APPLICATION OF POSTPONEMENT STRATEGY FOR LOW-VOLUME-HIGH-MIX DEMAND: A CASE STUDY OF MED EQUIP CO.,LTD.

By
WASSANA SRIVIROJ

A Final Report of the Six-Credit Course
SCM 2202 Graduate Project

Submitted in Partial Fulfillment of the Requirements for the degree of
MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT

ABAC School of Management
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2. Where any part of this dissertation has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;

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Advisor Dr. Chajaw, lee Ruktananchai

Date lu /1/4/04/0$41.1Pay .2,a)49

ABSTRACT

Based on a particular case study, this paper presents results from the application of postponement strategy in the manufacturing and purchasing area on one business to manage low volume high mix under demand uncertainty and seasonal pattern. The aim of this research is to use this strategy to help improve order fulfillment lead time and labor cost.

The concept of postponement, as applied to manufacturing, retains the product in a neutral and non-committed status as long as possible in the manufacturing process. Because the inventory is generic, its flexibility is greater, meaning that the same components, modules or platforms can be embodied in a variety of end products. Thus, postponement is one of the most beneficial strategic mechanisms to manage the risks associated with product variety and uncertain sales.

The basic approach is analyses current products and processes to find the commonality in the processes and explore the level of material. By aggregate demand of the semi assembly commonality and pre build in the time that production has excess or idle capacity.

The project starts with setting up a project model between As-Is and To-Be when using the postponement strategy. The result from this implementation is the average order fulfillment lead times is reduced by 12.7%, and labor utilization results is lower labor cost spending.

ACKNOWLEGEMENTS

I would like to express my sincere gratitude to my advisor Dr. Chatchalee Ruktanonchai for his guidance, assistance, encouragement and kindness. Without his direction and expert knowledge I could not have finished this graduate project. I would also like to thank the management and my team at MED EQUIP Co.,Ltd. for giving me an opportunity to complete this project by supporting me.

At this moment, I wish to express my sincere appreciation to several people who have assisted and enabled me to conduct research for this study, as without them the completion of this project, which I did perceive as an arduous task initially, would not have been possible.

I am eternally grateful, blessed, and appreciative for the love, encouragement, support and patience of my family, particularly my husband and my son who has been a continual helpmate in completing this personal and professional goal.

Wassana Sriviroj
14 November, 2009.

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CHAPTER I
INTRODUCTION

This research project is about an attempt to improve operations effectiveness in a low-volume high-mix manufacturing environment. This chapter will provide an overview of this project, with general information concerning the industry involved, discussion of specific problems, and objectives of this research. These are followed by limitations of the research, and key definitions.

1.1 Background of the Study

In many industries today, customers are inevitably becoming more and more diversified and sensitive in their product preferences, while companies are competing to offer greater product variety and customizing to consumer's needs (The Economist, 2001; Time, 2002; and Business Week, 2002). This trend combined with an increased pace of technological change and shortening of product life cycles are leading many companies to increase product varieties. However, companies with expanding product varieties often face a dilemma of getting accurate demand forecasts, dealing with the complexity in supply chain and manufacturing processes, managing inventory proliferation, and providing high-quality service to customers (Shen, 2005). More importantly, supply chain management has become a key driver for managing and controlling the flow of material and the consumption of resources. Therefore market demand for a company's product can be satisfied in the most efficient and effective manner. Discriminating customers are demanding more choices, requiring greater customization and inciting today's worldwide trend toward high-mix manufacturing. Those who fail to respond effectively to this competitive reality will cease to exist (Mahoney, 2007).

Demand Complexity

Many companies share the same end goals of on-demand order fulfillment and lower costs of goods sold. However, the ability to realize gains from supply chain optimization is not the same among companies with different product mix and volume ratios. A high volume - low mix manufacturer producing consumer electronics for a broad global market has different leverage points within the supply chain than does a

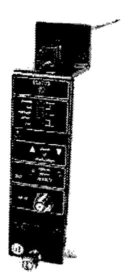
Low volume - high mix manufacturer who builds specialized technology products for a narrower market (Gill, Lopus and Camelon, 2007)

Case Study : Company Overview

The actual company name is not shown for confidentiality. In this research MED EQUIP is used as the company name. MED EQUIP is a leading ECM (Electronic Contract Manufacturing) provider of foundry services to optical component, module and subsystem, OEMs(Original Equipment Manufacturings), in Thailand. The services are based on precision optical and electro-mechanical process technologies and know-how that MED EQUIP has obtained through focus on the industry since company inception in early 2000. Recently, MED EQUIP has also begun to provide foundry services to the sensors market, a market that requires precision optical and electro-mechanical process technology similar to the optics market. There are 9 product groups as shown Figure 1.1 to 1.9 below.

