicit cost – the loss of customer’s willingness to purchase the products. Other portion is a portion that additional administrative or transportation or the costs of notifying the customer may occur to complete those back-orders. As a result, the shortage cost is normally estimated as 15% of the purchase cost.

4. Total Inventory Cost :

The total inventory cost should be calculated by summation of Purchase cost (PC), Inventory Holding Cost (IHC), Shortage Cost (SC) and Ordering Cost (OC). Thus, the total inventory cost; TC, is given by

$$\text{Total cost} = \text{inventory holding cost} + \text{shortage cost} + \text{ordering cost} \qquad \text{Eq. 2-4}$$

2.3 Inventory control policies

Inventory control has two major objectives. The first objective is to maximize the level of customer service by avoiding under stocking. Under stocking causes late deliveries, backlogged orders, lost sales, production bottlenecks, and unsatisfied customers. (Ballou 2004)

The second objective of inventory control is to promote efficiency in production or purchasing by minimizing the cost of providing suitable level of customer service.

Placing too much attention on customer service level can mislead to over stocking, which means the too much of cash is locked up in inventories.

These two main objectives often battle. Achieving high levels of customer service by maintaining certain inventories leads to higher inventory costs and less efficiency in production or purchasing. Inventory control becomes a balancing act. Many times a manager selects a desired level of customer service and tries to control inventory in a manner that achieves that level of customer service at the lowest cost possible. Thus the problem is requiring a balance in inventory levels, avoiding both overstocking and under stocking.

As already reviewed, inventory can be categorized. Nada R. S., 2013 reviewed that policies applied to each type of inventory based on ABC analysis leverage the sales imbalance drawn by the Pareto principle. So, it means that each item should get different handling or managing policy corresponding to its class or group. Nada R. S., 2013 suggested that, A items should have tight inventory control, more secured storage areas and better forecasts. Reorders should be frequent, with weekly or even daily reorder. Avoiding stock-outs on A items is a priority. Nada R. S., also suggest more that, reordering for C items should be made less frequently. Inventory policy for C items should be reorder only when an actual withdraw occurred. This will leads to stock-out which can be acceptable, since the C class exhibit low demand, variety of demand pattern can be observed and high chance of excess inventory. Class B items is at in between status of A and C. There are four main types of inventory control policies for single-echelon systems.

	Continuous review	Periodic Review
Fixed quantity orders	(s,Q)	(R,s,Q)
Variable quantity orders	(s,S)	(R,s,S) or (R,S)

Table 4.4 - Inventory control policies

$R = Review\ period, \quad i.e.\ the\ time\ interval\ between\ two\ reviews$

$s = (Re)order\ point \quad w.r.t.\ the\ inventory\ position$

$S = Order\ up\ to\ level$

$Q = Order\ quantity$

Figure 2-8 : Main types of inventory control policy (Nada R. S,2013)

2.3.1 Continuous review policy

For the continuous review policy, inventory level is monitored on a continuous base. The order can be place instantly when the inventory level drop to the reorder point. In practical, the quantity of inventory will be reviewed immediately after each withdrawal from inventory. An example of continuous review system is the traditional two-bin system, There are 2 bins that hold total inventory of the items (Purnomo, Wee et al. 2012). Items will be withdrawn from the first bin until it is empty, that point was called reorder point, the new order will be place and then the item in second bin continue to serve demands. The second bin usually have enough stock to fulfill the demands until the new placed order arrive and also able to cover some variation to protect stock out. (Tajbakhsh 2010)

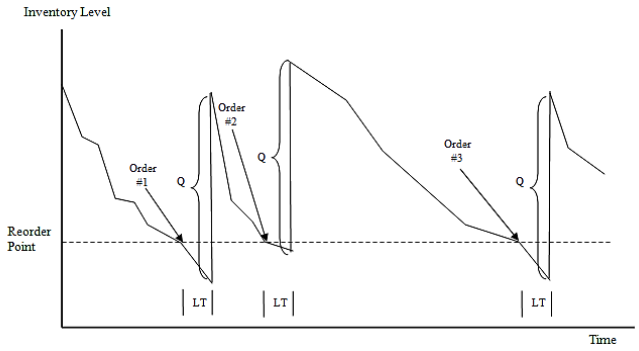


Figure 2-9 : Continuous review policy

The continuous review system, can be refer as a reorder point (ROP) system or a fixed order quantity system or the (R,Q) policy have a short description as follows, *"Place an order for Q* units whenever a withdrawal brings the inventory to the reorder point R." where

Q	=	Order quantity, which will can be calculated from EOQ
L	=	Lead time for replenishment
D	=	Average demand per period
R	=	Average demand during lead time (D_L) + safety stock (SS).

2.3.2 Periodic review policy

This approach maintains a constant time between the each order, but the order size is varied. It sometimes referred as a fixed interval system. The inventory level is periodically reviewed on daily, weekly, monthly or yearly basis. An order (Q) is placed equal to the amount of different between predefined target inventory level (order up to level (OUL), or a target level) and an actual inventory level (On hand inventory).(Purnomo, Wee et al. 2012)

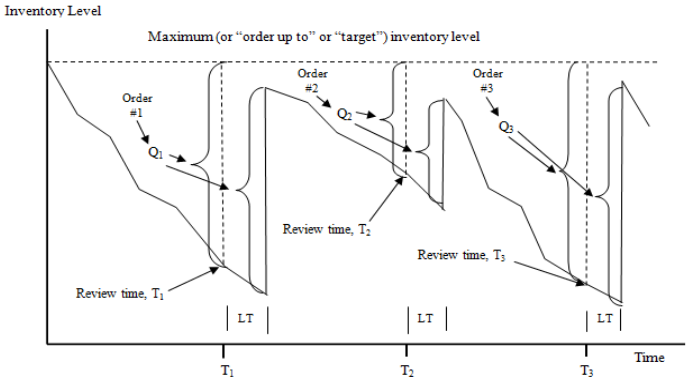


Figure 2-10 : Continuous review policy

Where;

T	=	Review interval
L	=	Lead time for replenishment
D	=	Average demand per period
OUL	=	Target inventory level determined by the forecasts
	=	Expected demand during review interval (D_{L+T})
		+ safety stock (SS)
Q	=	OUL(Order up to level) – actual inventory position

In conclusion, the continuous review policy has higher responsiveness due to the inventory level review immediately after each removal occurred as mentioned. So, the safety stock needed to cover only for the lead time period variation. While for periodic review, review interval is predefined, which is the reason that more safety stock is needed to cover both lead time and review interval. For the reason, if the review interval for periodic review is set to be more frequent, then the safety stock

require would be less. Advantages and disadvantages are concluded and summarized in the table 2-1 below,

Approach	Advantages	Disadvantages
Continuous review	- provides closer control over inventory items - less safety stock needed	- needed constant update and monitor - Items from the same suppliers may receive separately.
Periodic review	- Advantage in joint shipping when several items come from same source - No constant monitor needed, which consume less time and resource.	- require higher quantity of safety stock - provides looser control over inventory items

Table 2-1 : Advantages and disadvantages of review policy

Both types of review policy answer the question of when to order, but not how much to order. Economics Order Quantity (EOQ) would help, which will be discuss further in this chapter. EOQ will propose order quantity by consider each cost components mentioned earlier.

3.3.3 Replenishment

As discussed above, if the interval time of review in periodic review is set to be more frequent, then the safety stock required will be lessen. This replenishment cycle will illustrate more clearly on this. In general, replenishing more often results in a lower inventory value.(Tajbakhsh 2010) Please note that Figure 2-10 is a simplification, because many costs can increase, such as transportation costs and labour costs. Moreover, the benefits of receiving less frequently play an important role. Though, the figure below illustrate simplified version of how the inventory value can reduced by reducing cycle review time and receive less frequent.

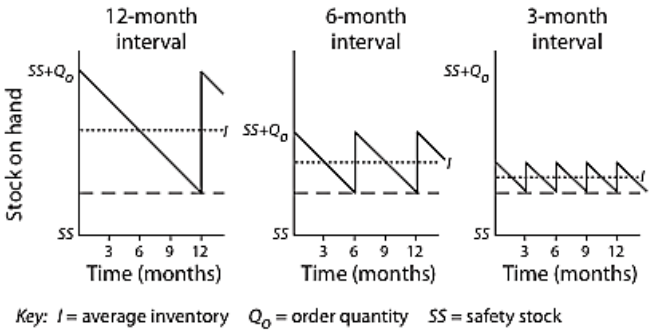


Figure 2-11: Reorder intervals vs inventory quantity on hand (Tajbakhsh 2010)

2.4 Safety Stock

Safety stock were introduced into supply chains to protect against various supply chain uncertainties, which can be shifting in customers demand, Inaccuracy in forecasting and lead time of both manufacturing and raw materials ordering variability (Shivsharan 2012). Moreover safety stocks in manufacturing operation are used as smoothing production process purposes (Stephen C., 1987). On production side, the safety stock act as a buffer to protect the production schedule and plan against variability. Similarly, on the supply side, the suppliers may sometimes unreliable in aspect of lead time and quantity (Aghezzaf et al 2007). Safety Stock also used to ensure good customers satisfactory and maintain service levels.

According to Blau, 2008, every business would like to deliver high service level, therefore the stock kept would be relatively higher and the cost would increases. So, the safety stocks are not supposed to clear all the stock out problem, but only the majority (Peter L., 2011). Some manufacturing guess and set the safety stock level based on experiences, or base on portion of 10 – 20 % of the cycle stock level (Peter L., 2011). Therefore, 3 common approaches are presented here to determine safety stock (Aghezzaf et al 2007), which are

Time supply approach –safety stock set equal to period of time that supply

Ordering cost approach – To minimize the cost of ordering and carrying

Service level approach – Aim to minimize cost while still satisfying the service level promised to customers

Since the variable are complex with uncertainties, In order to calculate safety stock level, Cetin at al, 2004 develop the safety stock formulations model for calculation to reduce complexity of stochastic variable and uncertainty lead time as follows figure. Cetin et al (2004) said that the model presented in figure, was able to set the safety stock targets, captured and account for uncertainty in both supply and demand.

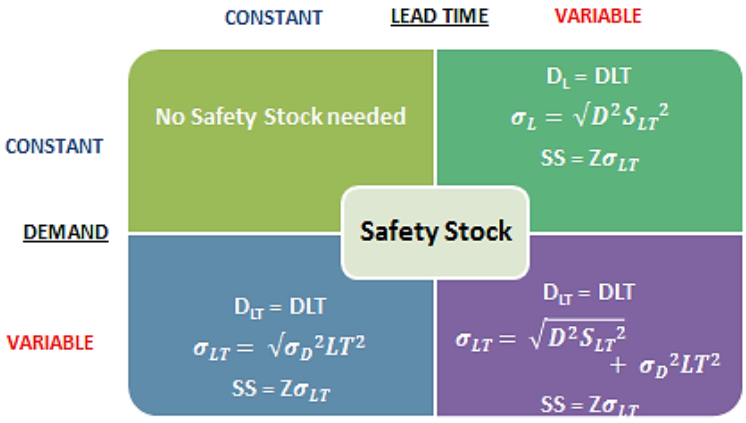


Figure 2-12 : Safety stock formulation model
Source : Adapted from Cetin et al., 2004 by author

Where,

SS	:	Safety Stock
LT	:	Average lead time for replenishment
D	:	The average demand in each period
D_{LT}	:	Demand during lead time
σ_D	:	Standard Deviation of demand in each period
s_{LT}	:	Standard Deviation of lead time
σ_{LT}	:	Standard Deviation of demand during lead time
CSL	:	Cycle Service Level
Z	:	Safety factor represents the inverse of service level percentage (Çelik 2013)

The assumptions of each variable used are listed below:

Normal distribution – it is a common continuous probability distribution which, most of safety stock models and formulas were based on the assumption of normal distributions (Çelik 2013)

Standard deviation – describe the spread of the distribution of numbers. it is a measure that is used to quantify the amount of variation of a set of numbers or data values (Çelik 2013)The standard deviation value that close to 0 shows that the data tend to be very close to the mean of those set, while the higher value of standard deviation means that the data distribute in wider range. The Standard deviation can also be calculated by function “STDEVPA” in ExceI.

Lead time – It is the time during the point order is placed until the order arrived, this should also include the lead time of suppliers (Çelik 2013)time to issue purchase order, approval process, receiving and inspection goods process or any other works related to purchasing process.

Demand during lead time –This is the pre determine demand during lead time or the forecasted demand over the period of lead time. For example, if lead time for RM 01 is 14 days, and forecasted demand is 20 units/day, then, demand during lead time equal to 14 x 20 = 280 units

Order cycle –the time between order of each item. Can be called replenishment cycle,.

Reorder point – The reorder point or (ROP) is the inventory level that initiate the ordering process. The formula of reorder point are as follows,

Reorder Point (ROP) = Lead Time Demand(LT) + Safety Stock (SS)\

Service level – Desired service level stated as a percentage.

Safety factor – the factor which is the inverse function of service level percentage. This value can be look up from Z table or can be calculate using Excel function of "NORMSINV" (Çelik 2013)

Service Level	Service Factor		Service Level	Service Factor
50.00%	0		90.00%	1.28
55.00%	0.13		91.00%	1.34
60.00%	0.25		92.00%	1.41
65.00%	0.39		93.00%	1.48
70.00%	0.52		94.00%	1.55
75.00%	0.67		95.00%	1.64
80.00%	0.84		96.00%	1.75
81.00%	0.88		97.00%	1.88
82.00%	0.92		98.00%	2.05
83.00%	0.95		99.00%	2.33
84.00%	0.99		99.50%	2.58
85.00%	1.04		99.60%	2.65
86.00%	1.08		99.70%	2.75
87.00%	1.13		99.80%	2.88
88.00%	1.17		99.90%	3.09
89.00%	1.23		99.99%	3.72

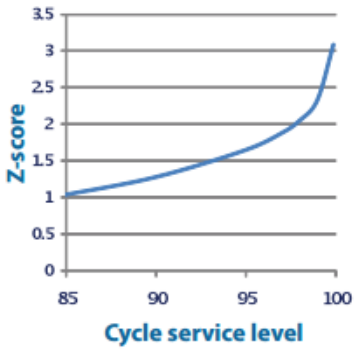


Figure 2-13 : service level and Z factor and relationship between service level and Z factor
Source : Adapted from Özge C., 2013 by author

Maintaining a low inventory cost is as important to a company as it is to achieve high service levels. The investment cost in the safety stock, along with a desire to maintain high level of service level, leads decision makers to a contradiction, which is difficult to deal with.

2.5 Service level

The level of customer satisfaction depends on the manufacturing company's ability to respond to orders with promptness (Beutel and Minner 2012). Many companies are facing a challenging trade-off between keeping low inventory levels and keeping high customer satisfaction level through on-time deliveries, illustrate in figure 2-14

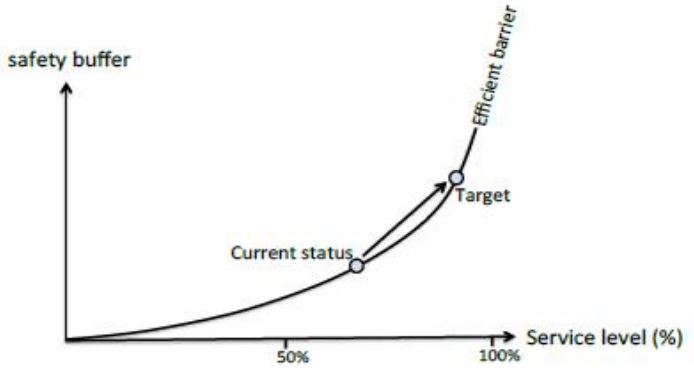


Figure 2-14 : The tradeoff between service level and amount of safety buffer
Source : Adapted from Spartt, 2006 by author

There are 2 main service level types used to keep track and control of inventory and successful of responding to demands (Shivsharan, 2012), which are cycle service and fill rate.

The cycle service – it is the probability of no stock out over the period (an inventory cycle), while fill rate – represents the portion of demand, which can be fulfilled with current inventory. As the definitions suggested, the cycle service and the fill rate express two different things, as illustrate in equation 2-5 and equation 2-6 (Jonsson & Mattsson, 2009).

$$Cycle\ service = 1 - \frac{No.of\ inventory\ cycles\ with\ shortage}{Total\ no.\ of\ inventory\ cycles} \quad \text{Eq. 2-5}$$

$$Fill\ rate = \frac{Part\ of\ demand\ that\ can\ be\ delivered\ directly\ form\ stock}{Total\ demand} \quad \text{Eq. 2-6}$$

To summarize, the cycle service is found to be easier to measure and calculate, while the fill rate give relatively lower average service level than what it is to be (Mattsson, 2013).

2.6 The Economics Order Quantity (EOQ)

As discussed in the inventory review policy, the question of how much to order is not answered yet, so, this section will review the most popular theory in ordering quantity (Relph and Newton 2014).

One of the most frequent decisions for managers is “how much” or “how many” of something to make or buy in order to satisfy both internal (production) and external demand (customers). Many times, this decision is made with little concern about its cost consequences (L.B. Schwarz, 2008). EOQ model was first developed by Ford Harris and R. Wilson in 1915. It is one of the oldest and most commonly known techniques in area of inventory management. The objective of EOQ is to determine economic order quantity (Q), which minimizes the total cost of an inventory. EOQ is a simple model that demonstrates the trade-offs between ordering and holding costs.

EOQ assumptions (MANS 3520, 2013) :

1. Demand is known and constant.
2. Lead time is known and constant. (Lead time is the amount of time interval between orders is placed until it is received.)
3. All the items in order placed received at once. (Instantaneous replenishment).
4. Unit cost of the ordered item is the same. (no quantity discounts)
5. Ordering cost are known and constant (not depends on quantity ordered)
6. No shortage and order arrived just when we would have run out.

EOQ symbols (MANS 3520, 2013):

D = Annual demand (units per year)
S = Cost per order (THB/ order)
H = Holding cost per unit per year
(THB to carry one unit in inventory for one year)
Q = Order quantity

On above condition, there will be only 2 costs vary; first is the total annual ordering cost and second is the total annual holding cost. The shortage cost would not incur due to the assumption (Joffrey Collignon and Vermorel 2012). Since, unit cost is the same, total annual item cost will be constant and not effect by the order quantity. Inventory level will vary over time as illustrate in figure 2-14

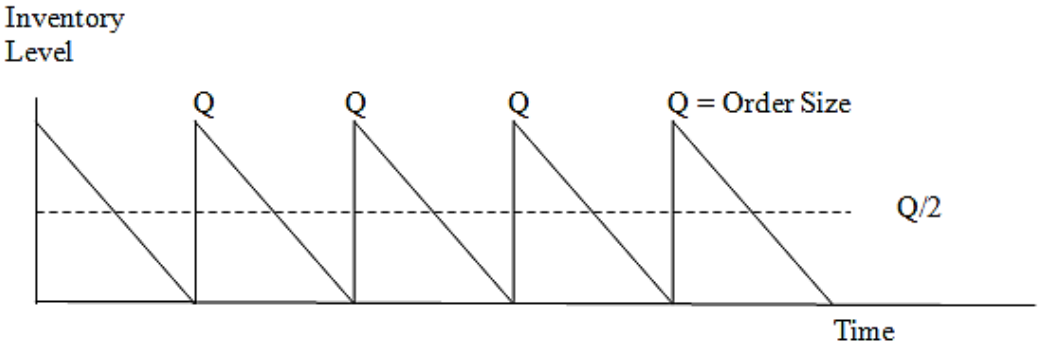


Figure 2-15 : inventory level over the time period of EOQ model. (MANS 3520, 2013).

Consequently, there are only 2 costs need to be considered for the EOQ model; the total annual ordering costs and the total annual holding costs (MANS 3520, 2013). These can be defined as follows:

Annual ordering cost	=	(D/Q)S
Annual holding cost	=	(Q/2)H
Total annual cost	=	TC = (D/Q)S + (Q/2)H

So, the EOQ present when,

$$\text{Ordering cost} = \text{Holding cost}$$

$$(D/Q)S = (Q/2)H$$

$$Q2 = (2DS)/H$$

$$Q^* = \sqrt{2DS/H}$$; Q^* is the optimal value of Q or called EOQ

Figure 2-15 displays the total cost curve, which is U shaped and reaches its minimum at the quantity for which the carrying and the ordering costs are equal. We can equate both these values to obtain the optimal order quantity Q*.

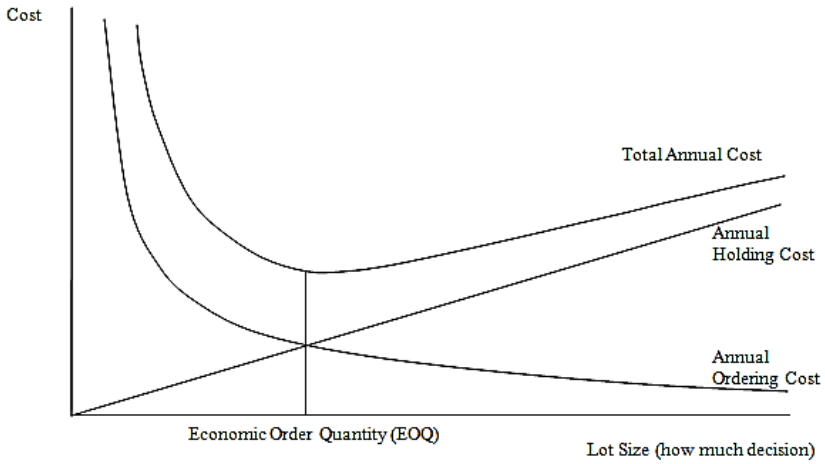


Figure 2-16 : The total cost curve.of inventory (MANS 3520, 2013):

Limitations Of The EOQ :

- Note that the EOQ formula is derived under several rigid assumptions which give rise to limitation on its applicability.
- In practice, the demand is neither known with certainty nor is uniform over the time period. If the fluctuations are mild, the formula is practically valid; but when fluctuations are wild, the formula loses its validity.
- It is not easy to measure the inventory holding cost and the ordering cost accurately. The ordering cost may not be fixed but will depend on the order quantity Q.
- The assumptions of zero lead-time and that the inventory level will reach to zero at the time of the next replenishment is not possible.
- The stock depletion is rarely uniform and gradual.

2.7 Storage management

2.7.1 Warehousing and warehouse design

Warehouse design is based on study of required inventories and management of inventory levels and based on the suitable of each operation by focusing on efficiency and safety.(Abbasi 2011) The objective of designing layout of warehouse is to minimize the unnecessary movements of material handling and inefficiency of space utilization. Warehouse layout design and optimization can improve efficiency of operations, which finally leads to cost reduction, lead time improvement while maintain or increase service levels.

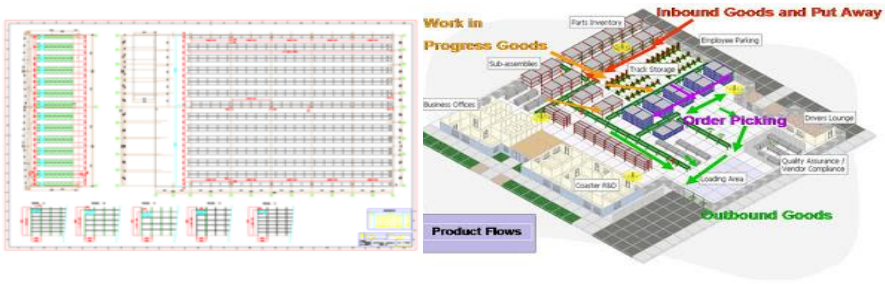


Figure 2-17 : Warehouse layout
Source : http://dcmproj.blogspot.com/2009/01/effective-warehousing.html

2.7.2 Process in warehouse

There are many steps in warehouses from receiving goods until their delivery to customers, including the following (Abbasi 2011)

- Receiving: products unloaded from transport trucks
- Inspection and quality control: product received must verified by inspection and quality control
- Put away: products move to storage area and location
- Order picking: product picked follows order
- Preparation for transportation to shipping area: Items are ready for delivery,
- Transportation of goods

Chapter 3 : Define Phase

In this define phase, current operation, process and data will be identified, which these current study will lead to problem identification. After that, cause of problems will be determined by creating cause-and-effect diagram to elaborate each factor and identify its important and suggest area to improve. Moreover, the measurement parameter will be proposed in order to measure the result of solution proposed.

3.1 Current process study

3.1.1 Overall process study

Overall process is illustrated in order to understand and reveal the dependencies and relationships between several departments within CMD Company. CMD is a company which adopted the make to stock policy, for the purpose of stay promptly to responds the customers' demand. As a result of the policy adopted, company has to purchase raw materials and manufacture based on forecast. As mentioned in the introduction part, CMD's customer normally forecast their demand to CMD 3 months in advance, in monthly basis.

The order fulfillment of CMD is triggered by customer's demand forecast, when forecast demand provided to CMD by customers, production department will normally assess those forecast and then convert it to first, production plan, and secondly, they translate those demand of finish goods to raw materials requirement follows each type of product's formula. Then, production department handover this data to warehouse, in order to check in current quantity of raw material in stock. After that, warehouse will pass the information to purchasing depart, to issue the purchasing order.

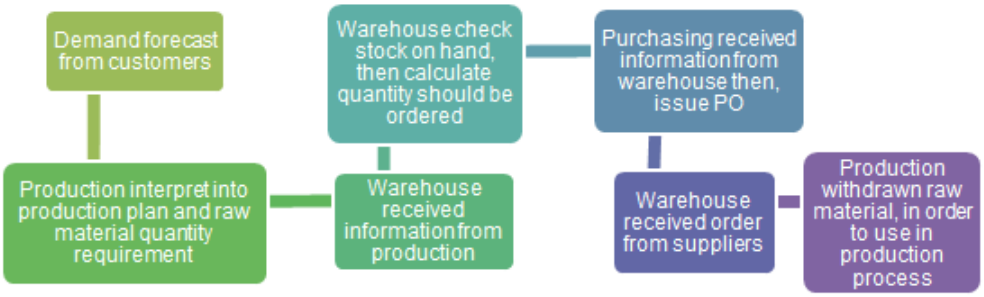


Figure 3-1 : Overall process of CMD Company

Customers

- Customer prepared forecast of demand for the whole year at the begining of the year and forward to the company.
- Customer further creates the 3 months in advance forecast of demand and forward to production manager every begining of each quarter.

Production

- Production manager recieved information by e-maill
- Production manager then assess the forecast information and convert it to production plan
- Production manager translate the information into raw materials requirement by calculating follow each type of product 's formula.
- No certain calculation method exist, production manager calculate this by hand and his experience.
- production staff forward the information to warehouse staff in paper based

Warehouse

- Warehouse received information and check on hand inventory (physical inventory currently sits in warehouse) by walking into warehouse and counting the amount of them.
- Then, calculate the real quantity to be order subjected to manager's judgement, this process also done by hand calculation and paper based.
- Warehouse forward the information calculated to purchasing by paper.

Purchasing

- Purchasing recieved information and then issue PO to each suppliers
- Quantity to be order sometimes adjusted due to suppliers limitation and policy.

Warehouse

- Warehouse recieved raw materials from suppliers follow the timel line
- Warehouse putaway raw materials recieved into random, free space inside the warehouse
- There is no labelling process or any appropriate information record
- There is no quality and appropriate quantity checking of raw material recieved

Production

- Production issue withdraw form of raw materials to use in production process
- The quantity withdrawn is estimated
- When prodution finished, the unused raw material will return to warehouse by production staff
- No appropriate record of return quantity and it have been place in some random free space inside the warehouse

Figure 3-2 : Overall process (detailed) of CMD Company

The important point of studied current process is to be able to identified problems and area to improve. From overall process analysis, as the current process involves a great deal of human factor, which leads to complexity, arguments and confusion during production, inventory control and purchasing. From careful investigation, the conclusion is that currently there is no effective and systematic inventory control policy. The subjective judgment of all department leads to unsynchronized information flow that resulted in high inventory levels for both raw materials and finish goods. The inventory control policy will help this situation.

3.1.2 Primary problem observed

From current process study and analysis, the primary problems can be observed during each process as illustrate in figure 3-3 below,

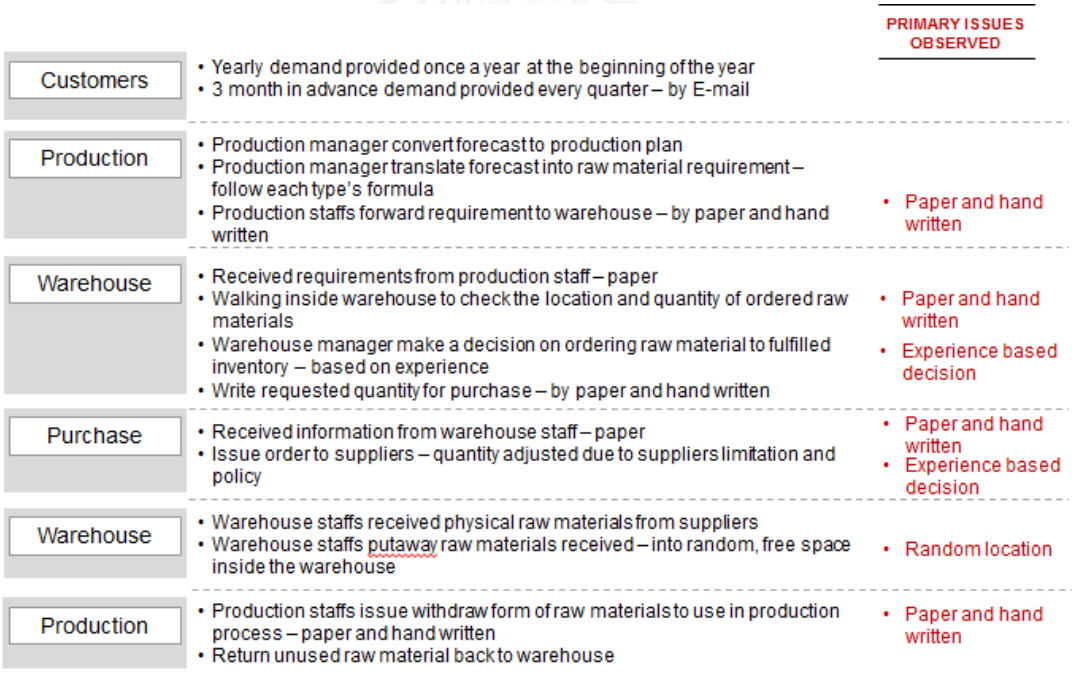


Figure 3-3 : Primary problems observed

From figure 3-3, primary issues observed from current process study indicated that CMD's process is currently relying mostly on human and decisions are made based on experience. In addition, traditional communication; pen and paper is now being used.

3.2 Current data analysis

3.2.1 Inventory data

Refer from chapter 1, statement of problem clearly identified that CMD Company is having a problem of excess inventory, which cause from both external factor; customer's policy to decrease price 5% every 3 year and numerous of internal factors, which mainly in an area of inventory management. Refer from figure 1-9 and 1-10, the inventory quantity and value keep raising and cost per unit shows the matching trend, while the finished goods sold shows the conversed situation, the focus is now on the unit cost. The cost breakdown is done to analyze the component of the cost, which will give a clearer picture.

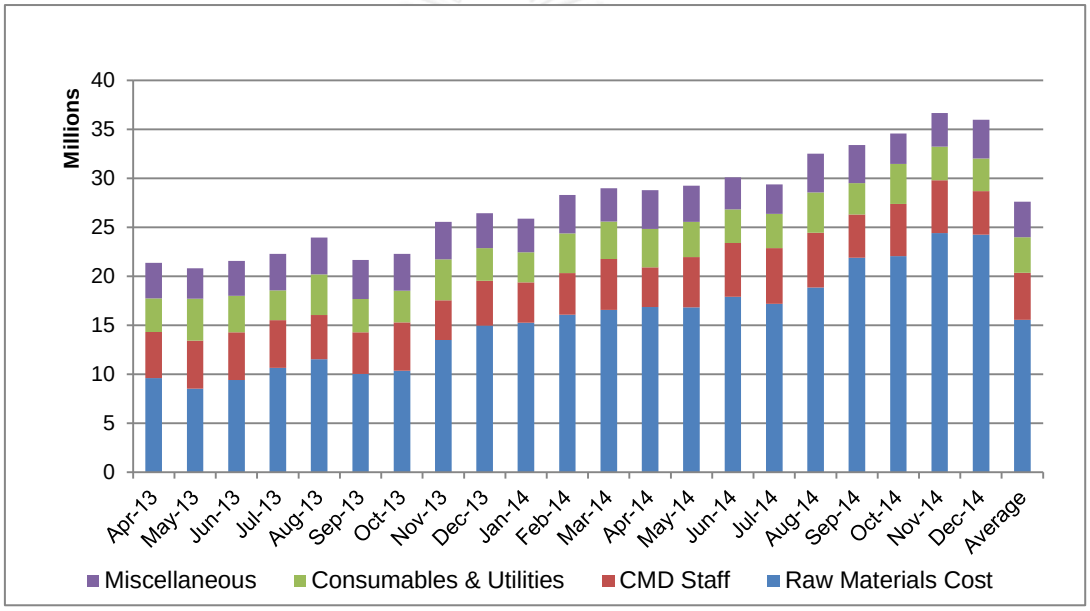


Figure 3-4 : Cost structure breakdown

As figure 3-4 above, cost structure breakdown shows the cost components in each unit of raw material monthly from April 2013 to December 2014. The raw material cost is the big main portion, this include the packaging cost, which continuously increase. The CMD staffs cost and consumable & utilities portion is average at 22% and 16% respectively. These 2 portion shows relatively steady trend compare to the raw materials cost. The miscellaneous cost is the cost that CMD cannot justified but from interviewing relevant person and author's opinion, it is the cost of facilities depreciation, bank charges, material handling equipment (MHEs), other maintenance cost and overhead cost, which account in average of 20% of the total cost.

The cost component shown is the estimation from quite a limited data. From the portion above, other costs portion except the materials cost increase very little or remain about the same, which can translate that, the company is not expanding. The cost of staff is not increase which can interpret that there is no significant in hiring new staffs. The cost of consumables and utilities has a very small variation, which means that there are no major changes or activity, ex., renting a new warehouse or factory to expand factory capacity. CMD still have quite steady operation, numbers of staffs and also spending about the same amount on consumables and utilities.

Additionally, when consider the inventory on hand of first top 10 value of raw material the quantity trend is increasing as illustrate in figure3-5 below,

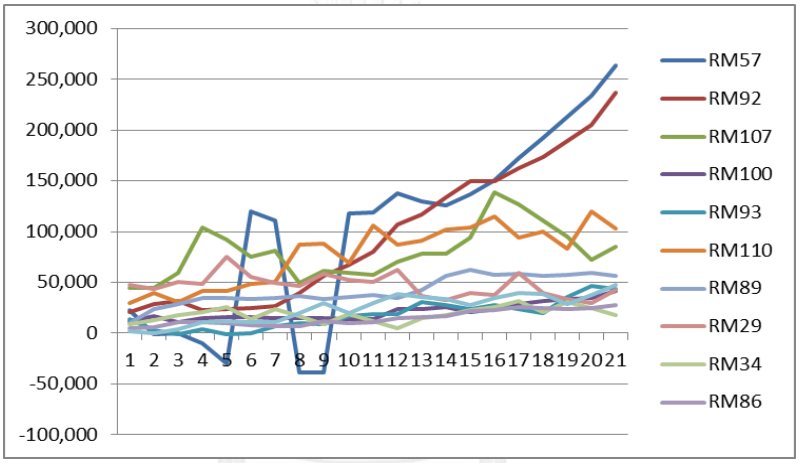


Figure 3-5 : 10 top value of inventory on hand trend

3.2.2 Cause-and-effect

Cause-and-effect diagram is a tool that helps to identify, sort out, organize and illustrate known or potential specific cause of the problem. It sometimes called an Ishikawa diagram, due to Kaoru Ishi invented it. It illustrates relationship between results and specific cause or factors that impact those results. In creating cause-and-effect diagram, involved persons needed to help in brainstorming to find the possible cause of the problems in a very structure and systematic way.

This will gather related departments together, brainstorm idea about the problem occur in CMD Company, it not only helps identify the real cause of problem, but it will help fulfill more knowledge of overall process across the company. Also, this will give an idea of how their work related. Cause-and-effect diagram of problem will be categorized and illustrated

In general, primary observation and both qualitative and quantitative analysis from data collected and discussed previously show that excess inventory is the main problem in CMD Company, which occur in 2 key areas; inventory management and warehouse management as presented in figure 3-6.

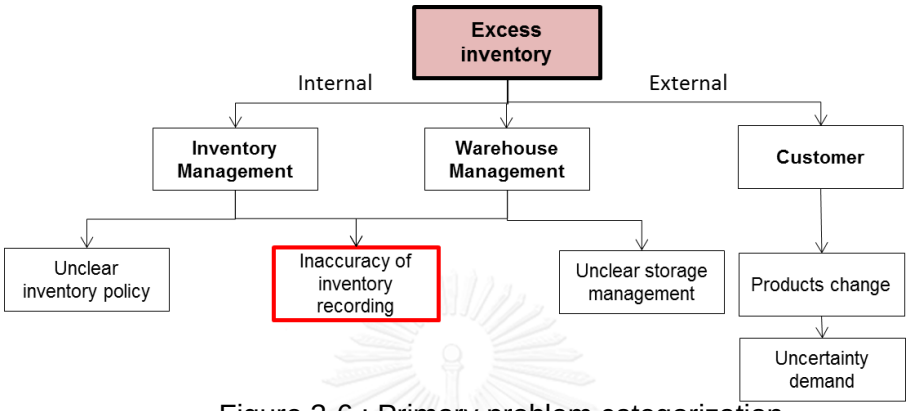


Figure 3-6 : Primary problem categorization

From brainstorming, the excessive inventory problem in CMD Company is mainly effect from 3 areas; the internal factors; the inventory management and warehouse management, and the external factor; customers. In aspect of external factor consideration, uncertainty in demand forecasting and product change may be the causes. But from earlier observation and analysis of data, customers forecast demand quite accurate and as they are large automotive manufacturers, their plan of production is quite accurate and has been forward to CMD every beginning of each quarter. For the point of products change, which can lead to unused raw materials ordered, there has rarely chance to occur, due to for the automotive manufacturer to change products they used in manufacturing, it took long time, about a year or more than that because several factors needed to be considered, so CMD have time to prepare and plan for stop ordering those canceled raw material.

On the other hand, the internal factor, the inventory management, there is no clear inventory control policy; as warehouse manager make decision based on personal judgment, and there is also no proper inventory recording as described in the current process study. For Warehouse management area, the unclear storage management and also inventory accuracy are main effect to the problem. To elaborate more in details of the causes for each primary problem stated, cause-and-effect diagram will be created and demonstrated below,

3.2.2.1 Unclear inventory control policy

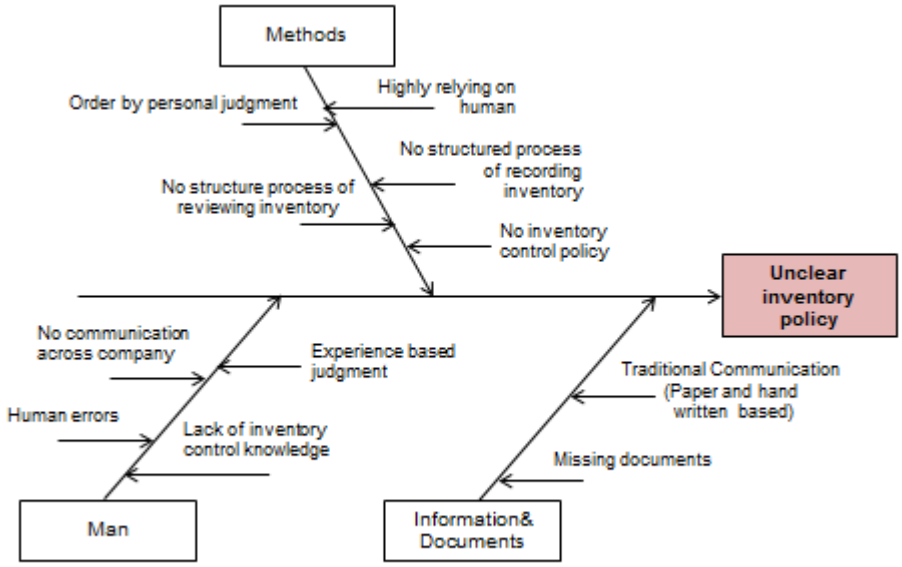


Figure 3-7 : Cause-and-effect diagram of unclear inventory control policy

For unclear inventory control issues, 3 main factors have been identified, which are man, method and information & documents. Refer to cause-and-effect diagram, Man factor; experienced staff may anticipate customers demand by experienced and don't trust the forecast. They may add up the demand, due to they believe that having more than need is better than don't have raw material to manufacture for the customers. Moreover, each department makes their own subjective judgment, for example, purchaser may agree on higher order quantities than necessary due to special agreements or purchasing price discounts. Warehouse staff my feel that the information from production is unreliable enough so they deviate from that suggested quantity. Staffs of CMD is lack of knowledge in inventory control, so they do everything from experience, CMD currently don't have any systematic in calculating how much to order and when to order which make the whole process highly relying on human. In addition, CMD using traditional way of calculating and communicating, which is the paper and pen. The big problem of this traditional way is that, they are not accurate and the documents are always missing.

3.2.2.2 Inaccuracy inventory record process

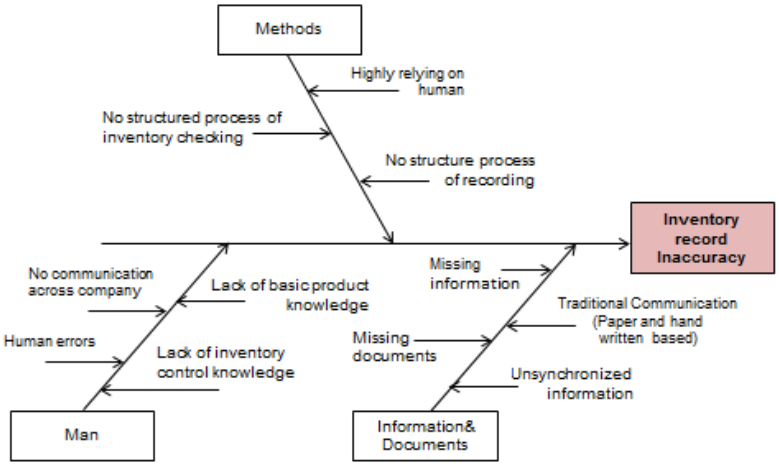


Figure 3-8 : Cause-and-effect diagram of inaccuracy inventory record

As discussed earlier, the inaccuracy of inventory record contributes to both problem in inventory management and warehouse management. there is no structured process in inventory control, so as inventory record, no structured process too. Some staffs check the quantity and record, while some don't. the information the has been recorded is also depends on staffs decision. At the moment the company is almost fully rely on its staff skills of recording information. Almost all the time that items in the warehouse are misplace and causing error when the staffs trying to check the quantity. This cause was found out during the interview section and data collecting process. One specific example of inventory record inaccuracy at CMD is, when the data of inventory on hand received from warehouse, the author randomly choose 5 items from the list, and checking the physical quantity of them inside the warehouse. What have been found is that the quantity stated in the record is differed from physical inventory sit in the warehouse for every item.

In addition, Most of staffs do not understand the importance of recording; they do the count and record mostly on approximation method. Most of staffs in warehouse familiar with the items and know by experience what the item is, but for new comers, they just have to guess or ask from experienced staff, in order to know what the item is. Human factors is a the biggest impact stock record accuracy. On the other hands, CMD currently do not have any system or any procedures for staff to guide them. The staffs just record in their own way, different staffs record in different styles, mainly on a piece of paper, which almost all the time cannot find when needed.

Another reason that affecting the inventory record accuracy is the documents related to inventory is unclear. Staffs at the warehouse don't know the real quantity ordered by purchasing, so they just receive and count, with no idea if it is the right quantity that have been ordered or not. There is also no label on the received items, so the product is not identified, which create confusion. Moreover, when staffs want to recheck the quantity, they cannot find the items or sometimes the same items stored at many different place inside the warehouse. Due to one staff handle the counting process and the other staff put those receive into random empty location without any communication.

3.2.2.3 Unclear storage management

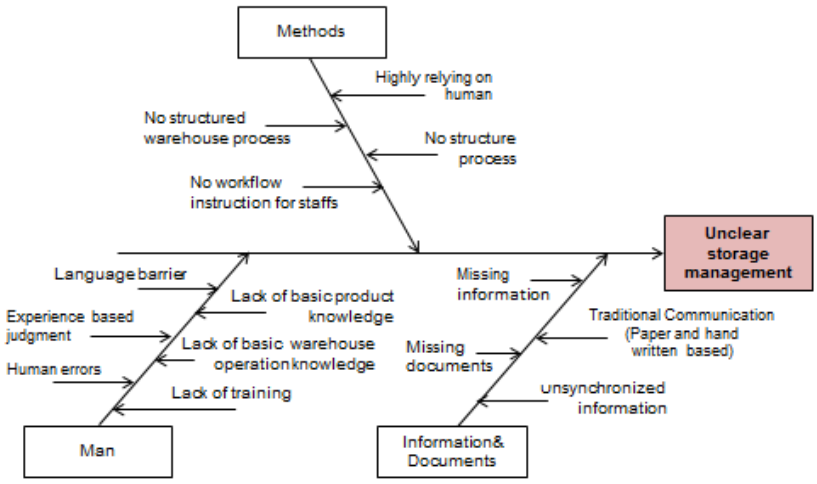


Figure 3-9 : Cause-and-effect diagram of unclear storage management

As discussed above, unclear storage management considered as a main cause of warehouse management. So, the cause-and-effect diagram of this is created.

For the man factor, warehouse staffs never have any training of the process in warehouse, they receive and put the item in location as the way they like, CMD do not have standard procedure for them to follow so, it is hard to control. Sometimes they count the item quantity, sometimes they don't, sometime they put away right after the item arrived but sometime the items stay on the floor for a week. Moreover, some staffs cannot understand English, the name of items some are English so, they don't know what it is. Or maybe staff cannot understand other staff's handwriting. There is always a common human error when human involved in the process, for

example, the counting may be wrong or they may right the wrong numbers into the paper based receiving sheet or even they may write the wrong product name.

Besides, the warehouse has no zoning, items can store wherever there is a space. When there is a request for the items, staffs have to walk around the warehouse to find them. Since location to store item is not predetermined, some of the items may store in 2 or more places, which create a heavy confusion in the quantity and also hard to find.

3.3 Measuring inventory control performance

To understand how well inventory is managed, Current key performance indicators (KPI) of CMD's will be reviewed in this section, which comprises of

- 3.3.1 Inventory holding days
- 3.3.2 Inventory level
- 3.3.3 Inventory value
- 3.3.4 Service level
- 3.3.5 Numbers of orders issued

The value of those KPIs of current process are calculated based on information collected from January 2015 – April 2015, total of 4 Months, presented as below table

Items	Inventory days	Inventory level	Inventory value	Service Level	Numbers of order
RM57	70	291,637	14,436,047	100.00%	7
RM92	59	167,277	15,556,742	100.00%	6
RM107	49	97,642	9,471,247	100.00%	7
RM100	53	94,826	8,249,882	100.00%	7
RM93	57	82,261	7,156,719	100.00%	5
RM110	52	74,589	7,160,525	100.00%	5
RM89	43	71,127	6,188,021	100.00%	7
RM29	62	95,984	4,415,254	100.00%	7
RM34	35	68,140	3,611,437	89.00%	7
RM86	64	72,484	2,754,385	100.00%	8
RM59	51	38,188	1,833,037	100.00%	4
Total	**595**	**1,154,155**	**80,833,295**		**70**

Table 3-1 : Current Key performance indicators (KPIs)

This KPIs will also use to measure the proposed method and solution in the implementation phase

3.4 Summary of define phase

After study the overall process of CMD Company, inventory control, inventory ordering process, analysis of inventory data, interviewing related persons and observing the real process, the problems and causes that affect the problem have been identified and presented through cause-and-effect diagram. This phase helps to explore and understand the real situation and behaviors of staffs in CMD Company that have major effects on excess inventory problem.

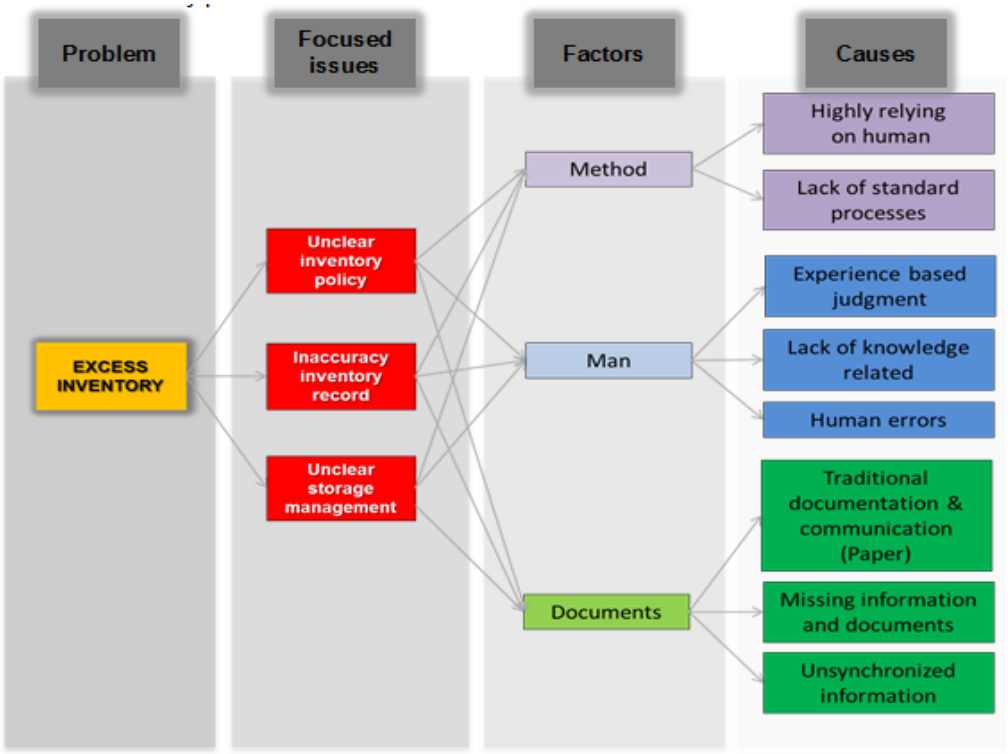


Figure 3-10 : Summary of define phase

From figure 3-10, the summary of problems defined has been summarized. *Excess inventory* is main problems that can be observed by just walking into the warehouse, plenty of physical inventory have no proper place to stored and have to stay on the floor, the quantity continue to raise so that the new incoming orders have to stay outside the warehouse. Next, when excess inventory observed, data have been collected in order to analyze in standpoint of quantitative information, to confirm to observation.

When the problem is confirmed, that the inventory is really excessed, then, CMD gather the staffs who involved in processes to help brainstorming to understand the cause of problems. After that, 3 main issues that contribute to excess inventory are identified, which are unclear inventory policy, unclear storage management and inaccuracy of inventory record. These three issues can be categorized into two areas; unclear inventory policy categorized in inventory management area, unclear storage management categorized in warehouse management area and inaccuracy inventory record are effect in both area.

To elaborate more in details, those three issues identified will be the focused. Cause-and-effect diagram, will be used in identify, sort out, organize and illustrate known and potential specific cause of each issue. Persons who involved in process are asked to join in creating this diagram as already illustrated in figure 3-6, 3-7 and 3-8. To summarized, there are three main factors that affect each issue, *man*, *method* and *information & documents*.

For man factor, it can conclude that at the moment, CMD depends almost purely on human; decision is made based on experience. Lack of knowledge is as well one of the main causes, for example, inventory control knowledge and warehouse operation knowledge, when lacked, staffs have to do things same as the ways they have been done, which is rely on experience and also there is a cause of human error, which unavoidable.

For Method, from overall observation and analysis, one major cause to the problem is CMD process structure is substantially relying on human without any standard process or workflow as a guideline. When there is no standard process, staffs will do whatever, whenever and however they want. This leads to unsynchronized information throughout the company. Moreover, there is no systematic and standard processes, tools or procedure to help in determine reliable appropriate level of inventory.

For information & documents factor, in term of information flow, based on current process study and cause-and-effect diagram, when information flow through each department involved, subjective judgment is made at every single department, the information received act only as a benchmark to the department due to they don't have trust, deviation is made from suggested quantity, unsynchronized information occur. In term of documents, with no standard document form, and paper based documents, they keep missing almost all the time. Additionally, when working with many people, many departments, unclear, unreliable and unsynchronized information and documents lead to complexity and confusion.

Finally, based on overall observation, current process study, data analysis and cause-and-effect diagram, causes are defined and listed above in figure 3-10.

Chapter 4 : Proposed Phase

The purpose of this phase is to develop and propose solution for improvement of inventory control process and warehouse process to achieve research objectives with helps of tools and techniques review in chapter 2. As previous chapter,3, has already pinpoint and clarify problems, the chapter will begin with Stock keeping units of raw materials' classification, proposed inventory policy are suggested and discussed, proposed stock record process are outlined and propose solution for warehouse issue.

4.1 Solution and methodology proposed

As above discussion on cause and effect of the problem in CMD Company, causes have been defined. Proposed solution and methodology will be presented and explained follow the summary relationship diagram in figure 4-1

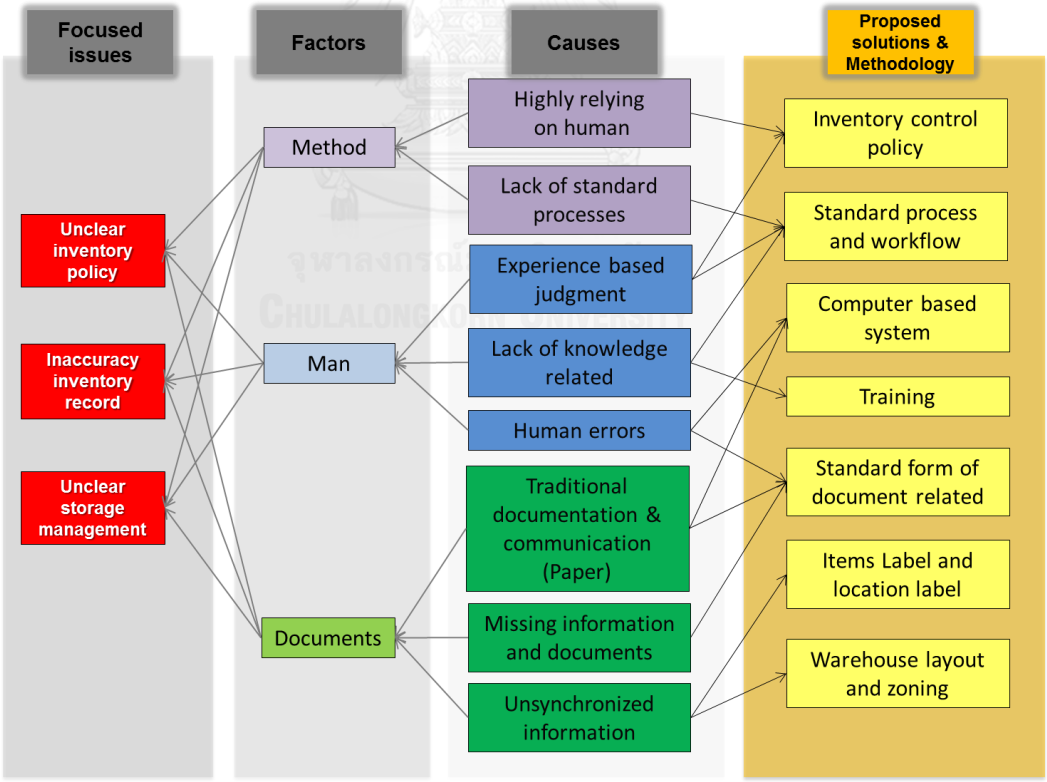


Figure 4-1 : Proposed solutions and methodology for defined problems

As above discussion on cause and effect of the problem in CMD Company, solutions and methodology have been proposed and listed in figure 4-1; which are set up an inventory control, establish standard workflow process, create computer based system, conduct training, create standard form of documents, create labels and redesign warehouse layout and zoning. For setting up inventory control policy, it will help reduce the process that depend and relying on human and reduce decision that based on experiences. Policy set up would be a tools and guideline helping in making decision.