Figure 1.1 Product group 1

Figure 1.2 Product group 2



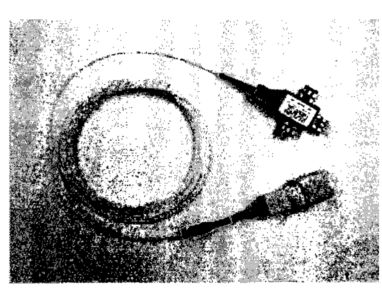


Figure 1.3 Product group 3

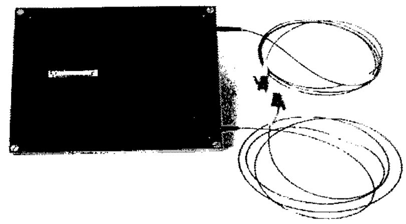


Figure 1.4 Product group 4

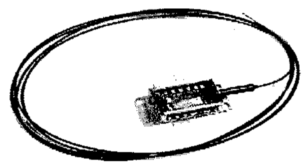


Figure 1.5 Product group 5

Figure1.6 Product group 6

Figure1.7 Product group 7

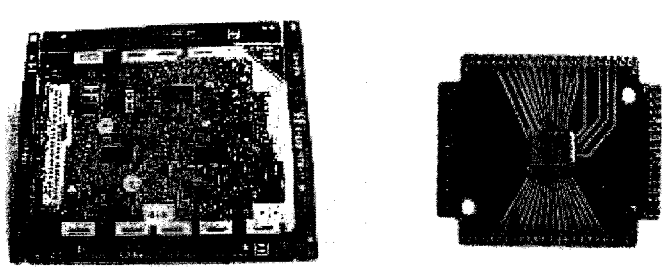


Figure1.8 Product group 8

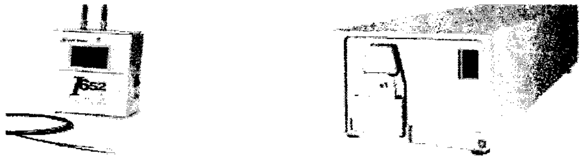


Figure1.9 Product group 9

Med Quip operates in an industry characterized by very high-mix, while keeping low volume production. It is a global engineering and manufacturing service provider of complex optical and electromechanical components, modules and bulk optics. The company serves data communications, telecommunications, networking, medical and automotive markets worldwide. It has over 20 different end-customers and each has unique requirements affecting the supply chain and manufacturing model.

One of unique features of MED EQUIP is that each customer has their designated area within MED EQUIP factory in order to safeguard their intellectual properties. MED EQUIP's global reputation for customer service is based in part on its serious commitment to the protection of customer processes and products. MED EQUIP organizes itself both physically and professionally into separate and discrete customer business units, providing each customer with their own secure manufacturing area and workforce, including engineering and materials management teams.

MED EQUIP augments this unique "factory within a factory" approach with rigorous security controls including guarded entries with key-card and biometric-controlled access, and fogged observation windows.

The company facilities comprise of approximately 1,050,000 total square feet, including approximately 114,000 square feet of office space and approximately 640,000 square feet devoted to manufacturing and related activities, of which approximately 180,000 square feet are MED EQUIP clean room facilities. The aggregate square footage of company facilities is approximately 800,000 square feet and is located in Thailand. The other 250,000 square feet is in the PRC and the U.S. The total amount of employees based in Thailand as of year 2008 was about 4,370 persons.

1.2 Information of the Case Study: MED EQUIP

In order to better understand the approach taken in this research, it is appropriate to describe the case study company, nature of its operations, its constraints, as well as other relevant factors.

1.2.1 Organization

The company was founded in January 2000, by a co-founder of Seagate Technology. The manufacturing headquarters is located at 294, Moo 8, Vibhavadi-Rangsit Road, Kookot, Lumlookka, Patumthanee, 12130, Thailand.

MED EQUIP designs its organization structure with regard to customer focus. It is divided into business units (BU), like small factories. Each customer will contact a designated business unit that has a BU leader who will take responsibility of profit and loss for that account. On the supporting side, there are shared resources as shown in the Figure 1.10. The shared resources are the group of the supporting staff to service **all** business units such as IT, Facilities, Sales and Marketing (RFQ).