Standard processes and workflow are proposed in order to directly cope with the lack of standard process defined, and to cope with experience based decision, so that decision made is based on policy set up and standard process and workflow. Also, with this, staffs that not familiar with process or newcomers are able to understand and work follow those standard.

Computer based system is proposed as a direct objective of reduce traditional documents and communication; paper and hand written based, in company. This computer based system of inventory record would play an important role, which should be designed and used to maintain the data, in order to be able to share with every related department in the company and help to support the company operation, which would result in more synchronized information throughout the company. Additionally, the human error, although it is unavoidable, but will certainly minimized by this computer based system.

Training should be one of the proposed solution and methodology to cope with the lack of knowledge of staffs, but it seems like a long term solution, due to one of the major causes stated in cause-and-effect diagram is lack of knowledge.

Standard form of each documents related are proposed, so that staff will have to fill in the same set of information in a standard form, information won't be missing and also reduce some of human error too. As mentioned several times, there is no appropriate form of any document. Range from raw material request by production to warehouse, order to be order from warehouse to purchase, receiving form, issuing form and label on both items and location. This unclear document lead to high confusion between process to process and also lead to ever problems mentioned

above. Without well manage documents, the whole process rely in on staffs' skills, which result in error and personal judgment as mentioned. This lack of proper document also leads to poor visibility of inventory. Therefore, to improve, a standard form of each document related should be created; this can indirectly force staff to fill in the information needed in a place prearranged.

Addition to that, label to attach on items will be create for staff to attach to the item right after they finish checking and counting the received items, as well as the label for location that should be created too. These labels would reduce wrong information, which leads to unsynchronized data and error from human. Lastly, warehouse layout will be redesign and categorized raw material into zone, in order to help staff work easier and more effective.

In summary, proposed solutions are presented for the intention to cope with excess inventory problem in CMD Company, which currently a major problem that leads the company to operate at a loss. These proposed solution are, inventory policy set up, created standard workflow process, create standard form of document related and redesign warehouse layout, which will be categorized into two main area discussed earlier; inventory management and warehouse management for better understanding. The categorization illustrate in figure 4-2

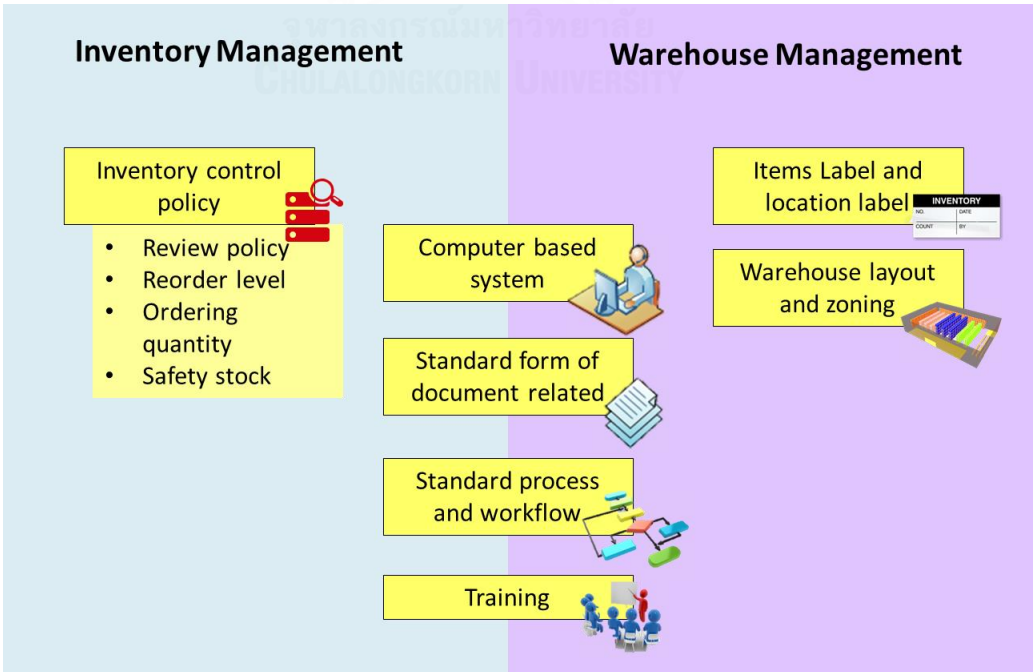


Figure 4-2 : Proposed solutions and methodologies categorization

The inventory control policy is in the area of inventory management, which consists of choosing suitable review policy, identified reorder level, ordering quantity and level of safety stock. For warehouse management, items label and location label will be created and redesign warehouse layout and zoning. For the computer based system, standard from of documents related, standard process and workflow and training will be proposed to support both warehouse and inventory management.

4.2 inventory policy control

In order to set up the inventory control policy, As mentioned in the first chapter, CMD offer wide range of adhesive and sealants, around 80 permanent types of adhesive and variety of customization for customers to order. This wide range of products resulted in more than 150 types of raw materials to be stock in order to support production process. The 150 types of raw material will be analyze using ABC classification method reviewed in chapter 2, because dealing with all 150 types would consume too much time and resource. So, the inventory classification should be done. There are 2 main goals for classification, first is help separate to important or critical SKUs from the normal ones, and second is to help in determine different inventory control policies to each different class. By ABC classification, CMD will be able to pay attention to the right group of raw material. After raw materials are classified into groups, inventory control policy will be selected for each group according to the characteristic analyzed and applied. The information will be discussed follow the step and section number in figure 4-3

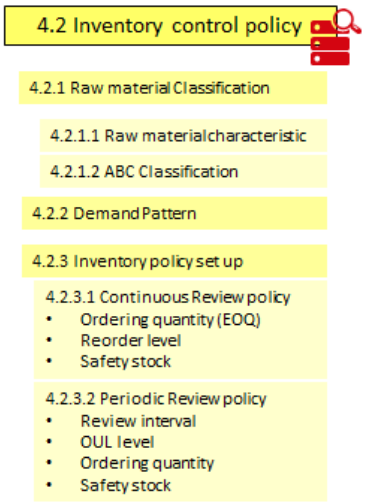


Figure 4-3 : Overview of Inventory control policy discussion step

4.2.1 Raw material classification

4.2.1.1 Raw material characteristics

Before classification, the characteristic of raw material will be discuss and analyzed. As mentioned earlier in chapter 1, CMD offer mainly for automotive sector and 80% of the finished goods serve two main customers from the sector. Raw materials can be classified roughly into four groups according to it physical, which presented in figure 4-4.

Type	Description	Example of package
Drum and Big bag	This type of raw materials normally have 1.6 m. in height, which is higher than standard pallet (1.2 m. heigh). Also this type of raw materials is major component of almost every types of finished products	
Powder bag pallet	This type of raw material have highest percentage from total raw materials, about 65%. This type of raw materials normally came in as a pallet, height of 1.2 m.	
Rubber based pallet	The rubber based raw material came in as a pallet, with normally 1.2 m. in height. Yet it rarely being used.	
Small size bag and liquig can	This type of raw material came in relatively small package compare to the rest of raw materials of CMD	

Figure 4-4 : Raw material characteristic of CMD

4.2.1.2 ABC Classification

To properly classify the inventory items, first, data of demand and unit cost of each item are collected during the study period, April 2013 – December 2014. An ABC criterion used for to analyze in this research is the annual inventory value. For CMD case, annual inventory value use as a criteria because the objective of this research is to improve inventory management which mean minimize related cost, So, inventory value is the value that reflect cost related. It would show that which items of raw materials have significant impact on but not only consider the amount of money that has been locked to inventory but also reflect the quantity of each raw materials used. Through this categorization, the supply manager can identify inventory with high value and high usage, then able to separate those out from the rest, particularly

those that are many but not that high value. The annual inventory value calculated from annual demand multiply by item cost per unit. Then, estimate annual inventory value by multiply unit cost and demand during the period. Then, List the items value in descending manner, accumulate the value, calculate percentage on total inventory value. Last step is the draw a graph of items list and percentage value, categorized items into Class A, B and C follow the Pareto rule.

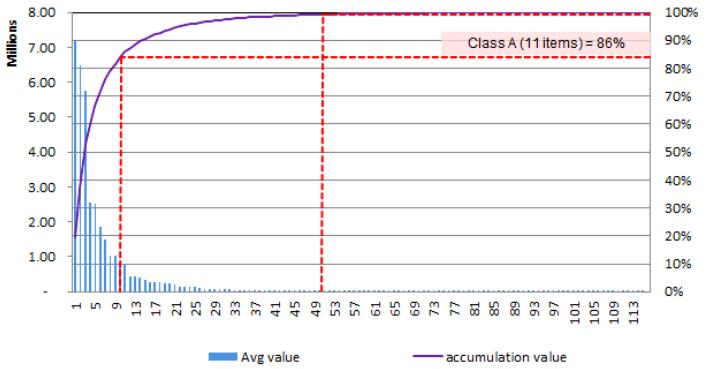


Figure 4-5 : Pareto diagram of ABC Classification of raw material inventory of CMD

After the data was convert into graph – Figure 4-3 above, the result display the same trend with Pareto's diagram, which states that a small percentage of items account for a large percentage of value. The total of 11 items of raw material considered to be in class A due to these 11 items out of total 150 items contributes to 86% of total inventory value, which is a very big portion. While, Class C consist of 65 items, but contribute to very small portion, 1%in total inventory value. Class B consists of 39 items that contribute to approximately 20% of total inventory value.

To continue further analysis, the data of inventory on hand of items in class A are collected and explored. When focus on class A, the trend of inventory still display similar trend of an overall trend. Inventory on hand is increasing gradually from April 2013 to December 2014.

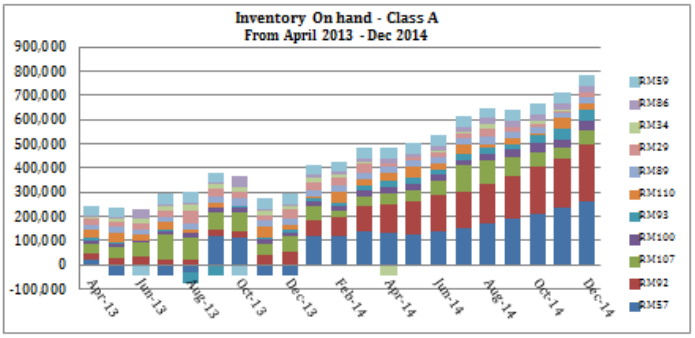


Figure 4-6 : Inventory on hand of class A during April 2013 to December 2014

Class A items of raw material are the common component, which is the main component of several type of adhesive and sealants, which have been use in almost every types of finished product. Class A not only contributes a large portion in term inventory value, but also in term of consumption. For Class B and Class C raw material list will be present in appendix C

From overall current process study and data analysis, overall process start from receive customers' forecast, translate that forecast into quantity of raw material requirement and situation of inventory of CMD Company have been assessed and explored, current data analysis show that inventory quantity increase significantly in class A, which shown similarity to overall trend. This can be resulted by several causes such as high fluctuation in demand or unsuitable inventory control. In addition to that, the real demand pattern should be studied.

4.2.2 Demand pattern

To elaborate the general idea of how varied the demand pattern for different items can be, the outbound charts for six inventory items are presented. As aforementioned, inventory has been classified by ABC classification theory. The demand value of 2 items of each class will be presented. In figure 4-7 and 4-8 represent the example of demand pattern of class A, so they expected to have relatively stable and high demand.

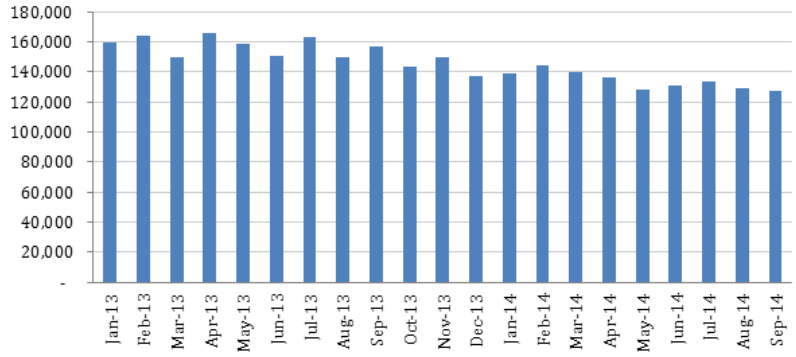


Figure 4-7 : Monthly demand of RM 57 (Class A item)

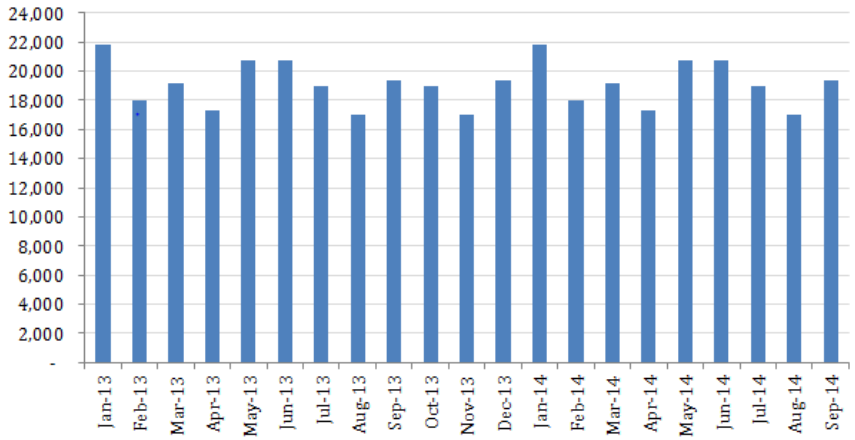


Figure 4-8 : Monthly demand of RM 57 (Class A item)

It can be observed from the sample demand pattern from Class A that the variation of demand is only about 8 – 20% between individual months within an observed year and the average co variance (CV) is . 0.13 which consider as low fluctuation.

For Class B inventory, demand pattern are shown in figure 4-9and 4-10 . For this RM 48 and RM 88 are selected as a representative of class B.

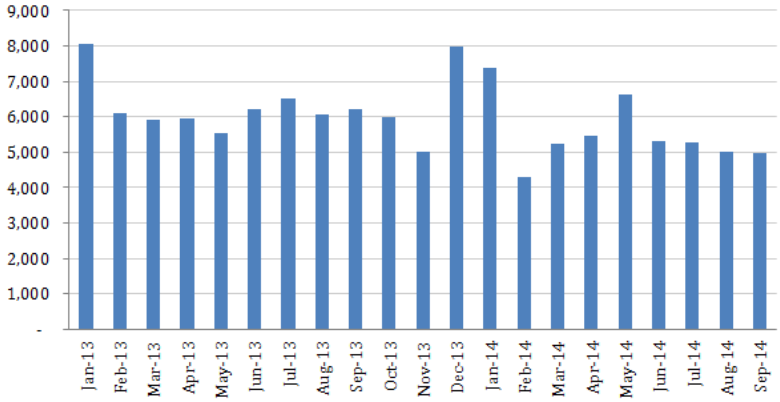


Figure 4-9 : Monthly demand of RM 48 (Class B item)

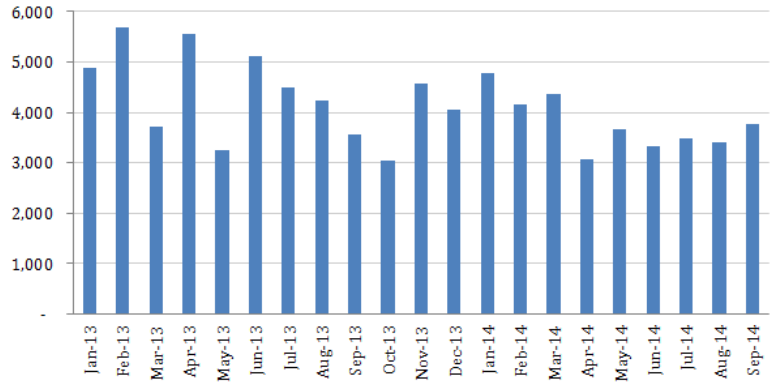


Figure 4-10 : Monthly demand of RM 88 (Class B item)

Figures 4-9 and 4-10 shows that demand pattern having higher variation if compare to class A and relatively with quite lower demand. For class B, percentage of variation that can be observed is up to 55%.

Lastly, for class C inventory, very variety of demand pattern can be observed as display in figure 4-11

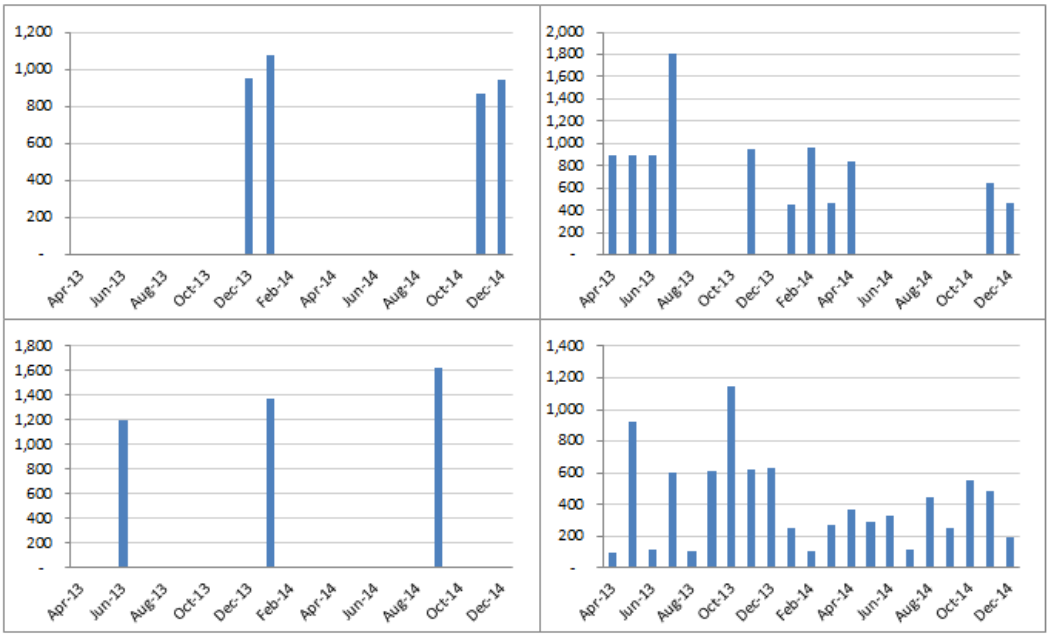


Figure 4-11 : Samples of monthly demand of Class C item

As a result from overall raw materials characteristic, classification and demand pattern, Group A have the highest accumulated value and high demand with lowest fluctuation, while Group C have highest number of items but got lowest accumulated value with highest fluctuation and very hard to predict. Group B items is in the middle, value of this class contribute to about 20% of total inventory value with medium demand fluctuation. The inventory control policy will be analyzed and set up for each class of raw material appropriately according to each group characteristic.

4.2.3 Inventory Control policy set up

Inventory control is required in order to control inventory in more efficient way. The literature reviewed in Chapter 2 will translated into applicable solution for CMD's inventory control problem. Which and how policy should be applied, how safety stock, reorder point and Economics order quantity should be determined will be explained. As the previous section, examples of demand pattern of each class have been presented. By refer to Joffrey C. and Joannes V., 2012, each item should get a weighted treatment correspondence to its class. All inventories cannot be controlled with equal attention.

This section will discuss on policy set up for each class of Inventory. After SKUs of raw material have been classified into 3 classes by ABC theory and from the fact that it is not possible to treat every SKUs equally, because of too much time and resource consuming, Classifying SKUs in to classes help prioritizing the attention require to less important class and focus on the class of SKUs that affect most. In addition, as review in chapter 2, there are two types of inventory review policy; continuous review and periodic review, advantage and disadvantages of those have been stated.

To capture, the pros of continuous review, it provides closer control, which reflects the need of Class A items, and also less safety stock needed. The quantity of items will be review immediately after each withdrawal. While for periodic review policy, less strict and effort need to put in. The inventory level is periodically reviewed on daily, weekly, monthly or yearly basis but the order size is varied. The advantages of periodic review is that the review period is set, so it do not need the monitor the level of each SKUs separately, less resource and time consume, which suitable for class B and C, due to the higher number of SKUs is in these two B and C class, it would be

too hard to monitor the level of each SKUs separately. The summary of policy set up present in the table 4-1 as follow,

Class	Demand characteristic	inventory review policy
Class A	High demand with low fluctuation	Continuous review policy
Class B	Medium demand with moderate fluctuation	Periodic review policy
Class C	Random demand pattern with high fluctuation	Periodic review policy

Table 4-1 : Summary of each class demand characteristic and appropriate inventory review policy

The method and information of inventory control policy will be discussed follow figure 4-10 below

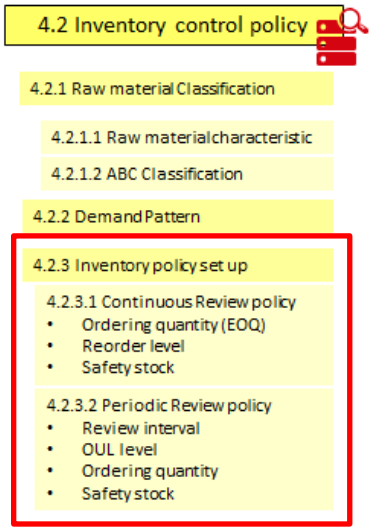


Figure 4-12 : Inventory control policy set up discussion step

4.2.3.1 Continuous review policy (Fixed order quantity model)

According to Chen, 2011, Class A inventory contribute to highest portion of value should be under the most strict and maximum control. In addition, as review in chapter 2, there are 2 type of inventory review policy; continuous review and periodic review, advantage and disadvantages of those have been stated. To capture, the pros of continuous review is it provide closer control, which reflect the need of Class A items, and also less safety stock needed. The quantity of items will be review immediately after each withdrawal. Hence, Class A, which contributes to a very large portion, the list of items in class A is shown below,

RM code	Goods Code	Goods Name	Packaging type	Kg/Unit	Price/Unit	UOM
RM57	02-MA-LI-003-02-A01	DINP	Bulk	15000	49.5	Kg
RM92	02-MA-PO-016-02-A02	Omyacarb-8	Bag	25	93	Kg
RM107	02-MA-PO-030-02-A01	Toson PVC Paste Resin R-750	Bag	20	97	Kg
RM100	02-MA-PO-023-02-A01	YCC Brand R-501	Bag	25	87	Kg
RM93	02-MA-PO-016-02-A03	Omyacarb-8	Bag	500	87	Kg
RM110	02-MA-PO-034-02-A01	Kane Vinyl Paste PBM-6	Bag	25	96	Kg
RM89	02-MA-PO-006-02-A01	Hakuenka CC	Bag	25	87	Kg
RM29	01-MA-PO-036-01-A01	Neolight SP	Bag	25	46	Kg
RM34	01-MA-PO-053-01-A01	Neolight SP-60	Bag	25	53	Kg
RM86	02-MA-PO-002-02-A05	Calcium Oxide	Bag	25	38	Kg
RM59	02-MA-LI-006-02-A01	Exxsol D-80 Fluid	Bulk	9000	48	Kg

Table 4-2 : List of raw materials items in class A

As a result, Continuous review is proposed to Class A inventory. There are 2 main questions that inventory policy need to answer, When to order and How much to order. These two questions will be discussed respectively within this section. Before the calculation in the next sections, the parameter to be used will be identified in the table 4-3 below,

Parameter	description		Fomular
D monthly	Monthly Demand	Information	
L	Lead time (week)	Information	
T	Review interval (week)	Information	
CSL	Cycle Service Level	Define	
Davg	Average Monthly Demand	Calculated	$\frac{Sum\ of\ Monthly\ demand\ (kg.)}{sum\ of\ number\ of\ month}$
D	Annual demand (units per year)	Calculated	Average Monthly demand x 12
EOQ (Q*)	Economics order quantity	Calculated	$Q^* = \sqrt{\frac{2KD}{h}}$
K	Ordering cost per order (THB/ order)	Calculated	$Top-down = \frac{Total\ amount\ of\ variable\ ordering\ costs}{Number\ of\ order\ lines}$
h	Holding cost /unit/year (THB to carry one unit in inventory for a year)	Calculated	30% of Unit cost
σ	Standard deviation (month)	Calculated	STDEV(range of monthly demand) - MS Excel
σweek	Standard deviation (week)	Calculated	STDEV(range of weekly demand) - MS Excel
µL	Average demand during leadtime	Calculated	$L\ (\frac{D}{52})$
σL	Standard deviation of demand during leadtime	Calculated	$(\sqrt{\sigma week})\ L$
µL+T	Expected average demand during lead time (L) and revie	Calculated	$L+T\ (\frac{D}{52})$
σL+T	Standard deviation of demand Lead time (L) and review i	Calculated	$(\sqrt{\sigma week})\ (L+T)$
Z value	Service factor	Calculated	Using Z table NORMSINV" function in Microsoft Excel
SS	Safety Stock	Calculated	Z x σL
R	Reorder level	Calculated	µL x SS
OUL	Target inventory level determined by the forecasts (Order up to level)	Calculated	µL+T + SS
Q	Order quantity	Calculated	OUL - onhand inventory at review period

Table 4-3 : List of Parameters in calculation

- EOQ calculation

  Refer to Chapter 2, Economic order quantity (EOQ) will help in proposing order quantity by consider each cost components mentioned. The mathematical equation for EOQ calculation is

$$Q^* = \sqrt{\frac{2KD}{h}}$$ (L.B. Schwarz, 2008)

Where;

Q* = Economics order quantity

K = Ordering cost per order (THB/ order)

D = Annual demand (units per year)

h = Holding cost /unit/year , according to Leroy B. S., 2008, Estimated to be 30% of unit cost.

EOQ equation has been applied to items in Class A and calculated using Microsoft Excel. Unit price is collected from purchasing department, annual demand calculated from data of demand during April 2013 to December 2014 – 20 months' period, averaged and converted to estimate annual demand (D). Table 4-4, present the average annual demand calculated.

RM code	Goods Code	Goods Name	Unit	Kg/Unit	Price/ Unit	Unit	Avg Demand /month	ANNUAL DEMAND (D)
RM57	02-MA-LI-0	DINP	Bulk	15000	49.5	Kg	145,802.00	1,749,624.00
RM92	02-MA-PO-	Omyacarb	Bag	25	93	Kg	69,586.11	835,033.33
RM107	02-MA-PO-	Toson PV(	Bag	20	97	Kg	59,236.11	710,833.33
RM100	02-MA-PO-	YCC Brand	Bag	25	87	Kg	29,160.56	349,926.67
RM93	02-MA-PO-	Omyacarb	Bag	500	87	Kg	28,833.33	346,000.00
RM110	02-MA-PO-	Kane Viny	Bag	25	96	Kg	19,350.00	232,200.00
RM89	02-MA-PO-	Hakuenka	Bag	25	87	Kg	17,308.78	207,705.33
RM29	01-MA-PO-	Neolight S	Bag	25	46	Kg	22,585.89	271,030.67
RM34	01-MA-PO-	Neolight S	Bag	25	53	Kg	19,466.67	233,600.00
RM86	02-MA-PO-	Calcium C	Bag	25	38	Kg	22,023.61	264,283.33
RM59	02-MA-LI-0	Exxsol D-8	Bulk	9000	48	Kg	16,893.56	202,722.67

Table 4-4 : Annual demand (D) calculation in Microsoft Excel

K is ordering cost per order, according to literature review, Jonsson & Mattsson, 2009 suggest to simplified and estimate the average order cost, instead of calculate each specific item's ordering cost because it would be too complex and difficult. The ordering cost is a variable costs that are happened when perform the ordering process, which include to all costs that directly depends on the amount of orders placed, but without concern on the quantity in each order. Walter D., suggest that ordering cost should comprise mainly of the costs of staffs time and effort expanded in raising order and following up with the suppliers and receiving goods into warehouse. The staff involve in this activity includes CEO, Managing director, General Manager supply, store manager and procurement staff. The portion of total staff cost take into account of ordering estimated at 35%. Other related cost is estimated at 30% of total of each component. The component directly incur when ordering is illustrate below, the number used in calculation, some are an estimation from interview session and some are data collection from CMD Company. Table 4-5 present the cost components and calculation of ordering cost.

Ordering cost		
	Monthly	**Yearly**
Labour cost	1,265,000	15,180,000
Indirect Lanour	1,135,000	13,620,000
Direct Labour	130,000	1,560,000
Warehouse cosumables & Utilities cost	150,000	1,800,000
Warehouse Equipment	120,000	1,440,000
Office consumables & Utilities cost	100,000	1,200,000
Miscellaneous	100,000	1,200,000
Total ordering cost	**3,000,000**	**36,000,000**
Numbers of purchasing order	**40**	**480**
Ordering cost per order (K)		**75,000**

Table 4-5 : Ordering cost (K) calculation in Microsoft Excel

Ordering cost per order is calculated based on equation 2-1 , the top-down method, in chapter 2 (Jonsson & Mattsson, 2009) and estimated to be THB 75,000.

For the holding cost (h), according to Barfield et al, 2003)., it is estimated to be about 30% of unit cost, each item's holding cost will be display in table 4-6. When every variable in EOQ formula have been determined, Microsoft Excel is used to calculate Q* for each item, as following.

RM code	Goods Code	Goods Name	Unit	Kg/Unit	Price/ Unit	Unit	Avg Demand /month	ANNUAL DEMAND (D)	K	h	Q*
RM57	02-MA-LI-0	DINP	Bulk	15000	49.5	Kg	145,802.00	1,749,624.00	75,000.00	14.85	133,700.00
RM92	02-MA-PO-	Omyacarb	Bag	25	93	Kg	69,586.11	835,033.33	75,000.00	27.90	67,500.00
RM107	02-MA-PO-	Toson PV0	Bag	20	97	Kg	59,236.11	710,833.33	75,000.00	29.10	61,000.00
RM100	02-MA-PO-	YCC Brand	Bag	25	87	Kg	29,160.56	349,926.67	75,000.00	26.10	45,100.00
RM93	02-MA-PO-	Omyacarb	Bag	500	87	Kg	28,833.33	346,000.00	75,000.00	26.10	44,800.00
RM110	02-MA-PO-	Kane Viny	Bag	25	96	Kg	19,350.00	232,200.00	75,000.00	28.80	34,900.00
RM89	02-MA-PO-	Hakuenka	Bag	25	87	Kg	17,308.78	207,705.33	75,000.00	26.10	34,800.00
RM29	01-MA-PO-	Neolight S	Bag	25	46	Kg	22,585.89	271,030.67	75,000.00	13.80	54,500.00
RM34	01-MA-PO-	Neolight S	Bag	25	53	Kg	19,466.67	233,600.00	75,000.00	15.90	47,600.00
RM86	02-MA-PO-	Calcium C	Bag	25	38	Kg	22,023.61	264,283.33	75,000.00	11.40	59,100.00
RM59	02-MA-LI-0	Exxsol D-8	Bulk	9000	48	Kg	16,893.56	202,722.67	75,000.00	14.40	46,100.00

ANNUAL DEMAND (D)	K	h	Q*
1,749,624.00	75,000.00	14.85	=(SQRT(2*I54*J54/K54))
835,033.33	75,000.00	27.90	67,500.00
710,833.33	75,000.00	29.10	61,000.00

Table 4-6 : Economic order quantity (Q*) calculation in Microsoft Excel

After the question How much to order already answered by EOQ, the next question that need to be answer in inventory control is when to order. As discussed, the continuous review policy will be applied to Class A item due to the item in class A contribute to high portion of value, which lead to the need of closer control.

- Safety stock (SS) Calculation

According to literature review in chapter 2, Aghezzaf et. al., 2007 suggest total of 3 approach to calculate safety stock, but the popular one is service level approach, which the service lever desired will be predetermine, while trying to minimize cost. In addition, the formula to be used in calculating safety stock depends on 2 variables, Lead time and demand. The model present by Cetin et al, 2004 will present.

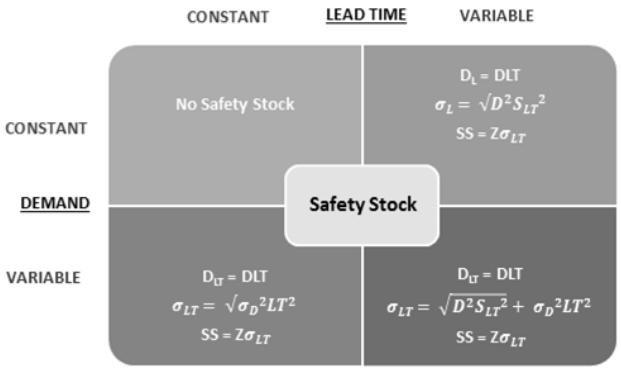


Figure 4-13 : Lead time formula for each situations

As the lead time of items in class A depends on each suppliers but it can be determine and constant, on the other hand, demand is variable. As a result of that, the set of formula to be use is displayed in the blue block above.

The continuous review continually monitors the inventory level and a fixed order quantity will be placed when the inventory level reached the reorder point (R). this type of review only have a risk of stock out during lead time, due to during lead time any range of demand can occur as display in figure 4-14

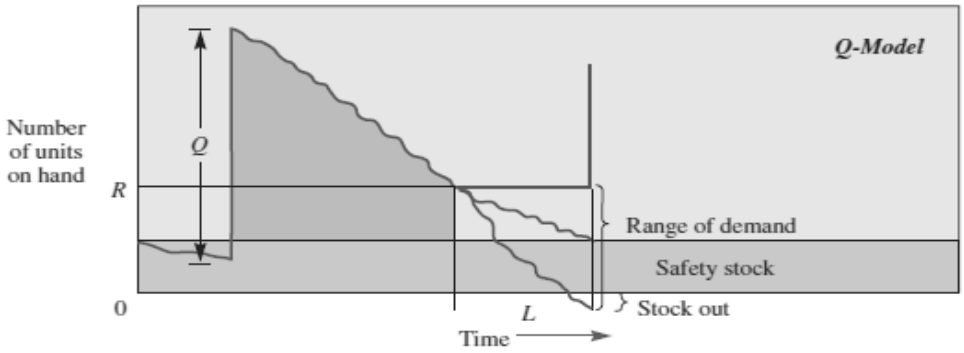


Figure 4-14 : Possibility of demand during lead time of continuous review policy

Source : Jacob3e_sample

The amount of safety stock will depend on service level predetermined and calculated from the formula discussed above by Microsoft Excel which can be seen in below table.

RM code	Goods Code	Goods Name	Avg Demand /month	ANNUAL DEMAND (D)	SD - month	Lead time	SD - week (σ_{WEEK})	SD - Leadtime (σL)	Service Level	Z value	SS
RM57	02-MA-LI-0	DINP	145,802.00	1,749,624.00	32,652.39	2	15,764.72	22,294.68	99.5%	2.60	57,966.18
RM92	02-MA-PO-	Omyacarb-8	69,586.11	835,033.33	19,819.06	4	9,568.73	19,137.46	99.5%	2.60	49,757.40
RM107	02-MA-PO-	Toson PVC Paste R	59,236.11	710,833.33	8,466.34	2	4,087.59	5,780.72	99.5%	2.60	15,029.87
RM100	02-MA-PO-	YCC Brand R-501	29,160.56	349,926.67	5,152.43	6	2,487.61	6,093.39	99.5%	2.60	15,842.81
RM93	02-MA-PO-	Omyacarb-8	28,833.33	346,000.00	9,181.53	2	4,432.88	6,269.05	99.5%	2.60	16,299.52
RM110	02-MA-PO-	Kane Vinyl Paste PI	19,350.00	232,200.00	3,391.96	4	1,637.66	3,275.31	99.5%	2.60	8,515.81
RM89	02-MA-PO-	Hakuenka CC	17,308.78	207,705.33	5,473.81	6	2,642.78	6,473.46	99.5%	2.60	16,830.99
RM29	01-MA-PO-	Neolight SP	22,585.89	271,030.67	4,960.15	6	2,394.79	5,866.00	99.5%	2.60	15,251.60
RM34	01-MA-PO-	Neolight SP-60	19,466.67	233,600.00	7,231.11	6	3,491.21	8,551.69	99.5%	2.60	22,234.41
RM86	02-MA-PO-	Calcium Oxide	22,023.61	264,283.33	3,233.08	4	1,560.95	3,121.89	99.5%	2.60	8,116.92
RM59	02-MA-LI-0	Exxsol D-80 Fluid	16,893.56	202,722.67	2,037.59	2	983.76	1,391.24	99.5%	2.60	3,617.24

Table 4-7 : Safety stock (SS) calculation in Microsoft Excel

Standard deviation (week) is used due to the lead time of suppliers is in weekly basis, after that, converted into Standard deviation of lead time(σ_L) by multiply the SD- weekly to lead time period. Next, identified the desired service level, due to this is an important group of raw material that used as a

component of almost every product in production; the service level desired is high, set to be 99.5%, which result in Z value of 2.6, using the Z table in appendix C or Excel “NORMSINV” function. Safety stock (SS) is now can be calculated from equation below,

$$SS = Z \times \sigma_L$$

- Reorder point (R) Calculation

After safety stock quantity is calculated, the reorder point is then can be set. The reorder point is set to cover the expected demand during lead time and plus the safety stock calculated earlier from predetermine service level. The formula for reorder point is

$$R = \mu L + SS$$
$$= L_{week} \times \text{Average demand}_{week} + Z \times \sigma_L$$

Where;

R = Reorder point

μL = Avg demand during lead time

L_{week} = Lead time period (week)

$\text{Average demand}_{week}$ = Average demand (week)

SS = Safety Stock

RM code	Goods Code	Goods Name	ANNUAL DEMAND (D)	SD - month	Lead time	SS	Avg demand during LT (μL)	Reorder point (R)
RM57	02-MA-LI-0	DINP	1,849,827.27	32,652.39	2	57,966.18	71,147.20	129,113.38
RM92	02-MA-PO-	Omyacarb-8	755,145.00	19,819.06	4	49,757.40	58,088.08	107,845.48
RM107	02-MA-PO-	Toson PVC Past	660,906.00	8,466.34	2	15,029.87	25,419.46	40,449.33
RM100	02-MA-PO-	YCC Brand R-50	314,932.20	5,152.43	6	15,842.81	36,338.33	52,181.14
RM93	02-MA-PO-	Omyacarb-8	351,060.00	9,181.53	2	16,299.52	13,502.31	29,801.83
RM110	02-MA-PO-	Kane Vinyl Past	216,465.00	3,391.96	4	8,515.81	16,651.15	25,166.97
RM89	02-MA-PO-	Hakuenka CC	223,422.60	5,473.81	6	16,830.99	25,779.53	42,610.52
RM29	01-MA-PO-	Neolight SP	258,327.60	4,960.15	6	15,251.60	29,807.03	45,058.64
RM34	01-MA-PO-	Neolight SP-60	207,675.00	7,231.11	6	22,234.41	23,962.50	46,196.91
RM86	02-MA-PO-	Calcium Oxide	255,000.00	3,233.08	4	8,116.92	19,615.38	27,732.30
RM59	02-MA-LI-0	Exxsol D-80 Flui	203,451.60	2,037.59	2	3,617.24	7,825.06	11,442.30

Table 4-8 : Reorder point (R) calculation in Microsoft Excel

In conclusion, as discussed above, lead time is constant but the demand is variable that contain uncertainty. Although for Class A, the fluctuation is low based on CV calculated earlier, average of 0.13. But it that uncertainty, or the fluctuation in

demand is taken into account in the calculation of Safety stock (SS). For the order quantity, which calculated by EOQ equation, the uncertainty are not included. The safety stock take into account the uncertainty, so the more value of standard deviation, means the more safety stock (SS), which will result finally in the higher reorder point (R) or the greater the safety stock, the sooner the order is placed.

4.2.3.2 Periodic review policy (Fixed –time period model)

From pervious analysis of characteristic of SKUs and categorizing into 3 classes, Class B and Class C have much more less portion contribute in total value than Class A, so, The periodic review policy is suggested, in order to manage these 2 classes. The periodic review set up the fixed review interval(T) for example, every 2 weeks or every month, which mean that the inventory will be counted only at the predetermine time, but the order quantity will varied, which equal to the amount of different between predetermined target inventory level (order up to level (OUL), or a target level) and an actual inventory level (On hand inventory). As previously discussed, the uncertainty in demand will be captured in safety stock calculation, same as continuous review policy, therefore, the quantity of safety stock for the periodic review policy will be larger, due to it needed to cover not only uncertainty in lead time period and as well as to cover the uncertainty during review interval too. Figure 4-15 exhibit the graphical relation and possibility of stock out in periodic review policy.

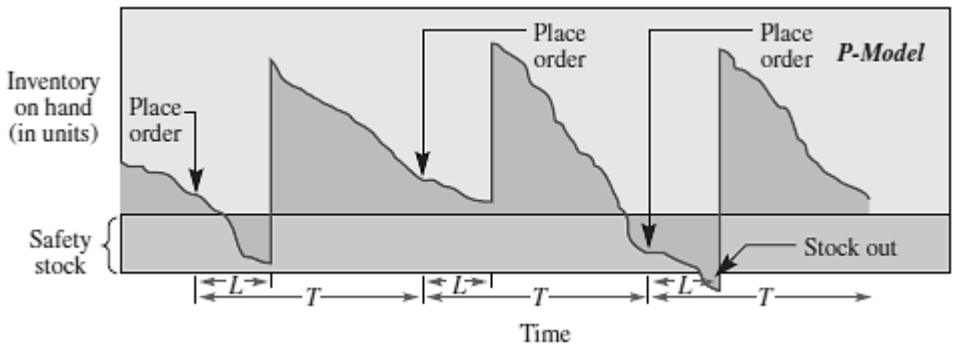


Figure 4-15 : Possibility of demand during lead time of periodic review policy
Source : Jacob3e_sample

- Safety stock (SS) Calculation

Safety stock (SS) and OUL level calculated using equation below

Safety stock (SS) = Z x σ_{L+T}

OUL = μL+T + SS

Q = OUL(Order up to level) – inv.position (IP)

Where;

T	=	Review interval (week)
L	=	Lead time for replenishment (week)
D	=	Average demand per period
OUL	=	Target inventory level determined by the forecasts (Order up to level)
μ_{L+T}	=	Average demand during lead time (L) and review interval (T)
σ_{L+T}	=	Standard deviation of demand Lead time (L) and review interval (T)
Q	=	Order quantity OUL(Order up to level)

Before safety stock and OUL level will be calculated, Class B inventory consists of 39 items in total, but from collecting data, these 39 items supported by 7 suppliers as can be seen below. Lead time and maximum order per month are presented in the table too. to sum up, Class B inventory will be categorized into 3 minor group, by lead time and maximum order per month criteria. Then, review interval chosen in relative to maximum order per month limitation from suppliers. For example, if maximum order per month allow from suppliers is 1 time/month, then the review interval should set to be every 4 weeks, for a good collaboration between review period and order frequency.

	No of RM	Maximum order frequency (per month)	Lead time (week)	Group
Supplier A	8	2	2	B
Supplier B	4	1	2	A
Supplier C	2	1	2	A
Supplier D	6	2	1	C
Supplier E	6	1	2	A
Supplier F	2	1	2	A
Supplier G	11	2	2	B

	No of RM	Maximum order frequency (per month)	Lead time (L) - week	Review interval (T) -week
Group A	14	1	2	4
Group B	19	2	2	2
Group C	6	2	1	2

Table 4-9 : Class B items in minor grouping by lead time and review interval

Next, service level desired for class B and C is lower than Class A, 97% is defined, so the Z factor is 2.01. An example of calculation is done in Microsoft Excel as shown below

RM code	Goods Code	Goods Name	Unit	Kg/Unit	AVG demand	Demand year	SD month	SD WEEK	L - Week	T - Week	service level	Z	μ(L+T)	σ(L+T)	SS	OUL
RM91	02-MA-PO-012	Sipenat 820A	Bag	25	587	7,041	539	260	2	4	97%	2.60	812.44	637.06	1,657	2,470
RM104	02-MA-PO-027	Kane Ace UC506	Bag	25	1,167	14,003	711	343	2	4	97%	2.60	1,615.71	840.70	2,186	3,802
RM112	02-MA-PO-038	Advancell EMH204	Bag	20	468	5,619	234	113	2	4	97%	2.60	648.40	276.58	720	1,369
RM78	02-MA-PA-015	Adeka Resin QR-9327-1	Drum	180	3,782	45,382	1,443	697	2	4	97%	2.60	5,236.40	1706.72	4,438	9,675
RM90	02-MA-PO-007	Hakuenka CCR	Bag	25	4,068	48,813	1,904	919	2	4	97%	2.60	5,632.22	2251.46	5,854	11,487
RM77	02-MA-PA-014	Adeka Resin QR-1636-2I	Drum	180	1,519	18,223	860	415	2	4	97%	2.60	2,102.64	1017.02	2,645	4,748
RM51	02-MA-CO-011	SBR 1009 AF	Kg	1	4,142	49,707	854	412	2	4	97%	2.60	5,735.40	1009.76	2,626	8,362
RM85	02-MA-PA-032	KA-112	Drum	180	1,404	16,842	1,068	516	2	4	97%	2.60	1,943.35	1263.38	3,285	5,229
RM88	02-MA-PO-005	CCR-SS	Bag	25	5,953	71,433	967	467	2	4	97%	2.60	8,242.22	1144.18	2,975	11,218
RM48	02-MA-CO-007	JSR N 230 S	Bag	35	3,771	45,253	1,167	563	2	4	97%	2.60	5,221.45	1380.06	3,589	8,811

Table 4-10 : Example of calculation of periodic review parameter in Microsoft Excel – Group A

RM code	Goods Code	Goods Name	Unit	Kg/Unit	AVG demand	Demand year	SD month	SD WEEK	L - Week	T - Week	service level	Z	μ(L+T)	σ(L+T)	SS	OUL
RM71	02-MA-LI-041-(	Globinex W-23 S	Drum	200	630	7,559	368	178	2	2	97%	2.60	581.49	355.56	925	1,507
RM56	02-MA-CO-047	Ubepol-BR150 B	Bag	35	1,703	20,434	540	261	2	2	97%	2.60	1,571.82	521.21	1,356	2,928
RM106	02-MA-PO-029	B-325	Bag	25	522	6,266	242	117	2	2	97%	2.60	481.98	234.01	609	1,091
RM74	02-MA-PA-003	Npel 128	Drum	240	4,488	53,854	952	460	2	2	97%	2.60	4,142.64	919.43	2,391	6,534
RM80	02-MA-PA-017	Takenate B-7105	Drum	200	496	5,950	278	134	2	2	97%	2.60	457.66	268.52	699	1,157
RM68	02-MA-LI-037-(	Flexon 641 P	Drum	172	3,913	46,955	1,100	531	2	2	97%	2.60	3,611.96	1,062.38	2,763	6,375
RM64	02-MA-LI-021-(	Monocizer W-242	Drum	190	396	4,747	249	120	2	2	97%	2.60	365.12	240.88	627	993
RM33	01-MA-PO-052	Neolight AT-23	Bag	25	1,988	23,859	864	417	2	2	97%	2.60	1,835.31	833.95	2,169	4,005
RM69	02-MA-LI-039-(	Baerostab MTS 1200	Drum	220	614	7,373	239	115	2	2	97%	2.60	567.18	230.68	600	1,168

Table 4-11 : Example of calculation of periodic review parameter in Microsoft Excel – Group B

RM code	Goods Code	Goods Name	Unit	Kg/Unit	AVG demand	Demand year	SD month	SD WEEK	L - Week	T - Week	service level	Z	μ(L+T)	σ(L+T)	SS	OUL
RM16	01-MA-PA-010	Nipol DN601	Drum	180	617	7,408	501	242	1	2	97%	2.60	427.38	419.13	1,090	1,518
RM32	01-MA-PO-044	Dianal LP 3105	Bag	20	676	8,107	743	359	1	2	97%	2.60	467.71	621.51	1,616	2,084
RM95	02-MA-PO-017	PVC Past Resin PG740	Bag	25	3,442	41,298	3,308	1,597	1	2	97%	2.60	2,382.60	2,766.20	7,193	9,576
RM79	**02-MA-PA-016**	**Takenate B-5010**	**Drum**	**200**	**382**	**4,588**	**662**	**320**	**1**	**2**	**97%**	**2.60**	**264.71**	**553.47**	**1,440**	**1,705**
RM52	**02-MA-CO-017**	**540 Rubber Batch Kg**	**Kg**	**1**	**597**	**7,162**	**407**	**197**	**1**	**2**	**97%**	**2.60**	**413.18**	**340.48**	**886**	**1,300**
RM45	02-MA-CO-002	CS-4795B RubberBatch	Kg	1	1,589	19,065	855	413	1	2	97%	2.60	1,099.91	715.22	1,860	2,960

Table 4-12: Example of calculation of periodic review parameter in Microsoft Excel – Group C

For periodic review, order quantity is not fixed, but varied equal to OUL minus on hand inventory at review period. So, the uncertainty in demand is taken into account in Safety stock, which used to calculate OUL level. The safety stock for periodic review will be higher than for continuous review, due to it take into account the uncertainty during both lead time and review interval, while for continuous review, safety stock only protect against uncertainty during lead time. But, the periodic review would benefit more when order can be combining, as review in chapter 2. When, the order interval is fixed and constant for the same suppliers, then order of items of the same suppliers can be combine, transport cost and ordering cost would reduce.

Besides to that, formal design of inventory record form, inventory checking form, labels and accuracy report form will be proposed to enhance the inventory policy applied and improve overall performance of inventory management.

4.3 Standard process and workflow

For standard process and workflow, topic to be discussed and explain will follow the steps in figure 4-16

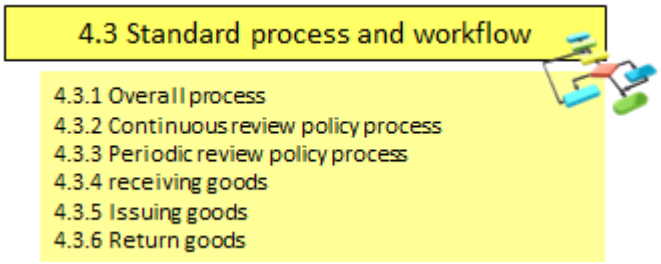


Figure 4-16 Standard process and workflow discussion step

4.3.1 Overall work flow process

For the overall inventory process, main department and processes involve still similar to the current one, customers will forward demand forecast to production, then convert demand to raw material requirement. Warehouse have 3 main roles, first is receive information from production department, check the availability then continue process of issuing goods to production. Second role is to perform receiving process when the inventory ordered arrives. Last role, but the most important one, is to review current status of inventory on hand and perform reordering process follow the policy set up, alongside with maintain and keep inventory recording system updated.

Purchasing department will take the information of quantity to be order from warehouse, deal with suppliers, make an appointment of shipping date and inform warehouse to be prepared for incoming goods.

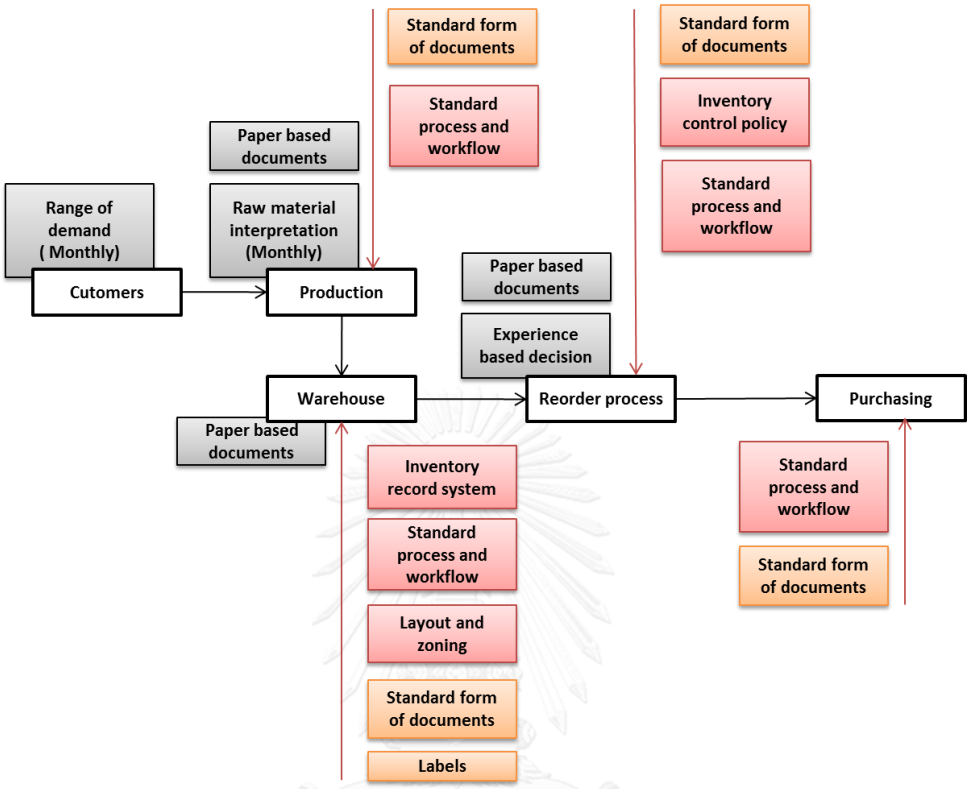


Figure 4-17 : Overall inventory process

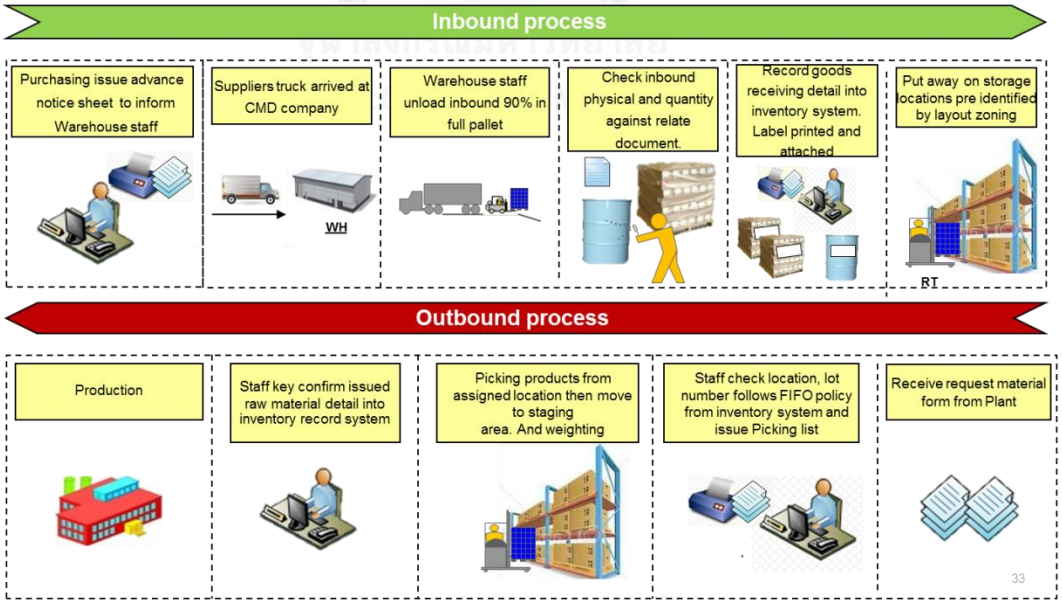


Figure 4-18 : Overall warehouse process

4.3.2 Standard work flow process of Continuous review policy

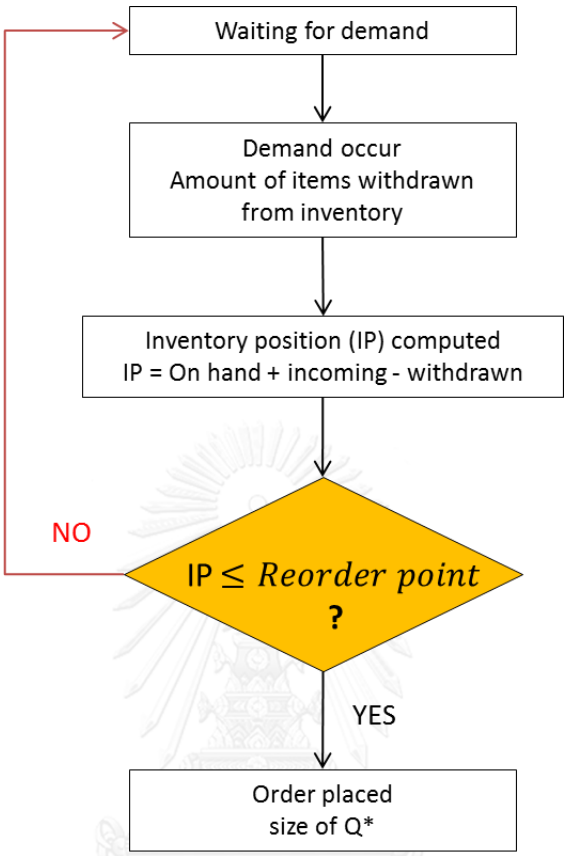


Figure 4-19 : Standard work flow process of Continuous review policy

As explain and discussed in detail in section inventory control policy set up above, work flow of continuous review process illustrate in figure 4-19. As well as Figure 4-20, workflow of periodic review policy presented.

4.3.3 Standard work flow process of Periodic review policy

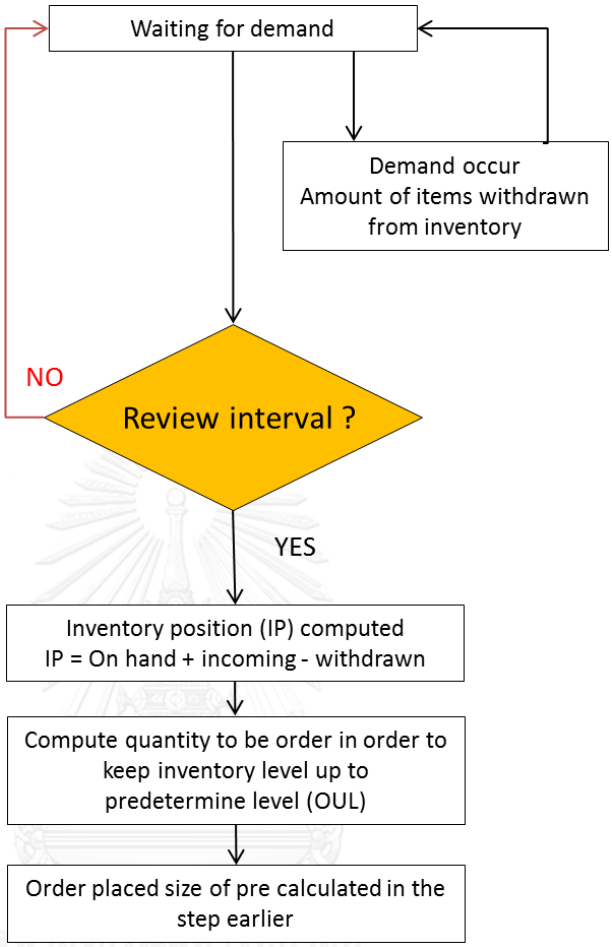


Figure 4-20 : Standard work flow process of Periodic review policy

Currently, there is no workflow instruction for warehouse staffs to follow in receiving, putaway or replenishment the items. More structure process should be established in order to enhance the overall performance of inventory management. Figure 4-21 and 4-22 represents the proposed workflow of warehouse process.

4.3.4 Standard workflow process of receiving goods

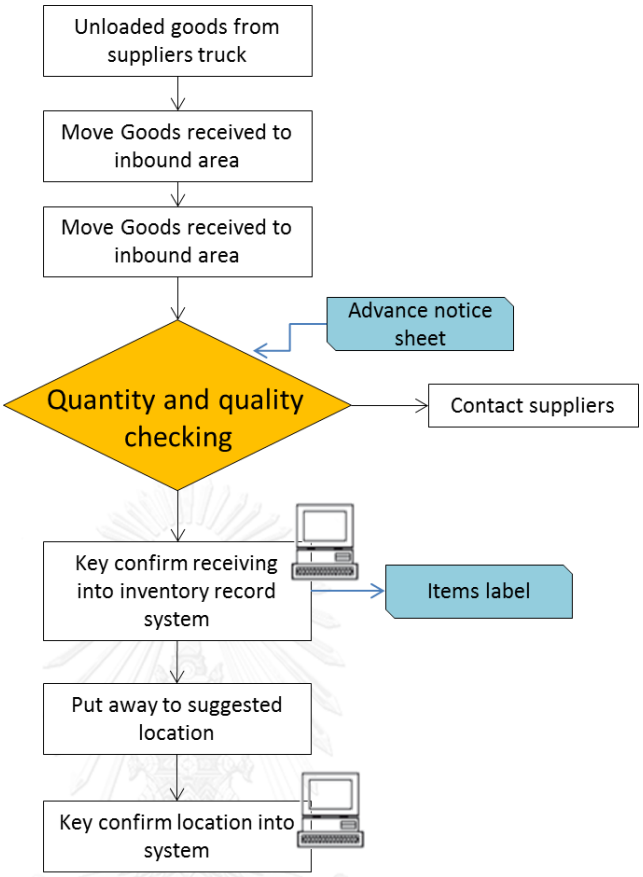


Figure 4-21 : Standard workflow process of receiving goods

For the inbound process, it would be better if purchasing or supplier provide the information of material to be arriving in advance for warehouse staff. The shipment delivery window or time frame should be provided, details of delivery vehicle and quantity should also provide. At the time when materials arrive at the company, Staffs should identify material types, checking physical quality and count quantity at receiving zone, when staff finish the process, of physical checking, information should be soon to input into inventory record in the system, in order to keep information up to date. Inventory label will then be print out, staff attach the label to each unit of received raw material. Putaway the raw material follow zoning suggested, Label the shelf with shelf label for the ease of tracking. After that, location information should be put into the inventory system too. If this process is not done properly, errors will occur and resulted in inaccuracy inventory record and also large amount of time and effort will have to spend in correcting those errors.

4.3.5 Standard workflow process of issuing goods

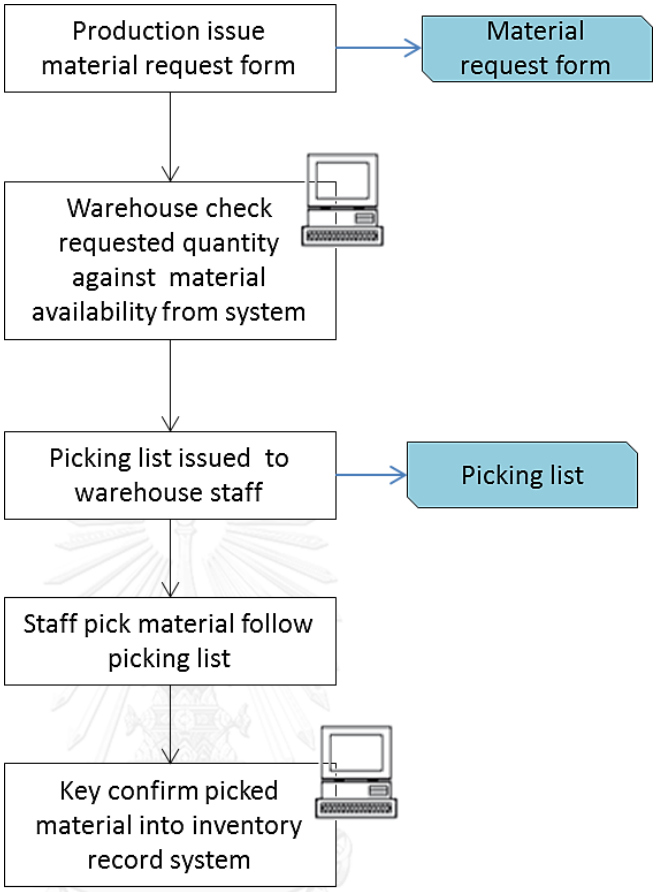


Figure 4-22 : Standard workflow process of issuing goods

Start with order from production, in an request raw material form. Staffs check the availability, location of that desired items, FIFO should also concern. When staff got the information, picking list will be issued and staff will pick follow the picking list, picking list will consist of information about location, quantity and FIFO. Staff picks raw material ordered and move those to production area. Next, order issued' details must be input into inventory recording system, to keep the system updated. In case of returns, this can be a major cause of inventory control problems if they're not handled properly. Return product which came back from production should be inspected and count before return to location. The quantity of return should as well be checked and input into the inventory recording system.

4.3.6 Standard workflow process of return goods

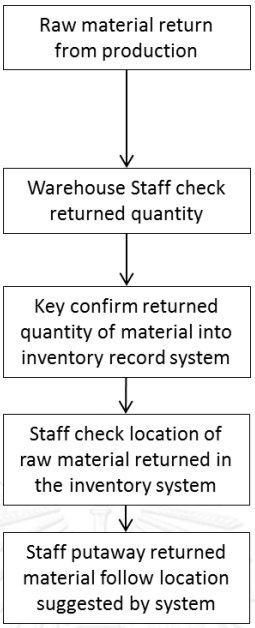


Figure 4-23 : Standard workflow process of returned goods

When production return raw materials from production, warehouse staff first have to check the quantity of the returned raw materials. Then, key the quantity of returned raw material back into inventory record system, in order to keep the quantity in the system updated. After key confirmed, location of the same items of raw material will be known by the system, then staff putaway those returned raw material to the location.

4.4 Warehouse layout and zoning

4.4.1 Proposed warehouse layout

As discussed in chapter 3 in cause-and-effect diagram, warehouse layout is cause of unclear storage location, which is also leads to inaccuracy inventory record and leads to excess inventory in the end. Warehouse layout is proposed, zoning by product categories and sizes.

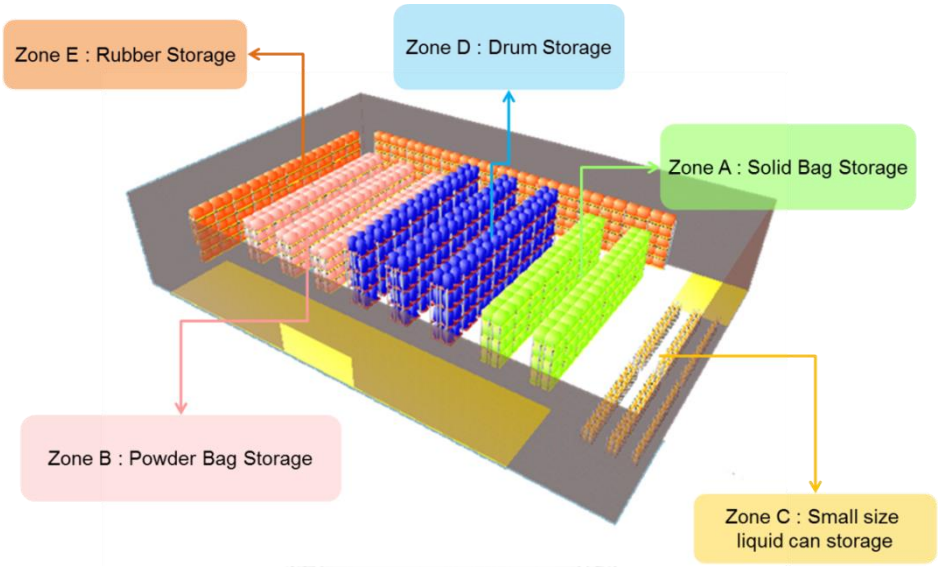


Figure 4-24 : Warehouse layout proposed for CMD Company

Source : Adapted by researcher with CLASS program

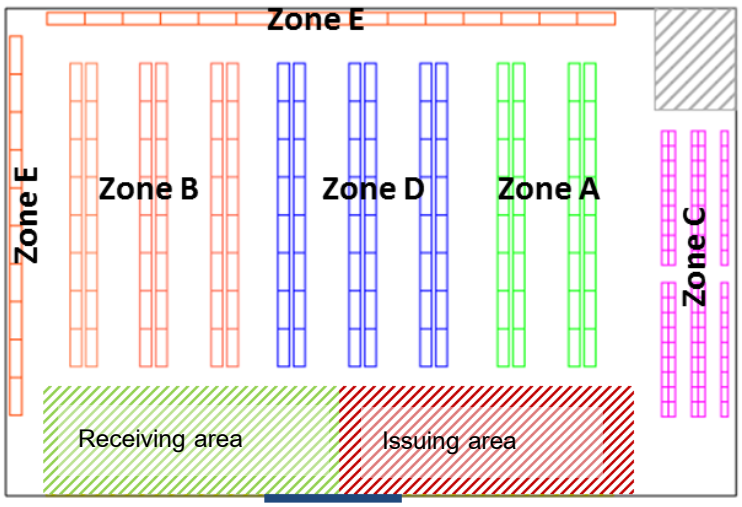


Figure 4-25 : Warehouse layout proposed for CMD Company – Zoning

Source : Adapted by researcher with CLASS program

Current warehouse and facility have the total area of 875 Sq.m. with dimension of 35 m. x 25 m. Proposed warehouse layout and zoning, is based on current rack set up due to limited budget.

The overall warehouse have been categorized into 5 zones, in order to separate different type of raw materials for the ease of picking, storing and visibility. As discuss in the topic of raw material characteristic, there are 3 main types of raw materials items

- Drum and big bag raw materials, This type of raw materials normally have 1.6 m. in height, which is higher than standard pallet (1.2 m. heigh). Also this type of raw materials is major component of almost every types of finished products. So, the location of rack is set to be in the middle and near to the warehouse entrance and exits – Zone D, as this type of raw materials got high frequency of usage; almost everyday, then located near to the exit would bring benefit in reducing time of picking and MHEs used.
- Powder bag raw materials, This type of raw material have highest percentage from total raw materials, about 65%. This type of raw materials normally came in as a pallet, height of 1.2 m. So, the location is set to be in Zone A and Zone B. For Zone A, it is target to store the imported powder bag raw materials, while for local powder will be stored in Zone B.
- Rubber, the rubber based raw material came in as a pallet, with normally 1.2 m. in height. Yet it rarely being used. So, the location is set to be at Zone E, quite far from entrance and exits but due to low frequency usage, this location is appropriated.
- Small size bag and liquid can storage, This type of raw material came in relatively small package compare to the rest of raw materials of CMD. Shelving should be used for storage instead of racking so the space utilization would be better. Another reason for shelving is that it have better visibility, due to the depth of shelf is proper for small size package, unlike 1m. depth of rack, which it is not able to see and identified what is in the back.

4.4.2 Rack and shelf specification

Zone D : Rack – Drum and big bag storage

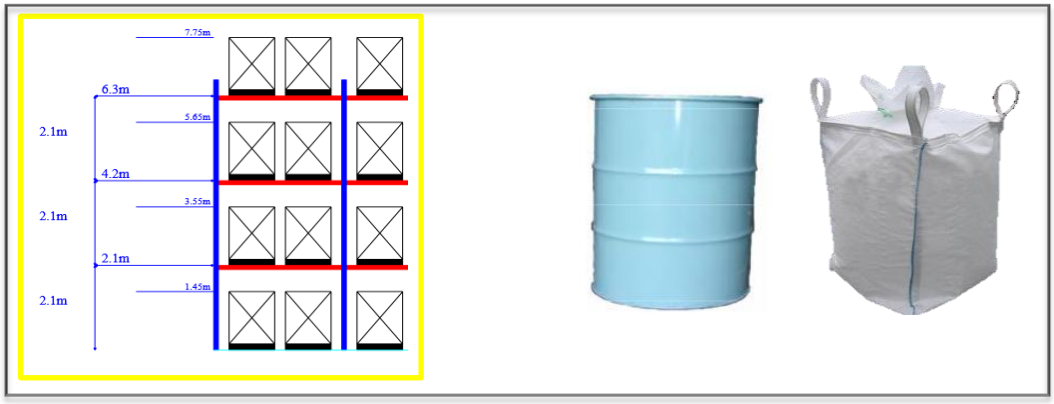


Figure 4-26 : Zone D Rack – Drum storage

Zone A, B and E : Rack – Powder bag storage (palletized) and rubber storage

Figure 4-27 : Zone A, B and E Rack – Powder bag storage (palletized) and rubber storage

Zone C : Shelf – Small size bag and liquid can storage

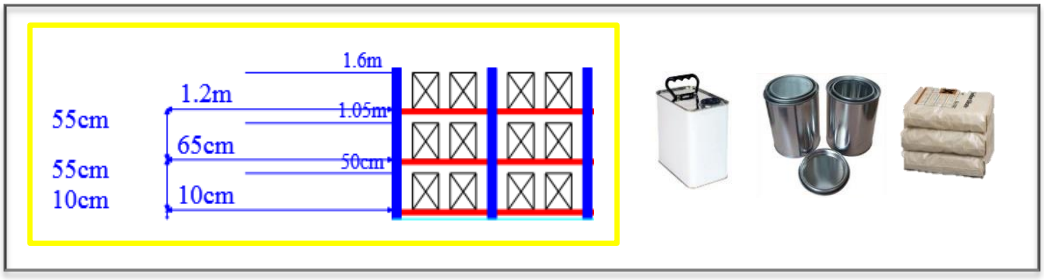


Figure 4-28 : Zone C Shelf – Small size bag and liquid can storage

4.5 Standard form of documents related

As mentioned, without standardized document related, the information needed maybe lack, due to information recorded will depend on staff judgment. The author

then create a standard form of documents related to inventory management, which are displayed below,

4.5.1 Advance notice sheet

Advance notice sheet will be given to warehouse staff in order to be prepare for incoming goods by purchasing staff. Purchasing staff will know the delivery date from suppliers, or in case of delays purchasing staff will be the first department to know. This Notice sheet will help warehouse aware of incoming and delayed goods, in order to plan for the space, location and manpower for receiving process.

Advance Notice Sheet

RM Code	Good code	Description	UOM	Kg/UOM	Quantity to be received (UOM)	Date
RM03	00-MA-PA-027-01-A02	LIR-403	Pail	15	5	13/05/2015
RM118	02-MA-SO-010-02-A02	Antage BHT	Bag	20		13/05/2015
RM110	02-MA-PO-034-02-A01	Kane Vinyl Paste PBM-6	Bag	25	20	13/05/2015

Figure 4-29 : Example of Advance notice sheet

4.5.2 Picking list

Order No.	15050045		Picker	Somchai
Date	13/05/2015			
No.	RM Code	Description	Quantity required	Quantity picked
1	RM 13	Gleck ML-510A	5	5
2	RM58	Ethyl Acetate	12	12
3	RM108	Adeka Hardener EH-4358S	4	4

Figure 4-30 : Example of picking list

4.5.3 Request Materials sheet

Request No.	15050043			
Date	12/05/2015			
No.	RM Code	Description	Quantity requested	Quantity received
1	RM 13	Gleck ML-510A	5	
2	RM58	Ethyl Acetate	12	
3	RM108	Adeka Hardener EH-4358S	4	

Figure 4-31 : Example of picking list

4.6 Items label and locations label

4.6.1 Items Label

Items label should printed out when goods pass the process of inspection and quantity checking, staff will key information in the system, then label will be generate equal to the amount of packages received. Items label will be attach to the packages of goods to eliminate confusion of types and quantity of each items.

Company: **Cemedine Company**			
Date	Location		
RM Code.	Goods Code	UOM	Kg/UOM
RM04	**00-MA-PA-028-01-A01**	**Pail**	**18**
Description			
Adeka Resin EPR-1309			
	Counted By	Checked By	

Figure 4-32 : Example of Item label

4.6.2 Rack and Shelf label

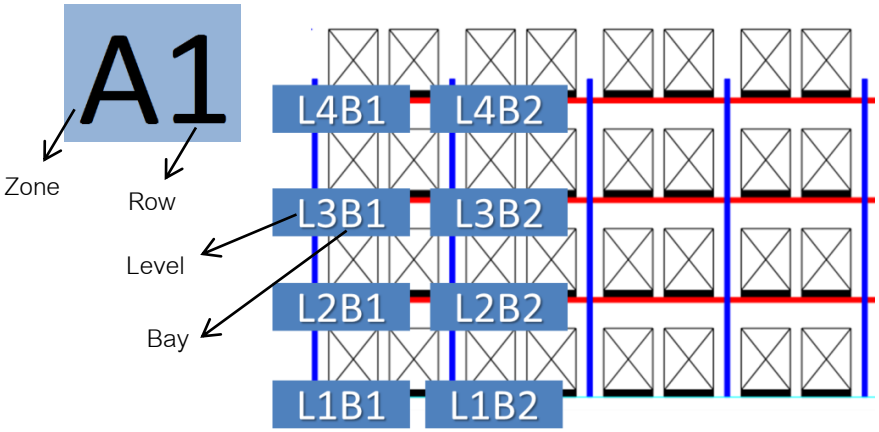


Figure 4-33 : Example of Rack and shelf label

Rack and shelf label will be attach with the meaning illustrate above in figure 4-33.

4.7 computer based system

Inventory recording system

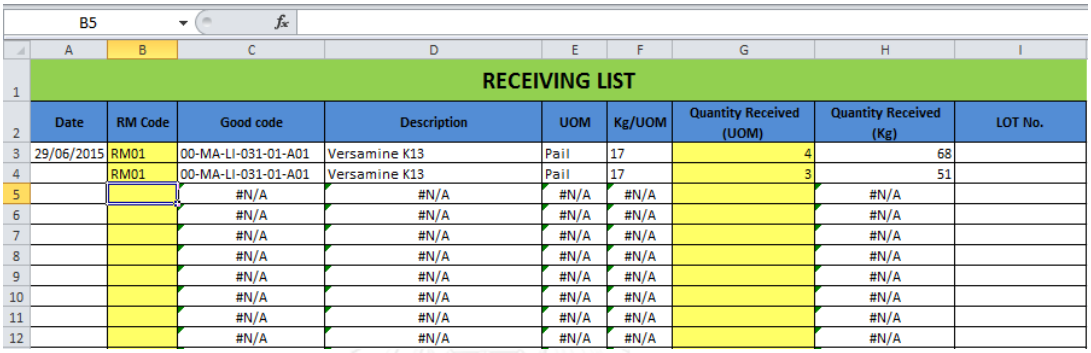
The computer based inventory recording system is will contain 4 main pages. For the first page, the items list, this page will act like a database or the SKUs master of overall inventory list that CMD Company ordered, which contain both active and inactive SKUs. In addition, the stafety stock level from calculation inventory policy set up will be listed too, In case of new item to be order, the name and detail of that item must be input into this page.

D15 | fx | Can

	A	B	C	D	E	F
1	ITEMS LIST					
2	RM Co	Good code	Description	UO	Kg/UC	Price/UO
3	RM01	00-MA-LI-031-01-A01	Versamine K13	Pail	17	32
4	RM02	00-MA-PA-026-01-A01	Epiclon B-570	Drum	220	44
5	RM03	00-MA-PA-027-01-A02	LIR-403	Pail	15	37
6	RM04	00-MA-PA-028-01-A01	Adeka Resin EPR-1309	Pail	18	49
7	RM05	00-MA-PA-029-01-A01	Adeka Resin EPU-78-11	Pail	18	56
8	RM06	00-MA-PO-028-01-A02	Printex XE2B	Bag	5	40
9	RM07	00-MA-PO-045-01-A01	MFL- 100CA	Bag	70	12
10	RM08	00-MA-PO-050-01-A01	DN-B	Bag	25	31
11	RM09	00-MA-PO-060-01-A01	Calbatec Viscolte-OS	Bag	20	36
12	RM10	00-MA-SO-032-01-A01	Arkon P-100	Bag	25	47

Figure 4-34 : Computer based inventory recording system – Items list page

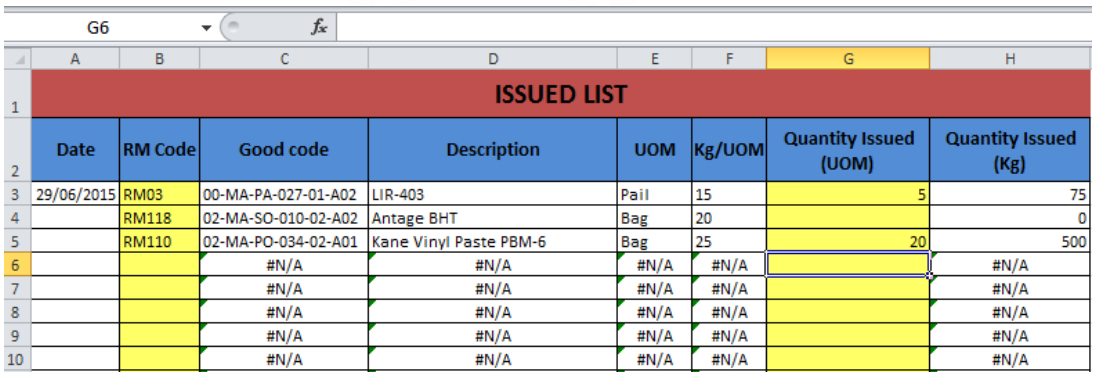
Next to the items list, is the receiving list page, this page allow you to input only the Raw material code (RM Code) , then the rest of the information, Goods code, description, UOM and the KG/UOM will be linked automatically from items list, which will reduce errors in wrong name, wrong goods code and wrong Kg/UOM. Next input you need is the Quantity received, which is the number of package received, for example, you receive 4 pails of RM01, and then 4 will be input. The quantity in Kilogram will be calculated automatically in column H. If there is lot No. then you can input in the column I.



RECEIVING LIST								
Date	RM Code	Good code	Description	UOM	Kg/UOM	Quantity Received (UOM)	Quantity Received (Kg)	LOT No.
29/06/2015	RM01	00-MA-LI-031-01-A01	Versamine K13	Pail	17	4	68	
	RM01	00-MA-LI-031-01-A01	Versamine K13	Pail	17	3	51	
		#N/A	#N/A	#N/A	#N/A		#N/A	
		#N/A	#N/A	#N/A	#N/A		#N/A	
		#N/A	#N/A	#N/A	#N/A		#N/A	
		#N/A	#N/A	#N/A	#N/A		#N/A	
		#N/A	#N/A	#N/A	#N/A		#N/A	
		#N/A	#N/A	#N/A	#N/A		#N/A	
		#N/A	#N/A	#N/A	#N/A		#N/A	
		#N/A	#N/A	#N/A	#N/A		#N/A	

Figure 4-35 : Computer based inventory recording system – Receiving list page

Next to receiving list, will be the issued list, similar to received list, staff will have to input the RM Code and Quantity issued (UOM)

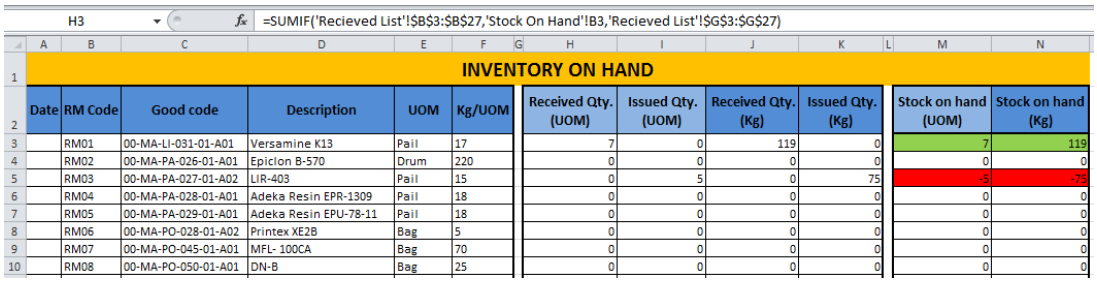


ISSUED LIST							
Date	RM Code	Good code	Description	UOM	Kg/UOM	Quantity Issued (UOM)	Quantity Issued (Kg)
29/06/2015	RM03	00-MA-PA-027-01-A02	LIR-403	Pail	15	5	75
	RM118	02-MA-SO-010-02-A02	Antage BHT	Bag	20		0
	RM110	02-MA-PO-034-02-A01	Kane Vinyl Paste PBM-6	Bag	25	20	500
		#N/A	#N/A	#N/A	#N/A		#N/A
		#N/A	#N/A	#N/A	#N/A		#N/A
		#N/A	#N/A	#N/A	#N/A		#N/A
		#N/A	#N/A	#N/A	#N/A		#N/A
		#N/A	#N/A	#N/A	#N/A		#N/A

Figure 4-36 : Computer based inventory recording system – Issued list page

Last page is the Inventory on hand; this page will show the balance of inventory, the quantity on hand. No input needed in this page. For the column M and N, there will be green and red color in order to notify you if this items need any concern. The green color indicate that inventory on hand level still above the safety stock set in the

item listed page, while the red color indicate that the inventory on hand is now lower than the safety stock.



H3 =SUMIF('Recieved List'!$B$3:$B$27,'Stock On Hand'!B3,'Recieved List'!$G$3:$G$27)

INVENTORY ON HAND

Date	RM Code	Good code	Description	UOM	Kg/UOM	Received Qty. (UOM)	Issued Qty. (UOM)	Received Qty. (Kg)	Issued Qty. (Kg)	Stock on hand (UOM)	Stock on hand (Kg)
	RM01	00-MA-LI-031-01-A01	Versamine K13	Pail	17	7	0	119	0	7	119
	RM02	00-MA-PA-026-01-A01	Epicion B-570	Drum	220	0	0	0	0	0	0
	RM03	00-MA-PA-027-01-A02	LIR-403	Pail	15	0	5	0	75	-5	-75
	RM04	00-MA-PA-028-01-A01	Adeka Resin EPR-1309	Pail	18	0	0	0	0	0	0
	RM05	00-MA-PA-029-01-A01	Adeka Resin EPU-78-11	Pail	18	0	0	0	0	0	0
	RM06	00-MA-PO-028-01-A02	Printex XE2B	Bag	5	0	0	0	0	0	0
	RM07	00-MA-PO-045-01-A01	MFL- 100CA	Bag	70	0	0	0	0	0	0
	RM08	00-MA-PO-050-01-A01	DN-B	Bag	25	0	0	0	0	0	0

Figure 4-37 : Computer based inventory recording system – Inventory on hand page

4.8 Training

Training session for every proposed solutions will be held according to below schedule. So, staffs who involve will have more understand about the process and objectives and also be able to handle their jobs better.

Topic	Date and Time
Understanding Inventory control policy	TBA
Understanding Standard process	TBA
How to use documents	TBA
How to use computer based inventory recording	TBA
Understanding warehouse operation	TBA

Figure 4-38 : Training schedule

4.9 Summary of proposed solutions

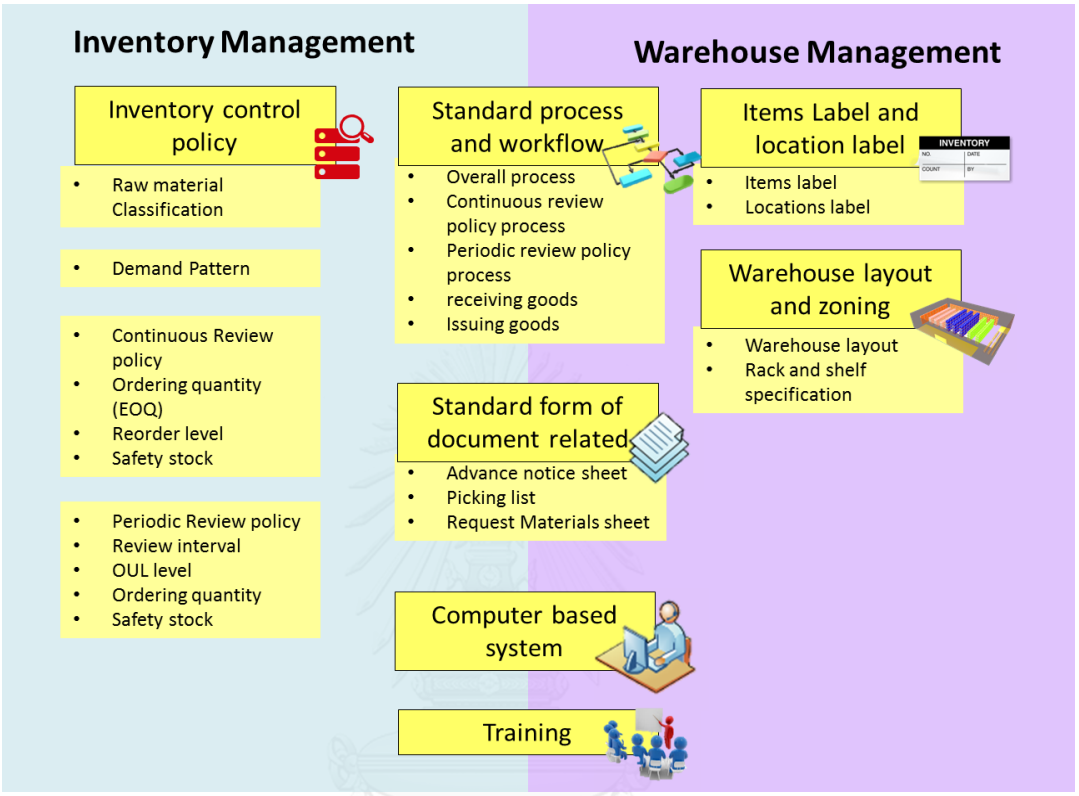


Figure 4-39 : Summary of proposed solutions and methodology

For conclusion, this chapter presents the proposed solution and methodology based on data collected from the company. Inventory data, demand pattern and SKUs of inventory characteristic have been analyzed. Then, ABC classification method is proposed to classify more than 150 SKUs into 3 classes. Then, the inventory policies reviews in chapter 2 have been select to fit with each class and basic calculation is performed.

The continuous review policy has been selected to apply for class A, relevant cost of inventory have been evaluate and identify. EOQ and safety stock is then calculated based on historical data, April 2013 to December 2014. Reorder level and safety stock have been calculated

The periodic review policy then applied for Class B and C due to lower priority, advantages of combining orders and not ever expensive cost of holding. Continuous review for every items in class B or C would consume too much time and resources. Review interval has been set aligning with suppliers' limitation in maximum ordering frequency per month. The order up to level and safety stock have been calculated.

Moreover, workflow processes have been suggested, in order to be a guideline for staffs and standardized activities to be done by different staffs as well as standard documents have been create, according to cause-and-effect diagram', which point out these cause are effecting in inefficient inventory control. Besides, warehouse layout and zoning, items label and location label have been proposed for the ease of putaway, locating, picking inventory SKUs in warehouse. Also, Training topic and schedule is proposed.

Chapter 5 : Implementation Phase and Result discussion

Since proposed solution and methodology have been explain and discussed in previous chapter, the simulation of the methodology and inventory policy set up will be demonstrate and discuss in this chapter. Results will be discussed and evaluated.

The proposed method is evaluated with a set of actual 4 month demand data started from January 2015 to April 2015. The initial inventory level is an actual quantity refers from historical data. The proposed inventory policies are test and simulate in Microsoft Excel, then compare results with current method. Details of calculation sheet will be explained for both Continuous review policy and periodic review policy. As proposed discussed in chapter 4, of total three Classes, Continuous review policy will be applied to class A, and periodic review policy will be applied to class B and C.

5.1 Continuous review policy simulation

The simulation is done on a daily basis on Microsoft Excel, as format display below.

						Cemedine Inventory Simulation								
						Leadtime →			30					
		Reorder Point →		107,845.48		Order Quantity →			65,100	Expected Value →				
										Costs				
		Day	Beginning Inventory	Receipts	Demand	Ending Inventory	Order?	Lead Time	Lead Time Count	Order (THB)	Holding (THB)	Shortage (THB)	Total (THB)	Average (THB)
9	01/01/2015	JAN	1	236,650	-	2,590	234,060	No	-	-	-	6,530,274.00	-	6,530,274.00	6,530,274.00
10	02/01/2015	JAN	2	234,060	-	1,653	232,407	No	-	-	-	6,484,155.30	-	6,484,155.30	6,507,214.65
11	03/01/2015	JAN	3	232,407	-	1,618	230,789	No	-	-	-	6,439,013.10	-	6,439,013.10	6,484,480.80
12	04/01/2015	JAN	4	230,789	-	2,702	228,087	No	-	-	-	6,363,627.30	-	6,363,627.30	6,454,267.43
13	05/01/2015	JAN	5	228,087	-	2,529	225,558	No	-	-	-	6,293,068.20	-	6,293,068.20	6,422,027.58
14	06/01/2015	JAN	6	225,558	-	2,810	222,748	No	-	-	-	6,214,669.20	-	6,214,669.20	6,387,467.85
15	07/01/2015	JAN	7	222,748	-	1,821	220,927	No	-	-	-	6,163,863.30	-	6,163,863.30	6,355,524.34
16	08/01/2015	JAN	8	220,927	-	5,448	215,479	No	-	-	-	6,011,864.10	-	6,011,864.10	6,312,566.81
17	09/01/2015	JAN	9	215,479	-	5,085	210,394	No	-	-	-	5,869,992.60	-	5,869,992.60	6,263,391.90
18	10/01/2015	JAN	10	210,394	-	5,526	204,868	No	-	-	-	5,715,817.20	-	5,715,817.20	6,208,634.43
19	11/01/2015	JAN	11	204,868	-	5,829	199,039	No	-	-	-	5,553,188.10	-	5,553,188.10	6,149,048.40
20	12/01/2015	JAN	12	199,039	-	5,072	193,967	No	-	-	-	5,411,679.30	-	5,411,679.30	6,087,600.98
21	13/01/2015	JAN	13	193,967	-	5,442	188,525	No	-	-	-	5,259,847.50	-	5,259,847.50	6,023,927.63
22	14/01/2015	JAN	14	188,525	-	4,384	184,141	No	-	-	-	5,137,533.90	-	5,137,533.90	5,960,613.79
23	15/01/2015	JAN	15	184,141	-	3,506	180,635	No	-	-	-	5,039,716.50	-	5,039,716.50	5,899,220.64
24	16/01/2015	JAN	16	180,635	-	3,173	177,462	No	-	-	-	4,951,189.80	-	4,951,189.80	5,839,968.71
25	17/01/2015	JAN	17	177,462	-	3,863	173,599	No	-	-	-	4,843,412.10	-	4,843,412.10	5,781,347.74
26	18/01/2015	JAN	18	173,599	-	3,179	170,420	No	-	-	-	4,754,718.00	-	4,754,718.00	5,724,312.75
27	19/01/2015	JAN	19	170,420	-	3,608	166,812	No	-	-	-	4,654,054.80	-	4,654,054.80	5,667,983.38
28	20/01/2015	JAN	20	166,812	-	3,737	163,075	No	-	-	-	4,549,792.50	-	4,549,792.50	5,612,073.84
29	21/01/2015	JAN	21	163,075	-	3,713	159,362	No	-	-	-	4,446,199.80	-	4,446,199.80	5,556,556.03
30	22/01/2015	JAN	22	159,362	-	1,563	157,799	No	-	-	-	4,402,592.10	-	4,402,592.10	5,504,103.12
31	23/01/2015	JAN	23	157,799	-	2,904	154,895	No	-	-	-	4,321,570.50	-	4,321,570.50	5,452,688.66

Figure 5-1 : Example of Class A Microsoft Excel simulation sheet

The beginning inventory (Cell D9) is the on hand inventory from 26 December, 2014 that brought forward to 1 January, 2014. In column E, Receipts, is the quantity of material received from order, which in this case for continuous review, order quantity is fixed, equal to EOQ in cell K4. Data of demand in column F is collected from production material requested, daily. Ending inventory in column G is calculated by

Column D + Column E – Column F. For the decision when to order, this continuous review depends on the reorder point (R), which calculation shown in chapter 4, state in cell F4. Column H, use IF(D9<$F$4,"Yes","No"), in order to compare value of ending inventory to reorder point.

If the ending inventory is lower than reorder point, it will show “Yes”, and will trigger the lead time, column I to start count down. The order will receive will appear in Column E, when the lead time counts to 1. An example of formula is display below in figure 5-2.

I19 | =IF(H19="Yes",VLOOKUP($K$3,$W$18:$X$20,2),0)

	A	B	C	D	E	F	G	H	I	J	K
1											
2									Cemedine Inventory Simulation		
3								Leadtime	→		14
4			Reorder Point	→		40,449.33		Order Quantity	→		58,800
5											
6				Beginning			Ending			Lead Time	
7			Day	Inventory	Receipts	Demand	Inventory	Order?	Lead Time	Count	Order (THB)
17	09/01/2015	JAN	9	42,083	-	1,232	40,851	No	-	-	-
18	10/01/2015	JAN	10	40,851	-	1,471	39,380	No	-	-	-
19	11/01/2015	JAN	11	39,380	-	1,274	38,106	Yes	14.00	14	75,000
20	12/01/2015	JAN	12	38,106	-	1,196	36,910	No	-	13	-
21	13/01/2015	JAN	13	36,910	-	1,602	35,308	No	-	12	-
22	14/01/2015	JAN	14	35,308	-	1,216	34,092	No	-	11	-
23	15/01/2015	JAN	15	34,092	-	1,245	32,847	No	-	10	-
24	16/01/2015	JAN	16	32,847	-	1,305	31,542	No	-	9	-
25	17/01/2015	JAN	17	31,542	-	1,658	29,884	No	-	8	-
26	18/01/2015	JAN	18	29,884	-	1,529	28,355	No	-	7	-
27	19/01/2015	JAN	19	28,355	-	1,088	27,267	No	-	6	-
28	20/01/2015	JAN	20	27,267	-	1,012	26,255	No	-	5	-
29	21/01/2015	JAN	21	26,255	-	2,035	24,220	No	-	4	-
30	22/01/2015	JAN	22	24,220	-	2,777	21,443	No	-	3	-
31	23/01/2015	JAN	23	21,443	-	2,056	19,387	No	-	2	-
32	24/01/2015	JAN	24	19,387	-	1,702	17,685	No	-	1	-
33	25/01/2015	JAN	25	17,685	58,800	1,033	75,452	No	-	-	-
34	26/01/2015	JAN	26	75,452	-	2,891	72,561	No	-	-	-
35	27/01/2015	JAN	27	72,561	-	2,400	70,161	No	-	-	-

Figure 5-2 : Example of Class A Microsoft Excel simulation sheet

This simulation is done in the period of 4 months, in comparison to current ordering method, which already mentioned that it is based on purely on human judgment and experience without concerning on any factor.

In figure 5-3 and 5-4, the inventory movement for each raw material is illustrated. It shows how the proposed continuous review policy is performed with class A raw material, in comparison to current method.

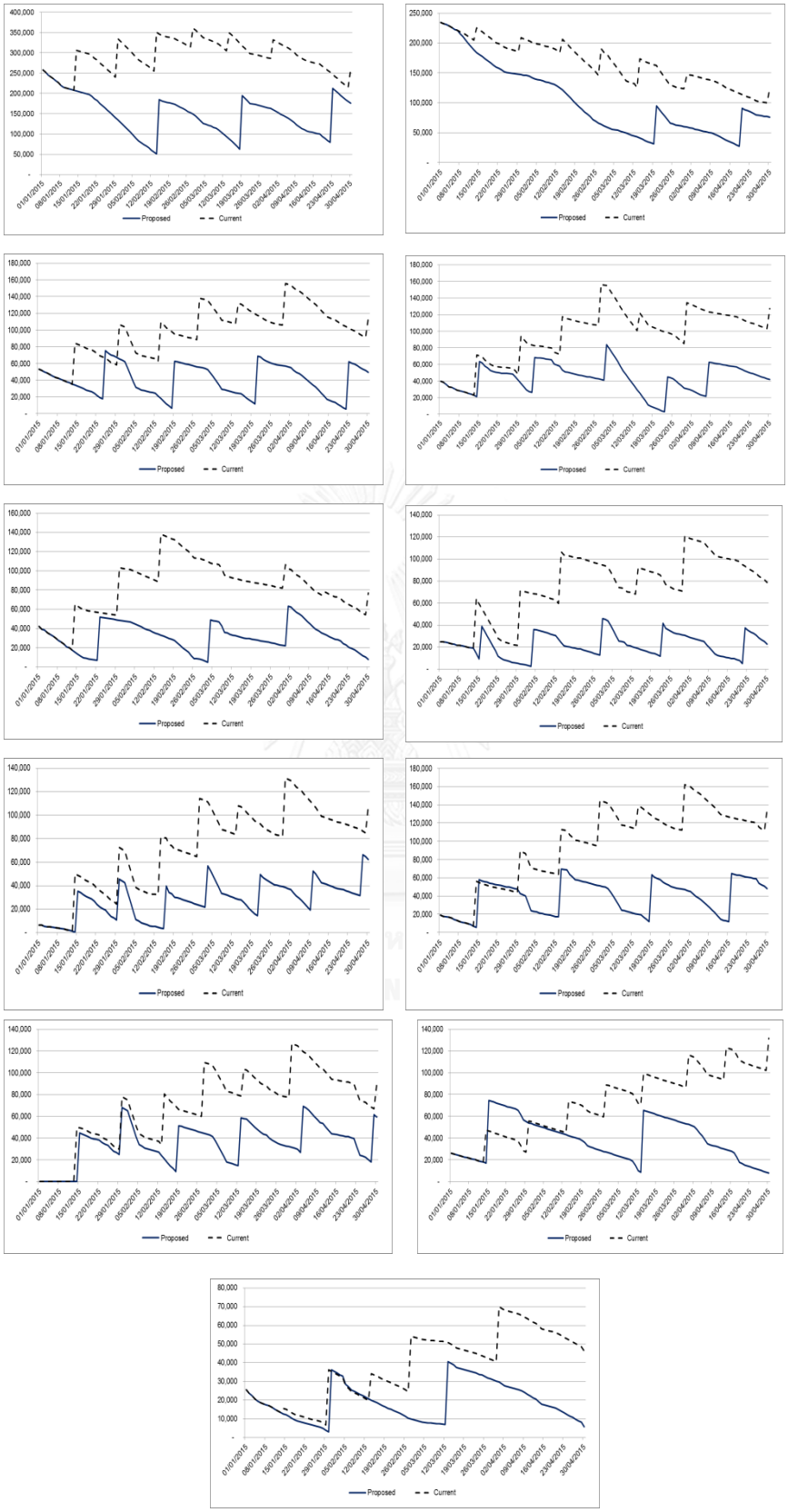


Figure 5-3 : Simulation result of proposed policy for class A raw material

5.2 Periodic review policy simulation

Similar to continuous review policy, calculation is done through Microsoft Excel, based on primary calculation of OUL and safety stock in chapter 4 and review interval that align with suppliers' limitation.

	A	B	C	D	E	F	G	H	I	J	K
1											
2							Cemedine Inventory Simulation				
3							Leadtime	→			14
4			Review interval	→		14.00	OUL	→			4,059
5											
6				Beginning			Ending		Lead Time	Lead Time	
7			Day	Inventory	Receipts	Demand	Inventory	Order?		Count	Order (THB)
47	08/02/2015	FEB	8	935	-		935	No	-	6	-
48	09/02/2015	FEB	9	935	-		935	No	-	5	-
49	10/02/2015	FEB	10	935	-		935	No	-	4	-
50	11/02/2015	FEB	11	935	-		935	No	-	3	-
51	12/02/2015	FEB	12	935	-		935	No	-	2	-
52	13/02/2015	FEB	13	935	-		935	No	-	1	-
53	14/02/2015	FEB	14	=IF(J52=1,$K$4-G39,0)			3,839	Yes	14.00	-	75,000
54	15/02/2015	FEB	15	3,8	IF(logical_test, [value_if_true], [value_if_false])			No	-	-	-
55	16/02/2015	FEB	16	3,684	-	147	3,537	No	-	-	-
56	17/02/2015	FEB	17	3,537	-	56	3,481	No	-	-	-
57	18/02/2015	FEB	18	3,481	-	178	3,303	No	-	-	-
58	19/02/2015	FEB	19	3,303	-	180	3,123	No	-	-	-
59	20/02/2015	FEB	20	3,123	-	140	2,983	No	-	-	-
60	21/02/2015	FEB	21	2,983	-	210	2,773	No	-	-	-
61	22/02/2015	FEB	22	2,773	-	136	2,637	No	-	-	-
62	23/02/2015	FEB	23	2,637	-	124	2,513	No	-	-	-
63	24/02/2015	FEB	24	2,513	-	80	2,433	No	-	-	-
64	25/02/2015	FEB	25	2,433	-		2,433	No	-	-	-
65	26/02/2015	FEB	26	2,433	-		2,433	No	-	-	-
66	27/02/2015	FEB	27	2,433	-		2,433	No	-	-	-
67	28/02/2015	FEB	28	2,433	-		2,433	YES	14.00	14	75,000

Figure 5-4 : Example of Class B and C in Microsoft Excel simulation sheet

The different from continuous review policy is that the order quantity is not fixed, so the column E, which is receive quantity, will be cell K4 minus ending inventory of the day at review interval.

In figure 5-6, the inventory movement for sample raw material is illustrated. It shows how the proposed periodic review policy is performed with class B and C raw material, in comparison to current method.

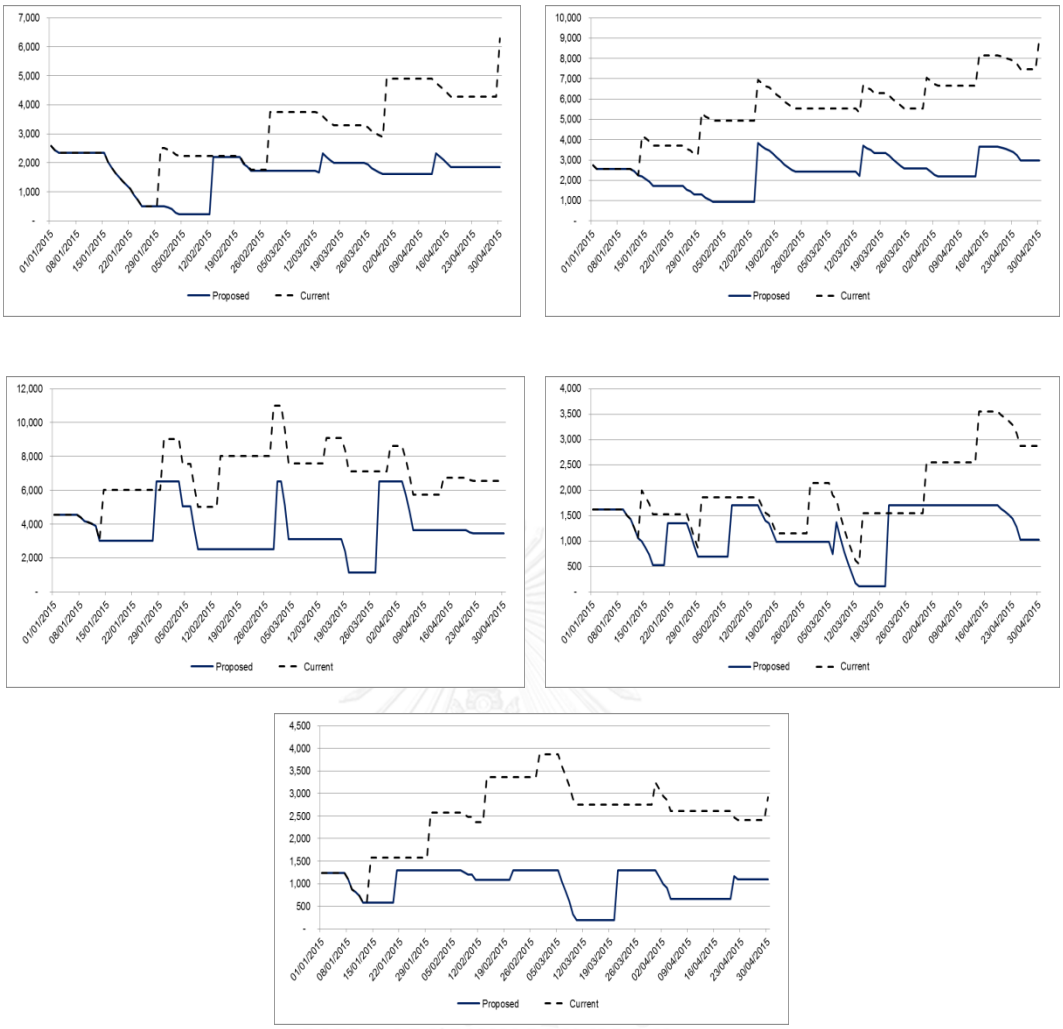


Figure 5-5 : Simulation result of proposed policy for class B and C raw material

5.3 Result discussion

5.3.1 Results discussion

For class A – Continuous review policy have been chosen and applied, the result is illustrate in figure 5-3. There is a major reduction in inventory level of every raw material; total of 11 items. Another clear and noticeable change of proposed method is the reduction in number of ordering time of each items if compare to current method. The proposed method set the certain level of re order point, which is the level that the system will notified staffs that the order need to be placed, unlike current method. Staffs rely on manager experience and place the order of the quantity that used to place, with no ideas of the on hand inventory quantity.

For class B & C – Periodic review policy have been applied, the overall trend of inventory level is reduced considerably during the simulating time period. As same as discussed in class A, for the current method, staffs order raw materials based on manager decision. But with proposed method, the review interval is fixed and set, so staffs have a reliable guideline which predetermined and already absorb the uncertainty.

5.3.2 Advantages and disadvantage of each review policy

It cannot be concluded which policy is better than the other, Each has advantages and disadvantages as performs better in different situation. The criteria of selecting which policy to adopt are not very obvious, but depend on preference of management team. From studied and implementing on both policy, the main benefit for periodic is its simple and convenient method, staff can perform routinely when to check stock, when to place and order and when the order will arrive. The stock level doesn't have to be monitor continuously, which consumes fewer resources and according to Silver, Pyke, & Peterson, 1999 reviewing costs and errors under continuous review are larger than under periodic review. Refer to Walters D., this periodic review is suitable for cheap item, due to the safety stock quantity will be higher than continuous review policy, as it need to cover uncertainty not only during lead time, but during review interval too. Another advantage for periodic review is that, it is easy to combine several items into one order or one supplier, so that when total quantity in the order become bigger, then this may encourage the suppliers to give some more discounts or this may result in less transport cost.

Then again, continuous review policy got a major advantage of fixed order quantity, which is relatively easier for staff to make the purchase and, moreover, easy for suppliers to make a reserved for. This fixed order quantity already calculated with concerning on cost factor by economic order quantity (EOQ), so it would be the quantity that results in lowest cost. While, for periodic review, the order quantity will be varied, If demand has been low during the prior time interval, inventory levels will be relatively high when the review time occurs, and the amount to be ordered will be relatively low. If demand has been high during the prior time interval, inventory levels will have been depleted to low levels when the review time occurs, and the amount to

be ordered will be higher. Since demand continues to occur during the lead time, inventory levels will increase when the replenishment order arrives, but not all the way up to the predetermined inventory level. One more advantage for continuous review is the quantity of safety stock is lowers, as explain above, it only need to cover lead time uncertainty. This contributes in overall lower inventory level and inventory cost.

5.3.2 Key performance indicators (KPIs)

The Key performance indicators (KPIs) suggested in Chapter 3, are calculated and reported in table5-1, which are an average inventory level (Kg), average inventory days (days), average inventory value (THB), service level (%) and Number of reorder cycle (Times).

5.3.2.1 Inventory level comparison - weekly

Details of inventory level of each individual item of raw materials in class A will be presented, as a result of proposed inventory control policy; the inventory level has been decrease for every item as shown below

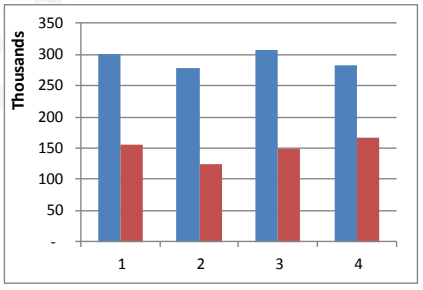
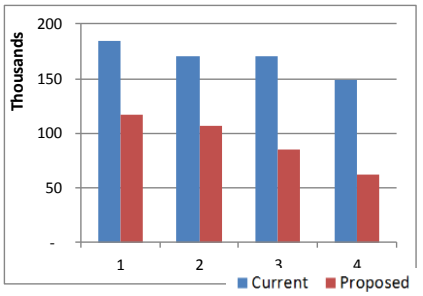
Items	Month	Ending Inventory Level (Kg)		Current method inventory level(Kg) vs Proposed method inventory level(Kg) - Monthly
		Current	Proposed	
RM57	1	300,958	154,833	
	2	278,961	123,908	
	3	307,797	148,636	
	4	281,679	166,137	
RM92	1	184,963	116,935	
	2	169,865	106,576	
	3	170,310	85,413	
	4	149,148	62,473	

Table 5-1 : Inventory level of current method implement compare to proposed method of Class A raw material - 1

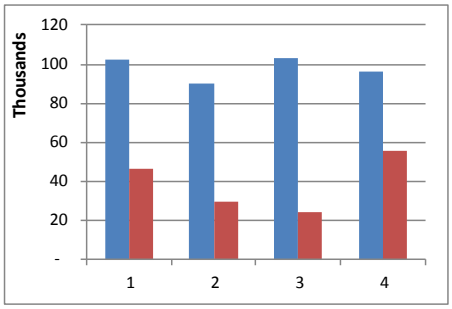
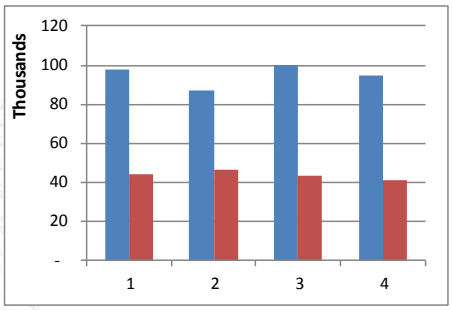
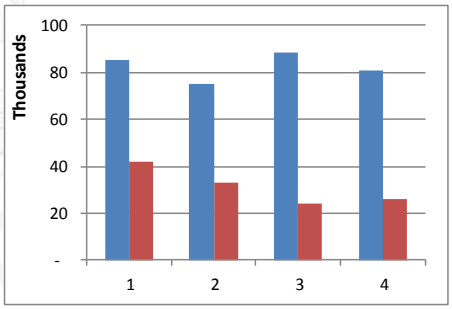
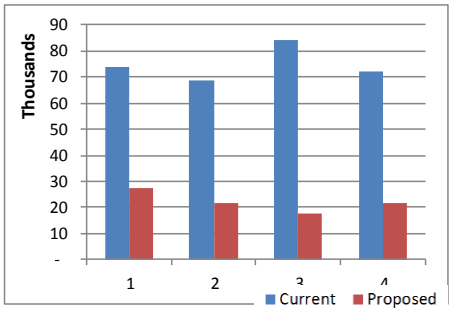
Items	Month	Ending Inventory Level (Kg)		Current method inventory level(Kg) vs Proposed method inventory level(Kg) - Monthly
		Current	Proposed	
RM107	1	102,139	46,589	
	2	89,986	29,972	
	3	103,103	24,703	
	4	95,850	55,761	
RM100	1	97,568	44,214	
	2	87,368	46,404	
	3	100,094	43,069	
	4	94,397	41,350	
RM93	1	85,170	42,017	
	2	75,333	33,283	
	3	88,515	23,965	
	4	80,523	25,909	
RM110	1	73,942	27,620	
	2	68,894	21,729	
	3	84,122	17,415	
	4	72,107	21,424	

Table 5-2 : Inventory level of current method implement compare to proposed method of Class A raw material - 2

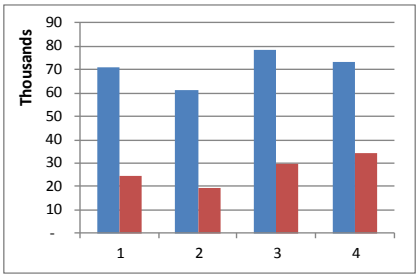
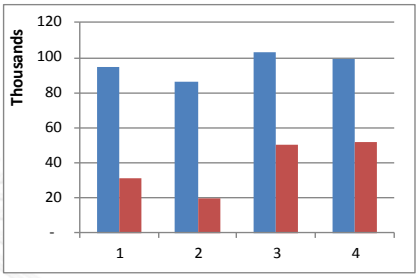
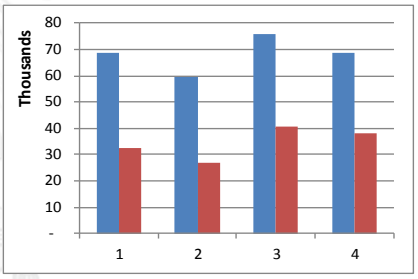
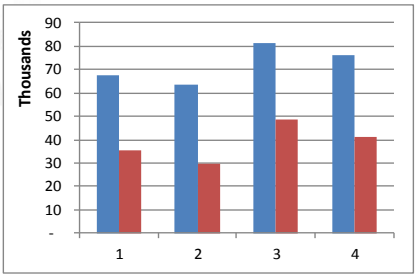
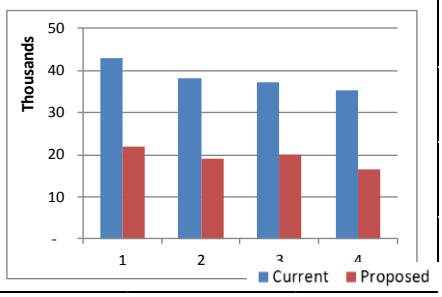
Items	Month	Ending Inventory Level (Kg)		Current method inventory level(Kg) vs Proposed method inventory level(Kg) - Monthly
		Current	Proposed	
RM89	1	71,035	24,785	
	2	61,131	19,516	
	3	78,658	29,758	
	4	73,115	34,115	
RM29	1	94,888	31,238	
	2	85,952	19,745	
	3	103,166	50,223	
	4	99,052	51,997	
RM34	1	68,590	32,515	
	2	59,337	26,826	
	3	75,915	40,739	
	4	68,591	38,016	
RM86	1	67,383	35,583	
	2	63,568	29,560	
	3	81,453	48,753	
	4	76,410	41,160	
RM59	1	42,865	21,915	
	2	38,256	19,078	
	3	37,062	20,062	
	4	35,374	16,396	

Table 5-3 : Inventory level of current method implement compare to proposed method of Class A raw material - 3

5.3.2.2 Overall KPIs - weekly

The overall Key performance indicators (KPIs) suggested in Chapter 3, are calculated and reported in table5-2, which are an average inventory level (Kg), average inventory days (days), average inventory value (THB), service level (%) and Number of reorder cycle (Times).

Items	Inventory (4 Months period)						Service Level		Number of order	
	Days		Kilograms		Value					
	Current	Proposed	Current	Proposed	Current	Proposed	Current	Proposed	Current	Proposed
RM57	70	*36*	291,637	149,562	14,436,047	7,403,335	100.00%	*100.00%*	7	*3*
RM92	59	*37*	167,277	90,824	15,556,742	8,446,659	100.00%	*100.00%*	6	*2*
RM107	49	*20*	97,642	40,357	9,471,247	3,914,602	100.00%	*100.00%*	7	*4*
RM100	53	*24*	94,826	43,599	8,249,882	3,793,089	100.00%	*100.00%*	7	*5*
RM93	57	*22*	82,261	30,934	7,156,719	2,691,299	100.00%	*100.00%*	5	*3*
RM110	52	*15*	74,589	22,005	7,160,525	2,112,525	100.00%	*100.00%*	5	*5*
RM89	43	*17*	71,127	27,515	6,188,021	2,393,806	100.00%	*100.00%*	7	*7*
RM29	62	*25*	95,984	39,214	4,415,254	1,803,834	100.00%	*100.00%*	7	*4*
RM34	35	*18*	68,140	34,757	3,611,437	1,842,119	89.00%	89.00%	7	*6*
RM86	64	*34*	72,484	38,924	2,754,385	1,479,105	100.00%	100.00%	8	*2*
RM59	51	*26*	38,188	19,165	1,833,037	919,917	100.00%	*100.00%*	4	*2*
	595	**274**	**1,154,155**	**536,856**	**80,833,295**	**36,800,289**			**70**	**43**
	%inventory Day Reduction	**46.11%**	**%inventory Level reduction**	**46.52%**	**%inventory Value savings**	**45.53%**			**%#Ordering savings**	**61.43%**

Table 5-4 : Key Performance Indicators (KPIs) report of Class A raw material

5.4 Summary of Implement Phase

Refer to ABC classification done in chapter 4, Total value of class A inventory account for 86% of total inventory value, so the report is conduct only in class A raw material, due to the percentage of change will not affect much if class B and class C are included, the trend will show similarity to Class A.

From report, proposed policy and method show that all items show significant reduction in inventory level, overall reduce by more than 40%, for the RM 92 has 61% reduction in inventory level. As well as inventory value every items show reduction in average of 40%, which equal to about 42 million bath worth of money that previously locked up in inventory. For the popular used raw material in CMD company, RM 57, RM 92 and RM 107 the inventory reduced as much as 50%. In term of reorder cycle, every items show the reduction in order times, which result in total of 61% reduction, due to fixed order quantity policy. On the other hand, current

method of ordering does not show the fixed quantity of order or any specific rule in making decision of how much to order, which can be seen in figure 5-3 and 5-4 above. The order quantity is randomly determined depends on staff judgment, some order can be very large and some order will be very small. This also point out that there is no consideration on economy of scale when making the purchase. In term of service level, ten out of eleven items successfully achieve the require service level at 99.5%, where there is only one item cannot met. It is because of too low in beginning inventory which is a consequence of decision making of previous year, although the order place immediately, the lead time still exist. Nothing can be done in that case. Additionally, most of items show reduction in almost every aspect, while still delivers the desired service level. It can be summarize that the proposed inventory policy and methodology are successful in developing new inventory policy and managing the inventory of CMD company. It can reduce overall inventory value, inventory holding cost and inventory ordering, which will result in reduction of total cost related to inventory, while the desired service level is still achieved.

5.5 Conclusion and Recommendations

The objectives of this research is to improve CMD's inventory management, which is to propose, design and develop a new inventory control policy in order to be able to control the inventory quantity, which would lead to the minimization of total inventory costs through simulation analysis. This research consists of five main parts, which are introduction, literature review, define phase, proposed phase and implement phase. The background of company and its current business environment are explained in the introduction, statement of problem, objectives and scope also presented. In literature review, related literatures have been explored and review, which are in the area of inventory management and policies, inventory related cost, Economics Order Quantity (EOQ) and storage management in warehouse. Problems of that stated in introduction and occur in inventory management field were analyzed in detail and identified in define phase. Then, solution and method to solve the problem identified were proposed and elaborated in proposed phase. Simulation on proposed method and result discussion were presented in implement phase.

5.5.1 Conclusion

In define phase, the overall process of CMD Company, inventory control process, inventory ordering process, analysis of inventory data have been discussed. Interviewing related persons and observing the real process, also done and the causes that affect the problem have been identified and presented through cause-and-effect diagram, which help helps to explore and understand the real situation and behaviors of staffs in CMD Company, which affect the inventory problem. Key performances Indicators for inventory control have been suggested, which are inventory level, inventory value, inventory days, order times, cost of ordering and cost of holding inventory. There are three cause-and-effect diagrams created, of those three diagrams, factor of man, method and documents is the main factors that effect on inventory problems. To sum up, as the current control process involves a great deal of human factor, this leads to complexity, argumentation and confusion in inventory control and overall process. As from careful observation, investigation and data analysis, the conclusion is that currently CMD Company does not have effective inventory control policy. The subjective judgment of all department leads to unsynchronized information flow that resulted in high inventory levels for both raw materials and finish goods. The inventory control policy will help this situation. Another important issue in inventory control is the matter of maintaining good systems and procedures and this calls for strict discipline in documentation

Proposed phase, presents the proposed solution and methodology based on data collected from the company. Inventory data, demand pattern and SKUs of inventory characteristic have been analyzed. Then, ABC classification method is proposed to classify more than 150 SKUs into 3 classes. Then, the inventory policies reviews in literature review have been select to cope with each class and basic calculation is performed. The continuous review policy has been selected to apply for class A, relevant cost of inventory have been evaluate and identify. EOQ and safety stock is then calculated based on historical data, April 2013 to December 2014. The periodic review policy then applied for Class B and C due to lower priority, advantages of combining orders and not ever expensive cost of holding. Continuous review for every item in class B or C would consume too much time and resources. Review interval has been set in according to suppliers' limitation in maximum ordering frequency per month. Moreover, workflow processes have been suggested, in order

to be a guideline for staffs and standardized activities to be done by different staffs as well as standard documents have been create, according to cause-and-effect diagram', which point out these cause are effecting in inefficient inventory control. Besides, warehouse layout and zoning, items label and location label have been proposed for the ease of putaway, locating, picking inventory SKUs in warehouse.

Implementation phase, proposed solution and method are used for simulation test by evaluate with a set of actual four months data, while current method are in used. Result shown the comparison between proposed method and current method, which can be summarize that the proposed inventory policy and methodology are successful in developing new inventory policy and managing the inventory of CMD Company due to it can reduce overall inventory value, inventory holding cost and inventory ordering, which will result in reduction of total cost related to inventory, while the desired service level is still achieved. The major saving will be achieved in reducing the inventory value, captured and compare to the current inventories, there is a saving up to 42 million baht during simulated period of four months, which is 54.5 % reduction. Inventory level is decrease significantly, both weekly and overall, inventory level reduction in total is around 620,00 kilograms, which is about 46.2 % For the observed impact of proposed standard workflow process of warehouse and overall process, staffs are now working as the workflow outlined in the same way, no confusion of the process, and the newcomers can easily understand and perform work faster. Label on products and on rack and shelves have been implemented, but not in a permanent version, there are still areas for improvement. For Computer based inventory record system, it helps the problem of missing documents but still not every useful due to the system is only on an excel based, when other department need the information, warehouse needed to print it out or let them see the file at warehouse, still not very convenient.

To sum up, to achieved the purposed of improvement of inventory control system, the proposed solutions and methodology should be done simultaneously. For example, to allow the proposed inventory policy used yield as effective as possible, the warehouse process should be done properly, documents should be correct, inventory data and information should be record accurately. Everything need to align and support each other. The inventory policy will surely failed if for example, the

warehouse staffs don't know where they kept the raw materials and level of inventory recorded into system is wrong. So, in order to perform effective inventory management and warehouse management, every activities involved should be done follow the proposed method so, they will support each other.

5.5.2 Recommendations

Over the few chapters, key principles which reflect from cause-and-effect diagram, to improve control are focused on. Along the improvement process, it's important to keep in mind that the essential factors to improving inventory management are gaining management commitment; developing effective cross functional teams, realizing accurate data, keeping appropriate policies and procedures, motivating and training staff and putting in a lot of hard work.

The computer based inventory system still need to develop more, a program based for inventory management should be adopted, so the information flow within the company would be more integrated. Moreover, wherever practical, receiving should be based on Auto ID processes to eliminate human error in inputting data. The ultimate goal is to achieve inventory optimization to minimize overall cash investment, while still satisfying customers without increasing the risk to the company. All of the factors that influence the actual inventory investment need to be reviewed on a regular basis. Inventory levels should be adjusted to account for changing business needs with the goal of minimizing the possibility of outdated or excess inventory.

5.5.3 Limitations

As this research was designed and done through simulating,not yet fully implement. The results came out based on ideal conditions, nothings goes wrong and staffs are fully understand and cooperated. But in reality, there might be some limitation in implementing. For example, staffs may against or not fully understand, or ther night be some big fluctuation in demand which will cause troubles to inventory policy.

5.5.4 Future work

As most of the inventory items and finish products store in the company contain chemical substances, which reactive and sensitive. From observation and interview done, fire occurred average about 2-3 times every year and there is no safety process in the plant area. Staffs using bare hand to clean the mixing batch with toluene, no safety shoes for workers, no clear signage of fire exits or signage of fire extinguishers. The study and improvement in area of safety is strongly recommended.

Appendices A – Stock keeping units (SKUs' master)

RM Code	Good code	Description	UOM	Kg/UOM	Price/UOM	Average usage	Average cost
RM01	00-MA-LI-031-01-A01	Versamine K13	Pail	17	32	8.89	284.44
RM02	00-MA-PA-026-01-A01	Epiclon B-570	Drum	220	44	87.02	3,828.98
RM03	00-MA-PA-027-01-A02	LIR-403	Pail	15	37	65.31	2,416.51
RM04	00-MA-PA-028-01-A01	Adeka Resin EPR-1309	Pail	18	49	12.42	608.69
RM05	00-MA-PA-029-01-A01	Adeka Resin EPU-78-11	Pail	18	56	49.49	2,771.38
RM06	00-MA-PO-028-01-A02	Printex XE2B	Bag	5	40	8.60	344.00
RM07	00-MA-PO-045-01-A01	MFL- 100CA	Bag	70	12	75.56	906.67
RM08	00-MA-PO-050-01-A01	DN-B	Bag	25	31	825.00	25,575.00
RM09	00-MA-PO-060-01-A01	Calbatec Viscolte-OS	Bag	20	36	12,406.67	446,640.00
RM10	00-MA-SO-032-01-A01	Arkon P-100	Bag	25	47	162.94	7,658.39
RM11	01-MA-CO-009-01-A01	Nipol Rubber Type 1001	Bag	35	56	145.33	8,138.67
RM12	01-MA-LI-004-01-A02	Diacizer 671 N	Drum	200	52	401.78	20,892.44
RM13	01-MA-LI-007-01-A01	Gleck ML-510A	Can	18	91	28.68	2,609.68
RM14	01-MA-LI-014-01-A01	CS-16	Can	17	38	307.89	11,699.78
RM15	01-MA-PA-008-01-A01	C-510 SE	Can	18	35	330.84	11,579.56
RM16	01-MA-PA-010-01-A02	Nipol DN601	Drum	180	41	1,090.00	44,690.00
RM17	01-MA-PA-010-01-A03	Nipol DN601	Drum	190	21	950.00	19,950.00
RM18	01-MA-PA-025-01-A01	Vulnoc GM Paste	Can	10	52	181.74	9,450.71
RM19	01-MA-PO-005-01-A01	Busan 11-MI	Bag	25	72	67.60	4,867.20
RM20	01-MA-PO-009-01-A01	Epiclon B-605IM	Carton	12	24	51.56	1,237.33
RM21	01-MA-PO-010-01-A01	Flothene UF1.5	Bag	20	17	68.71	1,168.09
RM22	01-MA-PO-013-01-A01	K-37FA	Carton	20	39	96.82	3,776.07
RM23	01-MA-PO-013-01-A02	K-37Y	Carton	10	45	3.33	150.00
RM24	01-MA-PO-014-01-A01	K-White#105	Bag	20	32	383.94	12,286.22
RM25	01-MA-PO-019-01-A01	Meta ZL-40	Bag	20	38	24.19	919.18
RM26	01-MA-PO-023-01-A01	Nocceller BG	Bag	20	24	63.14	1,515.47
RM27	01-MA-PO-025-01-A01	Nocrac NS-6	Bag	10	34	47.81	1,625.58
RM28	01-MA-PO-032-01-A01	Arbocel BWW-40	Bag	17.5	20	446.98	8,939.56
RM29	01-MA-PO-036-01-A01	Neolight SP	Bag	25	46	22,585.89	1,038,950.89
RM30	01-MA-PO-037-01-A01	1Hydroxy 2 Naphthoic Acid	Can	30	42	50.00	2,100.00
RM31	01-MA-PO-038-01-A01	Propyl Gallate	Can	10	23	25.56	587.78
RM32	01-MA-PO-044-01-A01	Dianal LP 3105	Bag	20	39	600.00	23,400.00
RM33	01-MA-PO-052-01-A01	Neolight AT-23	Bag	25	47	1,850.00	86,950.00
RM34	01-MA-PO-053-01-A01	Neolight SP-60	Bag	25	53	19,466.67	1,031,733.33
RM35	01-MA-SO-002-01-A01	Asaprene T-411	Bag	15	50	3.33	166.67
RM36	01-MA-SO-005-01-A02	Escorez 1202	Bag	20	39	2.22	86.67
RM37	01-MA-SO-006-01-A02	Coumarone Resin V-120	Bag	20	57	73.33	4,180.00
RM38	01-MA-SO-008-01-A02	Lunac S-70 V	Bag	20	40	0.17	6.67
RM39	01-MA-SO-014-01-A01	Picotex-LC	Bag	22.68	41	7.56	309.96
RM40	01-MA-SO-015-01-A01	Rezitop PS2980	Bag	25	40	155.56	6,222.22
RM41	01-MA-SO-026-01-A01	Tufprene-A	Bag	25	54	2.78	150.00
RM42	01-MA-SO-027-01-A01	Vinsol Ester Gum	Bag	20	56	171.11	9,582.22
RM43	01-MA-SO-028-01-A02	Sanatac-L	Bag	20	44	8.33	366.67
RM44	02-MA-CO-001-02-A01	366E RubberBatch	Kg	1	70	88.89	6,222.22
RM45	02-MA-CO-002-02-A01	CS-4795B RubberBatch	Kg	1	73	866.25	63,236.25
RM46	02-MA-CO-003-02-A03	Exxon Butyl #1066	Bag	34	59	120.17	7,089.83
RM47	02-MA-CO-004-02-A01	JSR N 210 S	Bag	35	57	2,295.17	130,824.50
RM48	02-MA-CO-007-02-A01	JSR N 230 S	Bag	35	68	3,390.22	230,535.11
RM49	02-MA-CO-008-02-A02	SBR-1712	Bag	35	54	244.34	13,194.60
RM50	02-MA-CO-010-02-A01	Rubber RSS#3	Bag	20	30	84.83	2,545.00
RM51	02-MA-CO-011-02-A02	SBR 1009 AF	Kg	1	81	3,307.83	267,934.32
RM52	02-MA-CO-017-02-A01	540 Rubber Batch Kg	Kg	1	75	416.89	31,266.67
RM53	02-MA-CO-019-02-A02	JSR EP33	Kg	17.5	79	153.17	12,100.17
RM54	02-MA-CO-021-02-A01	S-952 RubberBatch	Kg	1	82	19.11	1,567.11
RM55	02-MA-CO-023-02-A01	CS-3061D RubberBatch	Kg	1	84	7.71	647.73
RM56	02-MA-CO-047-02-A02	Ubepol-BR150 B	Bag	35	79	1,646.89	130,104.22
RM57	02-MA-LI-003-02-A01	DINP	Bulk	15000	49.5	145,802.00	7,217,199.00
RM58	02-MA-LI-005-02-A04	Ethyl Acetate	Gallon	3	62	0.44	27.56
RM59	02-MA-LI-006-02-A01	Exxsol D-80 Fluid	Bulk	9000	48	16,893.56	810,890.67
RM60	02-MA-LI-008-02-A02	IPA	Gallon	3	37	0.22	8.22

RM Code	Good code	Description	UOM	Kg/UOM	Price/UOM	Average usage	Average cost
RM61	02-MA-LI-019-02-A02	Toluene	Drum	170	32	1,473.33	47,146.67
RM62	02-MA-LI-021-02-A04	Monocizer W-242	Drum	170	37	25.44	941.44
RM63	02-MA-LI-021-02-A05	DINA	Drum	190	34	127.22	4,325.56
RM64	02-MA-LI-021-02-A06	Monocizer W-242	Drum	190	48	419.29	20,125.71
RM65	02-MA-LI-034-02-A02	Luperox 331-EB70	Drum	16	64	159.63	10,216.53
RM66	02-MA-LI-035-02-A01	Adeka Glycerol ED-503	Drum	210	47	15.61	733.72
RM67	02-MA-LI-036-02-A02	ADK Cizer PN-260	Drum	200	58	2,421.43	140,442.86
RM68	02-MA-LI-037-02-A02	Flexon 641 P	Drum	172	72	2,738.67	197,184.00
RM69	02-MA-LI-039-02-A02	Baerostab MTS 1200	Drum	220	37	594.04	21,979.64
RM70	02-MA-LI-040-02-A01	Preminol S 1004F	Can	18	73	14.87	1,085.27
RM71	02-MA-LI-041-02-A02	Globinex W-23 S	Drum	200	48	628.22	30,154.67
RM72	02-MA-LI-042-02-A01	Reofos 65	Drum	230	31	421.11	13,054.44
RM73	02-MA-PA-002-02-A02	Black Paste-403	Box	15	25	458.17	11,454.17
RM74	02-MA-PA-003-02-A02	Npel 128	Drum	240	76	3,612.78	274,571.11
RM75	02-MA-PA-006-02-A01	Weldmide#3210	Drum	190	27	2,060.16	55,624.20
RM76	02-MA-PA-009-02-A03	Polybutene HV-300	Drum	180	59	476.67	28,123.33
RM77	02-MA-PA-014-02-A02	Adeka Resin QR-1636-2l	Drum	180	83	928.13	77,034.38
RM78	02-MA-PA-015-02-A01	Adeka Resin QR-9327-1	Drum	180	86	2,608.89	224,364.44
RM79	02-MA-PA-016-02-A01	Takenate B-5010	Drum	200	71	1,200.00	85,200.00
RM80	02-MA-PA-017-02-A02	Takenate B-7105	Drum	200	75	379.88	28,490.63
RM81	02-MA-PA-018-02-A02	Takenate B-7030	Drum	200	84	142.00	11,928.00
RM82	02-MA-PA-019-02-A02	Polybutene PB-950	Drum	180	54	1,355.56	73,200.00
RM83	02-MA-PA-020-02-A01	Adeka Resin QR-9401-1	Drum	180	74	110.28	8,160.56
RM84	02-MA-PA-030-02-A01	jER 807	Drum	200	46	61.91	2,847.91
RM85	02-MA-PA-032-02-A01	KA-112	Drum	180	71	2,206.25	156,643.75
RM86	02-MA-PO-002-02-A05	Calcium Oxide	Bag	25	38	22,023.61	836,897.22
RM87	02-MA-PO-003-01-A02	DYHARD 100	Bag	15	47	532.36	25,020.71
RM88	02-MA-PO-005-02-A01	CCR-SS	Bag	25	69	6,150.00	424,350.00
RM89	02-MA-PO-006-02-A01	Hakuenka CC	Bag	25	87	17,308.78	1,505,863.67
RM90	02-MA-PO-007-02-A01	Hakuenka CCR	Bag	25	83	3,955.56	328,311.11
RM91	02-MA-PO-012-02-A01	Sipenat 820A	Bag	25	143	329.44	47,110.56
RM92	02-MA-PO-016-02-A02	Omyacarb-8	Bag	25	93	69,586.11	6,471,508.33
RM93	02-MA-PO-016-02-A03	Omyacarb-8	Bag	500	87	28,833.33	2,508,500.00
RM94	02-MA-PO-017-02-A02	PVC Past 74GP	Bag	25	54	7,719.00	416,826.00
RM95	02-MA-PO-017-02-A03	PVC Past Resin PG740	Bag	25	50	5,641.67	282,083.33
RM96	02-MA-PO-018-02-A02	CML- 31	Pail	20	47	12.42	583.84
RM97	02-MA-PO-019-02-A01	Sulphur	Bag	25	45	77.78	3,500.00
RM98	02-MA-PO-020-02-A03	Microtech AC-508 ZM	Drum	25	51	615.57	31,393.90
RM99	02-MA-PO-022-02-A01	Wacker HDK N 20	Bag	10	64	146.64	9,385.24
RM100	02-MA-PO-023-02-A01	YCC Brand R-501	Bag	25	87	29,160.56	2,536,968.33
RM101	02-MA-PO-024-02-A01	Zinc Oxide White Seal	Bag	25	68	725.94	49,364.22
RM102	02-MA-PO-026-02-A01	Whiteperse R-02	Bag	25	56	1,437.67	80,509.33
RM103	02-MA-PO-027-02-A01	Degalan UC506	Bag	25	37	5.56	205.56
RM104	02-MA-PO-027-02-A02	Kane Ace UC506	Bag	25	106	1,007.50	106,795.00
RM105	02-MA-PO-028-02-A01	Aerosil R972	Bag	10	51	263.11	13,418.67
RM106	02-MA-PO-029-02-A02	B-325	Bag	25	78	448.33	34,970.00
RM107	02-MA-PO-030-02-A01	Toson PVC Paste Resin R-750	Bag	20	97	59,236.11	5,745,902.78
RM108	02-MA-PO-030-02-A02	Adeka Hardener EH-4358S	Drum	15	62	17.22	1,067.78
RM109	02-MA-PO-033-02-A01	Glass Bubbles S38 CTN/50 Kg	CTN	50	76	136.11	10,344.44
RM110	02-MA-PO-034-02-A01	Kane Vinyl Paste PBM-6	Bag	25	96	19,350.00	1,857,600.00
RM111	02-MA-PO-035-02-A02	909 DU80	Bag	20	50	0.94	47.22
RM112	02-MA-PO-038-02-A01	Advancell EMH204	Bag	20	98	305.33	29,922.67
RM113	02-MA-PO-054-02-A02	Aradur 9506	Drum	68	62	7.97	493.93
RM114	02-MA-SO-004-02-A02	Shoprene WHV-100	Bag	25	71	16.33	1,159.67
RM115	02-MA-SO-005-02-A02	Shoprene WM-1	Bag	25	85	35.39	3,008.06
RM116	02-MA-SO-005-02-A03	Showa Denka Chloroprene WK	Bag	20	90	4.33	390.00
RM117	02-MA-SO-007-02-A01	Quinton R-100	Bag	25	39	0.00	-
RM118	02-MA-SO-010-02-A02	Antage BHT	Bag	20	68	0.11	7.56

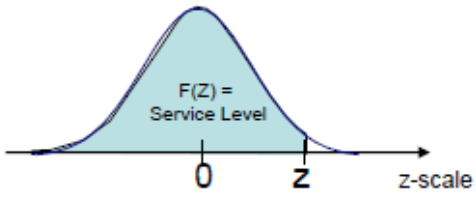
Appendices B – Monthly demand of Inventory

Goods Code	Goods Name	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14
02-MA-LI-003-02-A01	DINP	159,177	164,160	149,414	166,000	158,384	150,559	163,068	149,395	156,807	143,068	149,395	136,807	139,177	144,160	139,414	136,000	128,384	130,559	133,068	129,395	126,807
02-MA-PO-016-02-A02	Omyacarb-8	80,200	71,075	76,325	72,150	77,800	75,475	77,000	66,775	77,225	67,000	66,775	67,225	70,200	61,075	63,325	64,150	65,800	65,475	63,000	63,775	62,225
02-MA-PO-030-02-A01	Toson PVC Paste Resin R-750	64,050	50,460	57,680	51,600	61,255	61,255	53,580	56,760	60,940	61,580	56,760	50,940	54,050	50,460	57,680	51,600	61,255	61,580	61,580	56,760	60,940
02-MA-PO-023-02-A01	YCC Brand R-501	25,216	23,805	25,736	23,075	30,650	32,086	32,946	27,750	39,250	32,946	27,750	29,250	25,216	23,805	25,736	23,075	23,650	24,086	23,946	23,750	23,250
02-MA-PO-016-02-A03	Omyacarb-8	34,500	35,000	28,000	28,000	28,500	32,000	34,500	21,500	24,500	34,500	21,500	24,500	28,500	27,000	28,000	28,000	28,500	27,500	26,600	21,500	24,500
02-MA-PO-034-02-A01	Kane Vinyl Paste PBM-6	21,800	18,025	19,125	17,325	20,700	20,700	18,950	17,025	19,400	18,950	17,025	19,400	21,800	18,025	19,125	17,325	20,700	20,700	18,950	17,025	19,400
02-MA-PO-006-02-A01	Hakuenka CC	20,762	16,202	14,702	19,452	15,266	17,042	17,567	18,507	17,782	17,567	18,507	17,782	18,762	16,202	14,702	19,452	15,266	17,042	17,567	18,507	17,782
01-MA-PO-036-01-A01	Neolight SP	25,521	20,475	25,622	19,818	22,558	19,919	23,097	20,350	20,767	23,097	20,350	20,767	25,521	20,475	25,622	19,818	22,558	19,919	23,097	20,350	20,767
01-MA-PO-053-01-A01	Neolight SP-60	27,425	13,150	28,525	13,275	11,425	11,775	23,425	6,875	23,950	23,425	6,875	23,950	17,425	13,150	22,525	13,275	11,425	11,775	23,425	6,875	23,950
02-MA-PO-002-02-A05	Calcium Oxide	25,213	20,225	21,825	20,750	20,975	22,425	21,625	20,175	23,400	21,625	20,175	23,400	25,213	20,225	21,825	20,750	20,975	22,425	21,625	20,175	23,400
02-MA-LI-006-02-A01	Exxsol D-80 Fluid	17,242	16,156	15,353	13,149	19,823	18,863	18,908	18,050	15,301	18,908	18,050	15,301	17,242	16,156	15,353	13,149	19,823	18,863	18,908	18,050	15,301
00-MA-PO-060-01-A01	Calbatec Viscolte-OS	10,420	8,000	11,180	12,380	13,880	12,980	13,080	14,180	12,380	15794	13329	14993	15386	14820	13014	15288	11615	13939	11089	14674	11506
02-MA-PO-005-02-A01	CCR-SS	8,050	6,100	5,925	5,950	5,550	6,200	6,500	6,050	6,200	5973	5009	7965	7384	4298	5247	5448	6622	5316	5260	5003	4957
02-MA-PO-017-02-A02	PVC Past 74GP	8,108	8,825	7,875	7,825	8,825	7,450	6,075	-	-	5993	6626	8613	11920	6260	6983	6148	5690	5759	5357	5527	5488
02-MA-PO-007-02-A01	Hakuenka CCR	5,850	7,450	6,225	5,275	5,750	4,850	450	725	250	5727	5381	4744	4525	4391	3528	4008	3864	3165	2763	3397	3104
02-MA-PO-017-02-A03	PVC Past Resin PG740	-	-	-	-	-	-	2,625	6,600	7,700	8141	3870	5260	-	-	-	-	-	-	3235	7810	6382
02-MA-PA-003-02-A02	Npel 128	3,249	4,040	3,360	4,320	3,700	3,220	3,520	3,736	4,050	5744	5342	4588	5864	5130	5787	5898	4662	3697	4290	5920	4128
02-MA-CO-011-02-A02	SBR 1009 AF	3,156	4,144	3,570	3,564	3,047	3,159	3,100	3,115	3,489	4351	5464	4756	4277	4829	3564	5406	5756	4089	4582	4768	4800
02-MA-CO-007-02-A01	JSR N 230 S	4,882	5,695	3,715	5,567	3,244	5,111	4,486	4,223	3,570	3043	4578	4064	4780	4146	4375	3073	3658	3331	3486	3397	3769
02-MA-PA-015-02-A01	Adeka Resin QR-9327-1	3,730	2,687	3,420	2,800	3,600	1,586	1,631	1,640	1,653	3421	5750	5318	4494	3234	4909	5388	3953	5635	3606	5962	5002
02-MA-LI-037-02-A02	Flexon 641 P	2,650	3,720	2,518	3,332	2,558	2,752	2,580	2,580	3,160	4779	3590	4334	4611	5040	5430	4001	4329	5846	5793	3992	4577
02-MA-LI-036-02-A02	ADK Cizer PN-260	3,110	3,580	2,880	2,730	2,760	2,290	300	-	-	2169	2840	1396	1821	2720	2226	1063	1105	1974	1413	2874	987
02-MA-PA-032-02-A01	KA-112	-	-	-	-	-	1,980	1,840	2,160	1,845	1047	2505	2177	2266	-	-	-	-	1579	2991	822	2648
02-MA-CO-004-02-A01	JSR N 210 S	1,807	2,455	1,853	2,594	2,373	2,463	2,632	2,317	2,765	877	2439	2156	2069	1104	1232	2358	1564	1894	2369	991	1372
02-MA-CO-047-02-A02	Ubepol-BR150 B	1,516	1,907	2,649	1,640	1,563	1,620	2,613	1,682	1,890	2854	2533	1288	1030	1811	1375	1198	1374	1295	1641	1274	1006
02-MA-PO-027-02-A02	Kane Ace UC506	1,425	960	975	-	1,260	1,235	735	480	975	1042	2276	1718	-	987	2829	2650	876	652	616	798	819
01-MA-PO-052-01-A01	Neolight AT-23	2,075	4,225	1,775	-	1,450	2,600	1,825	1,650	1,650	2389	2186	1177	-	1875	2223	2817	1014	2304	2884	1221	2425
02-MA-PA-016-02-A01	Takenate B-5010	-	-	1,200	-	-	-	-	-	-	1379	-	-	-	-	-	-	-	1627	-	-	-
02-MA-PO-026-02-A01	Whiteperse R-02	1,424	1,442	1,494	1,421	1,491	1,400	1,370	1,320	1,525	2678	1796	1592	1870	1484	1880	856	2996	1802	2886	2291	1364
02-MA-PA-014-02-A02	Adeka Resin QR-1636-2I	1,305	1,350	1,215	1,035	1,170	990	90	405	-	1804	845	1208	2957	2362	1667	2259	2337	2944	1339	2780	1828
02-MA-PA-019-02-A02	Polybutene PB-950	1,350	1,080	1,440	90	990	1,440	1,980	1,670	1,800	1148	1426	2256	1391	1716	1976	2240	2000	1902	1879	2888	1012
02-MA-CO-002-02-A01	CS-4795B RubberBatch	594	792	792	1,188	396	990	1,188	990	-	2106	1991	1934	2058	2956	1267	1938	2807	1725	2819	2156	2677
02-MA-PA-006-02-A01	Weldmide#3210	2,200	1,875	1,900	1,590	2,002	2,378	2,100	2,242	2,230	1130	2099	1042	1085	2969	978	836	2071	2155	1093	1606	2071
02-MA-PO-024-02-A01	Zinc Oxide White Seal	744	671	791	660	785	650	752	659	703	2419	1288	2790	1965	926	843	2038	2392	2369	2587	2386	1103
02-MA-LI-019-02-A02	Toluene	1,530	1,190	1,530	1,530	1,360	1,530	1,360	1,360	1,530	1752	2954	2606	1064	2729	1999	2457	1072	2896	2049	1071	2814
02-MA-PO-012-02-A01	Sipenat 820A	450	233	282	300	250	341	366	333	361	764	975	578	268	446	317	568	696	694	669	949	582
01-MA-PA-010-01-A02	Nipol DN601	900	900	900	1,800	-	-	-	950	-	452	963	461	832	-	-	-	-	-	-	644	458
02-MA-PO-029-02-A02	B-325	735	480	475	5	605	625	375	240	500	379	767	841	669	380	1028	414	369	258	312	720	788
02-MA-PO-020-02-A03	Microtech AC-508 ZM	666	735	796	562	680	561	452	400	628	1059	1008	1072	937	705	425	692	771	690	1043	684	286
02-MA-CO-017-02-A01	540 Rubber Batch Kg	336	560	336	336	392	448	616	448	504	346	803	845	500	776	850	298	774	625	706	426	208
02-MA-LI-041-02-A02	Globinex W-23 S	1,130	1,755	668	14	814	970	390	400	600	396	475	202	391	895	451	722	330	611	810	615	590
02-MA-PO-038-02-A01	Advancell EMH204	296	235	280	260	367	325	313	343	285	347	678	277	918	670	561	385	507	421	950	462	955
02-MA-PA-017-02-A02	Takenate B-7105	515	430	312	-	400	600	200	240	460	713	871	955	287	-	378	554	120	363	948	886	684
02-MA-PA-009-02-A03	Polybutene HV-300	480	330	540	140	320	420	540	730	580	384	1139	343	1061	1137	958	448	207	785	1143	329	309
00-MA-PO-050-01-A01	DN-B	825	1,275	675	1,350	375	675	900	825	1,125	611	667	223	936	527	1142	747	588	681	1131	1049	1143
02-MA-PO-003-01-A02	DYHARD 100	476	627	521	607	584	495	503	500	585	240	560	240	818	990	1115	463	867	1052	570	644	969
01-MA-PO-044-01-A01	Dianal LP 3105	1,060	3,060	600	140	-	-	-	-	-	906	883	573	603	879	691	1003	1087	-	-	-	-
02-MA-LI-039-02-A02	Baerostab MTS 1200	505	690	760	680	601	548	552	439	502	348	201	894	1045	332	1114	705	385	651	608	939	405
01-MA-LI-004-01-A02	Diacizer 671 N	340	650	460	365	470	380	293	548	300	457	222	738	573	887	256	941	547	1008	720	1019	1065
02-MA-LI-021-02-A06	Monocizer W-242	-	-	380	173	553	484	583	382	-	757	223	354	221	458	777	612	249	-	326	629	750
01-MA-PA-010-01-A03	Nipol DN601	-	-	-	-	-	-	-	-	950	1078	-	-	-	-	-	-	-	-	-	866	945

RM code	Goods Code	Goods Name	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14
RM49	02-MA-CO-008-02-A02	SBR-1712	280	258	334	479	156	457	594	408	22	350	537	170	110	529	154	408	149	368	303	262	477
RM72	02-MA-LI-042-02-A01	Reofos 65	530	370	520	350	550	400	580	390	450	173	132	152	321	408	322	461	437	238	484	291	215
RM15	01-MA-PA-008-01-A01	C-510 SE	376	42	540	834	198	-	26	52	412	505	159	501	459	559	278	310	385	487	290	318	101
RM42	01-MA-SO-027-01-A01	Vinsol Ester Gum	300	160	-	280	300	160	200	100	200	468	343	402	338	338	558	408	190	533	409	101	318
RM24	01-MA-PO-014-01-A01	K-White#105	304	372	403	488	355	330	364	335	475	324	329	223	284	474	102	186	132	118	283	219	334
RM53	02-MA-CO-019-02-A02	JSR EP33	117	145	208	12	132	158	209	148	189	392	228	443	535	496	466	413	414	219	222	549	201
RM14	01-MA-LI-014-01-A01	CS-16	289	391	323	289	357	340	238	306	306	383	123	514	139	425	348	118	306	437	337	199	453
RM73	02-MA-PA-002-02-A02	Black Paste-403	420	465	551	420	470	459	398	465	390	214	443	483	347	359	439	165	324	262	273	424	241
RM109	02-MA-PO-033-02-A01	Glass Bubbles S38 CTN/50 Kg	100	100	150	25	125	125	200	175	175	113	320	159	451	123	395	547	409	328	425	410	199
RM65	02-MA-LI-034-02-A02	Luperox 331-E870	131	166	162	174	166	157	158	163	166	284	265	534	419	463	431	168	283	344	524	440	221
RM18	01-MA-PA-025-01-A01	Vulnoc GM Paste	177	250	168	228	171	179	165	173	207	544	556	527	173	436	319	552	155	357	189	255	371
RM37	01-MA-SO-006-01-A02	Coumarone Resin V-120	60	100	-	-	300	200	100	-	-	151	509	519	271	558	108	541	160	185	220	535	473
RM99	02-MA-PO-022-02-A01	Wacker HDK N 20	136	173	171	130	139	125	153	145	150	425	365	263	516	130	220	525	538	151	271	253	513
RM40	01-MA-SO-015-01-A01	Rezitop PS2980	300	150	-	300	300	200	200	100	-	477	449	121	139	540	474	372	225	229	301	443	140
RM28	01-MA-PO-032-01-A01	Arbocel BWW-40	90	927	112	600	107	611	1,145	621	626	247	109	266	367	288	329	116	445	254	557	480	190
RM10	00-MA-SO-032-01-A01	Arkon P-100	134	150	166	-	150	175	249	214	213	230	166	178	201	140	121	170	110	99	91	226	138
RM62	02-MA-LI-021-02-A04	Monocizer W-242	229	-	-	-	-	-	-	-	-	90	-	-	211	-	-	-	205	-	-	250	-
RM83	02-MA-PA-020-02-A01	Adeka Resin QR-9401-1	185	330	110	90	90	90	70	50	198	166	80	119	116	180	178	132	149	127	196	121	226
RM11	01-MA-CO-009-01-A01	Nipol Rubber Type 1001	100	176	121	129	135	162	208	168	164	163	164	160	117	162	91	218	192	164	240	105	142
RM63	02-MA-LI-021-02-A05	DINA	190	366	100	-	-	-	-	190	565	152	88	203	214	-	-	-	-	126	85	84	169
RM46	02-MA-CO-003-02-A03	Exxon Butyl #1066	111	128	117	175	73	153	181	148	7	157	178	191	124	202	129	174	206	91	231	224	101
RM44	02-MA-CO-001-02-A01	366E RubberBatch	100	100	100	100	-	100	100	150	50	129	162	101	139	86	216	73	196	136	221	84	105
RM55	02-MA-CO-023-02-A01	CS-3061D RubberBatch	69	-	-	-	-	-	-	-	-	97	-	-	-	-	-	-	-	-	-	-	-
RM19	01-MA-PO-005-01-A01	Busan 11-MI	13	110	100	160	75	-	7	14	139	179	158	240	196	196	172	201	106	103	182	148	108
RM84	02-MA-PA-030-02-A01	JER 807	129	103	-	103	-	-	65	130	130	91	226	166	167	111	85	151	96	130	185	129	218
RM05	00-MA-PA-029-01-A01	Adeka Resin EPU-78-11	103	82	-	82	-	-	52	104	104	239	216	211	180	216	240	183	185	166	226	89	71
RM97	02-MA-PO-019-02-A01	Sulphur	100	100	100	-	100	100	100	-	100	100	100	-	100	-	-	-	100	100	100	100	117
RM02	00-MA-PA-026-01-A01	Epiclon B-570	157	143	119	109	85	70	58	42	24	72	37	82	28	78	127	37	71	94	40	128	37
RM22	01-MA-PO-013-01-A01	K-37FA	82	101	121	97	70	98	97	116	70	51	24	28	56	95	64	101	43	72	101	113	78
RM54	02-MA-CO-021-02-A01	S-952 RubberBatch	43	-	-	43	-	-	43	-	-	48	13	8	32	5	38	32	29	13	11	43	21
RM115	02-MA-SO-005-02-A02	Shoprene WM-1	31	50	44	38	6	50	44	62	-	46	25	49	31	17	46	13	14	28	26	46	20
RM43	01-MA-SO-028-01-A02	Sanatac-L	-	-	-	-	-	-	-	75	-	-	-	-	-	-	50	-	50	27	-	-	-
RM30	01-MA-PO-037-01-A01	1Hydroxy 2 Naphthoic Acid	180	120	30	-	-	-	90	30	90	14	32	-	-	-	127	120	-	-	-	-	33
RM13	01-MA-LI-007-01-A01	Gleck ML-510A	31	62	34	28	24	36	14	38	20	37	10	48	9	13	28	43	10	25	42	33	45
RM50	02-MA-CO-010-02-A01	Rubber RSS#3	79	21	123	84	15	35	157	109	40	17	7	35	50	37	41	13	47	34	13	48	9
RM03	00-MA-PA-027-01-A02	LIR-403	58	97	54	91	46	55	73	73	84	46	14	47	40	26	23	12	20	35	39	22	12
RM116	02-MA-SO-005-02-A03	Showa Denka Chloroprene WK	-	-	-	-	-	-	-	20	19	-	-	-	-	-	34	-	-	-	-	-	37
RM26	01-MA-PO-023-01-A01	Nocceller BG	83	69	77	68	78	53	85	48	-	43	41	44	47	-	41	30	44	19	-	34	28
RM25	01-MA-PO-019-01-A01	Meta ZL-40	2	-	-	40	40	-	-	40	96	28	39	9	46	38	12	47	8	17	16	30	6
RM27	01-MA-PO-025-01-A01	Nocrac NS-6	46	45	47	47	49	48	60	40	48	6	5	33	22	38	26	12	33	19	13	25	33
RM113	02-MA-PO-054-02-A02	Aradur 9506	24	24	-	24	24	-	-	-	-	38	36	25	15	18	-	-	-	18	-	-	-
RM108	02-MA-PO-030-02-A02	Adeka Hardener EH-4358S	35	185	20	-	-	30	25	20	5	12	16	35	46	27	9	35	20	34	27	13	36
RM07	00-MA-PO-045-01-A01	MFL- 100CA	140	650	150	-	-	80	80	80	-	13	39	5	26	23	-	33	9	36	12	44	34
RM23	01-MA-PO-013-01-A02	K-37Y	-	-	-	-	-	-	-	-	30	30	-	-	30	-	-	-	-	30	30	-	-
RM41	01-MA-SO-026-01-A01	Tufprene-A	-	-	-	-	-	-	-	-	25	-	-	-	-	-	23	24	-	-	-	-	28
RM66	02-MA-LI-035-02-A01	Adeka Glycerol ED-503	29	22	-	22	-	-	15	-	-	24	-	-	27	-	-	30	-	-	28	-	-
RM21	01-MA-PO-010-01-A01	Flothene UF1.5	13	110	100	170	60	-	7	14	154	23	49	14	16	44	49	27	-	44	48	11	36
RM20	01-MA-PO-009-01-A01	Epiclon B-60SIM	36	64	53	96	20	55	35	70	46	6	34	48	41	33	40	20	42	43	20	14	35
RM114	02-MA-SO-004-02-A02	Shoprene WHV-100	7	1	1	25	25	25	25	19	19	14	-	22	8	21	23	-	-	8	25	-	-
RM04	00-MA-PA-028-01-A01	Adeka Resin EPR-1309	26	21	-	21	-	-	13	26	26	-	-	-	21	-	7	29	25	-	5	11	-
RM70	02-MA-LI-040-02-A01	Preminol S 1004F	11	7	19	16	13	9	7	23	18	16	13	14	10	33	13	42	44	7	25	8	37
RM96	02-MA-PO-018-02-A02	CML- 31	26	21	-	21	-	-	13	26	-	-	-	37	39	-	-	8	39	6	-	-	-
RM39	01-MA-SO-014-01-A01	Picotex-LC	-	23	-	-	23	-	-	23	23	25	25	21	16	43	30	25	40	35	28	26	33
RM103	02-MA-PO-027-02-A01	Degalan UC506	40	-	-	10	-	-	-	-	-	10	-	-	-	10	22	-	-	-	19	-	-
RM31	01-MA-PO-038-01-A01	Propyl Gallate	120	50	10	-	-	-	30	20	40	-	-	18	-	12	-	-	23	47	-	43	37
RM36	01-MA-SO-005-01-A02	Escorez 1202	-	-	-	-	-	-	-	20	-	6	-	33	-	-	43	46	-	-	-	-	30
RM35	01-MA-SO-002-01-A01	Asaprene T-411	-	15	-	-	-	15	-	-	15	-	13	32	29	11	29	-	23	23	-	-	6
RM06	00-MA-PO-028-01-A02	Printex XE2B	18	14	-	14	-	-	9	18	-	-	36	14	-	-	10	45	-	36	19	-	-
RM111	02-MA-PO-035-02-A02	909 DU80	9	-	-	-	-	-	-	-	-	18	-	23	-	-	16	-	-	-	-	16	-
RM01	00-MA-LI-031-01-A01	Versamine K13	6	3	3	12	11	3	19	13	10	12	10	8	7	13	15	8	13	6	11	10	13
RM58	02-MA-LI-005-02-A04	Ethyl Acetate	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-
RM60	02-MA-LI-008-02-A02	IPA	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RM118	02-MA-SO-010-02-A02	Antage BHT	10	-	-	-	-	-	-	15	-	-	-	-	-	-	-	5	-	-	-	-	-
RM38	01-MA-SO-008-01-A02	Lunac S-70 V	10	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-
RM117	02-MA-SO-007-02-A01	Quinton R-100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-

Appendices C – Z chart and Loss function L(z)

Z	F(Z)	L(Z)	Z	F(Z)	L(Z)	Z	F(Z)	L(Z)	Z	F(Z)	L(Z)
-3.00	0.0013	3.000	-1.48	0.0694	1.511	0.04	0.5160	0.379	1.56	0.9406	0.026
-2.96	0.0015	2.960	-1.44	0.0749	1.474	0.08	0.5319	0.360	1.60	0.9452	0.023
-2.92	0.0018	2.921	-1.40	0.0808	1.437	0.12	0.5478	0.342	1.64	0.9495	0.021
-2.88	0.0020	2.881	-1.36	0.0869	1.400	0.16	0.5636	0.324	1.68	0.9535	0.019
-2.84	0.0023	2.841	-1.32	0.0934	1.364	0.20	0.5793	0.307	1.72	0.9573	0.017
-2.80	0.0026	2.801	-1.28	0.1003	1.327	0.24	0.5948	0.290	1.76	0.9608	0.016
-2.76	0.0029	2.761	-1.24	0.1075	1.292	0.28	0.6103	0.274	1.80	0.9641	0.014
-2.72	0.0033	2.721	-1.20	0.1151	1.256	0.32	0.6255	0.259	1.84	0.9671	0.013
-2.68	0.0037	2.681	-1.16	0.1230	1.221	0.36	0.6406	0.245	1.88	0.9699	0.012
-2.64	0.0041	2.641	-1.12	0.1314	1.186	0.40	0.6554	0.230	1.92	0.9726	0.010
-2.60	0.0047	2.601	-1.08	0.1401	1.151	0.44	0.6700	0.217	1.96	0.9750	0.009
-2.56	0.0052	2.562	-1.04	0.1492	1.117	0.48	0.6844	0.204	2.00	0.9772	0.008
-2.52	0.0059	2.522	-1.00	0.1587	1.083	0.52	0.6985	0.192	2.04	0.9793	0.008
-2.48	0.0066	2.482	-0.96	0.1685	1.050	0.56	0.7123	0.180	2.08	0.9812	0.007
-2.44	0.0073	2.442	-0.92	0.1788	1.017	0.60	0.7257	0.169	2.12	0.9830	0.006
-2.40	0.0082	2.403	-0.88	0.1894	0.984	0.64	0.7389	0.158	2.16	0.9846	0.005
-2.36	0.0091	2.363	-0.84	0.2005	0.952	0.68	0.7517	0.148	2.20	0.9861	0.005
-2.32	0.0102	2.323	-0.80	0.2119	0.920	0.72	0.7642	0.138	2.24	0.9875	0.004
-2.28	0.0113	2.284	-0.76	0.2236	0.889	0.76	0.7764	0.129	2.28	0.9887	0.004
-2.24	0.0125	2.244	-0.72	0.2358	0.858	0.80	0.7881	0.120	2.32	0.9898	0.003
-2.20	0.0139	2.205	-0.68	0.2483	0.828	0.84	0.7995	0.112	2.36	0.9909	0.003
-2.16	0.0154	2.165	-0.64	0.2611	0.798	0.88	0.8106	0.104	2.40	0.9918	0.003
-2.12	0.0170	2.126	-0.60	0.2743	0.769	0.92	0.8212	0.097	2.44	0.9927	0.002
-2.08	0.0188	2.087	-0.56	0.2877	0.740	0.96	0.8315	0.090	2.48	0.9934	0.002
-2.04	0.0207	2.048	-0.52	0.3015	0.712	1.00	0.8413	0.083	2.52	0.9941	0.002
-2.00	0.0228	2.008	-0.48	0.3156	0.684	1.04	0.8508	0.077	2.56	0.9948	0.002
-1.96	0.0250	1.969	-0.44	0.3300	0.657	1.08	0.8599	0.071	2.60	0.9953	0.001
-1.92	0.0274	1.930	-0.40	0.3446	0.630	1.12	0.8686	0.066	2.64	0.9959	0.001
-1.88	0.0301	1.892	-0.36	0.3594	0.605	1.16	0.8770	0.061	2.68	0.9963	0.001
-1.84	0.0329	1.853	-0.32	0.3745	0.579	1.20	0.8849	0.056	2.72	0.9967	0.001
-1.80	0.0359	1.814	-0.28	0.3897	0.554	1.24	0.8925	0.052	2.76	0.9971	0.001
-1.76	0.0392	1.776	-0.24	0.4052	0.530	1.28	0.8997	0.047	2.80	0.9974	0.001
-1.72	0.0427	1.737	-0.20	0.4207	0.507	1.32	0.9066	0.044	2.84	0.9977	0.001
-1.68	0.0465	1.699	-0.16	0.4364	0.484	1.36	0.9131	0.040	2.88	0.9980	0.001
-1.64	0.0505	1.661	-0.12	0.4522	0.462	1.40	0.9192	0.037	2.92	0.9982	0.001
-1.60	0.0548	1.623	-0.08	0.4681	0.440	1.44	0.9251	0.034	2.96	0.9985	0.000
-1.56	0.0594	1.586	-0.04	0.4840	0.419	1.48	0.9306	0.031	3.00	0.9987	0.000
-1.52	0.0643	1.548	0.00	0.5000	0.399	1.52	0.9357	0.028			



***Z & L(z)* for special service levels**

Service Level F(z)	*z*	*L(z)*
75%	0.67	0.150
90%	1.28	0.047
95%	1.64	0.021
99%	2.33	0.003

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APPENDIX

VITA

Miss Nattcha Nerdnoi was born on May 13th, 1989 in Bangkok, Thailand. She graduated her bachelor's degree in Chemical Engineering, from Chulalongkorn University in 2011. After graduated, she continued her dual Master's degree program at Regional Centre for Manufacturing Systems Engineering (RCMSE), Chulalongkorn University in cooperation with University of Warwick in United Kiongdom, in major of Engineering Business Management