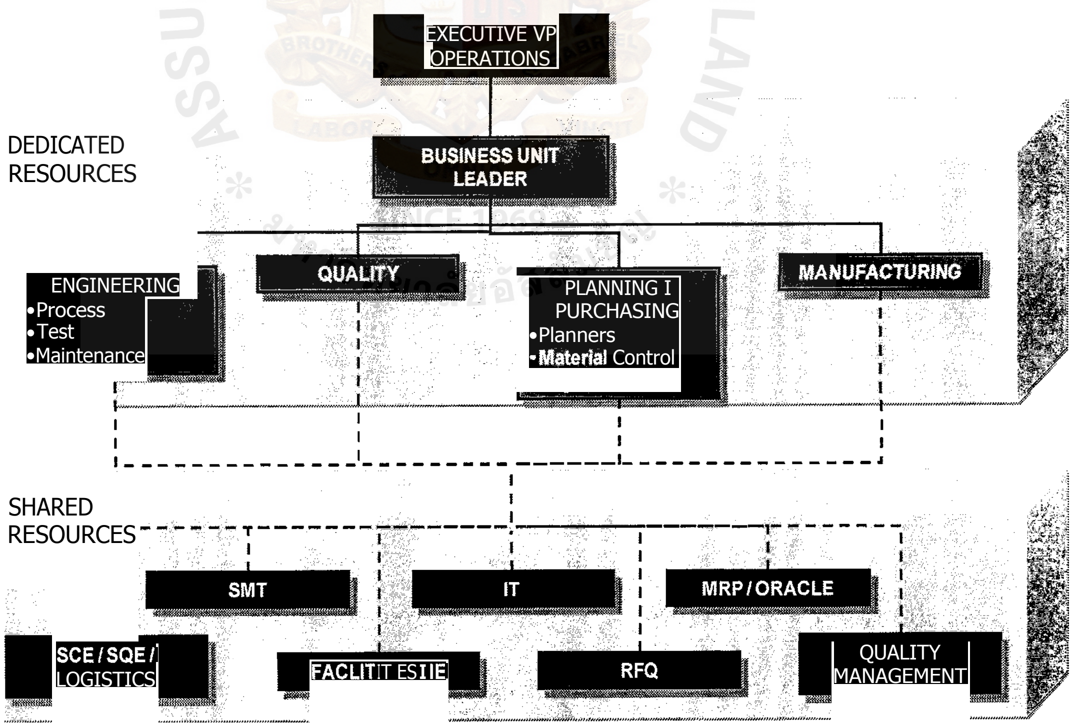


Figure 1.10 MED EQUIP's Organization Structure

The organization structure of the business unit that is used in this case study shows that all the people from Business unit Manager (BU Leader) are dedicated resource group. Figure 1.11 shows more details of the headcount on this business unit. There are 20 operators with one supervisor, 4 engineers and one quality engineer in this group as shown in Figure 1.11 below.

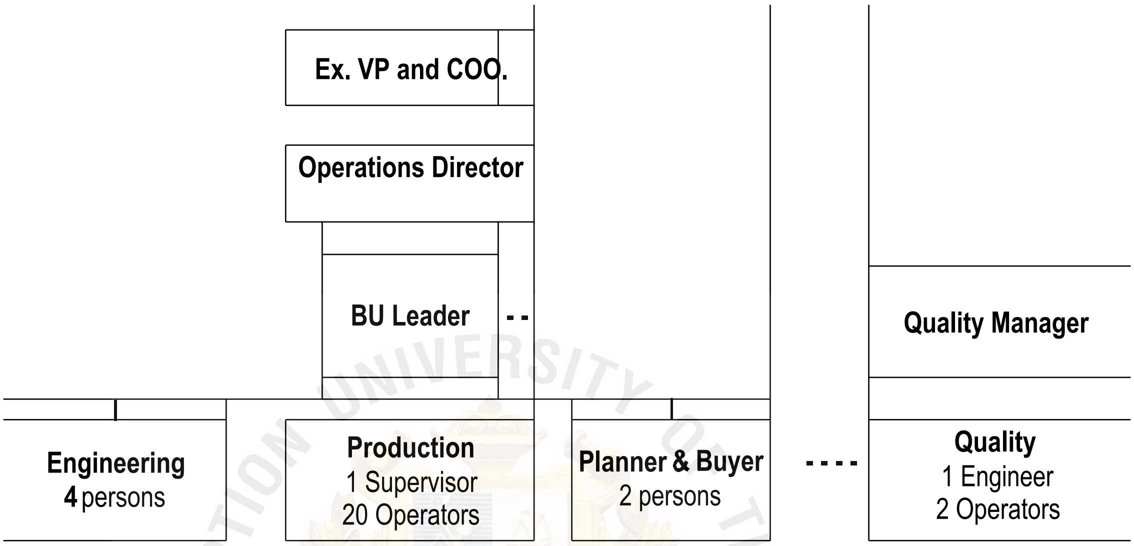


Figure 1.11 Medical Devices Business Units Organization Chart

1.2.2 Business Flow

The business flow starts when the company receives inquiry from new customers or potential customers, via the sales and marketing teams. Then the NPI (New Product Introduction) team will request input from the customer about the details of the product or other information about process flow, quality control, target price, and cost structure. After the NPI study the manufacturing feasibility, they prepare a quotation for the customer. If this is approved, then it will go to the planning and manufacturing process design team. Once the customer approve of the process design, then the FA (First Article) will start for product and process qualification. FA means the first lot of the products that are sent to customer for full quality checking to meet specifications as agreed. The customer will then issue a document called product qualification. For the first batch of production, there will be a record of process control to report to the customer. When the customer checks and approves it is called process qualification. Some customers will be in the factory during the first lot of production to monitor and validate the process and product qualification. After passing the FA, then the PO for normal production order will be released from customer to start the mass production phase. The mass production phase, there are different standard business process flows in each business unit based on the contract agreement. Medical business units will be explained in more details in Chapter 3.

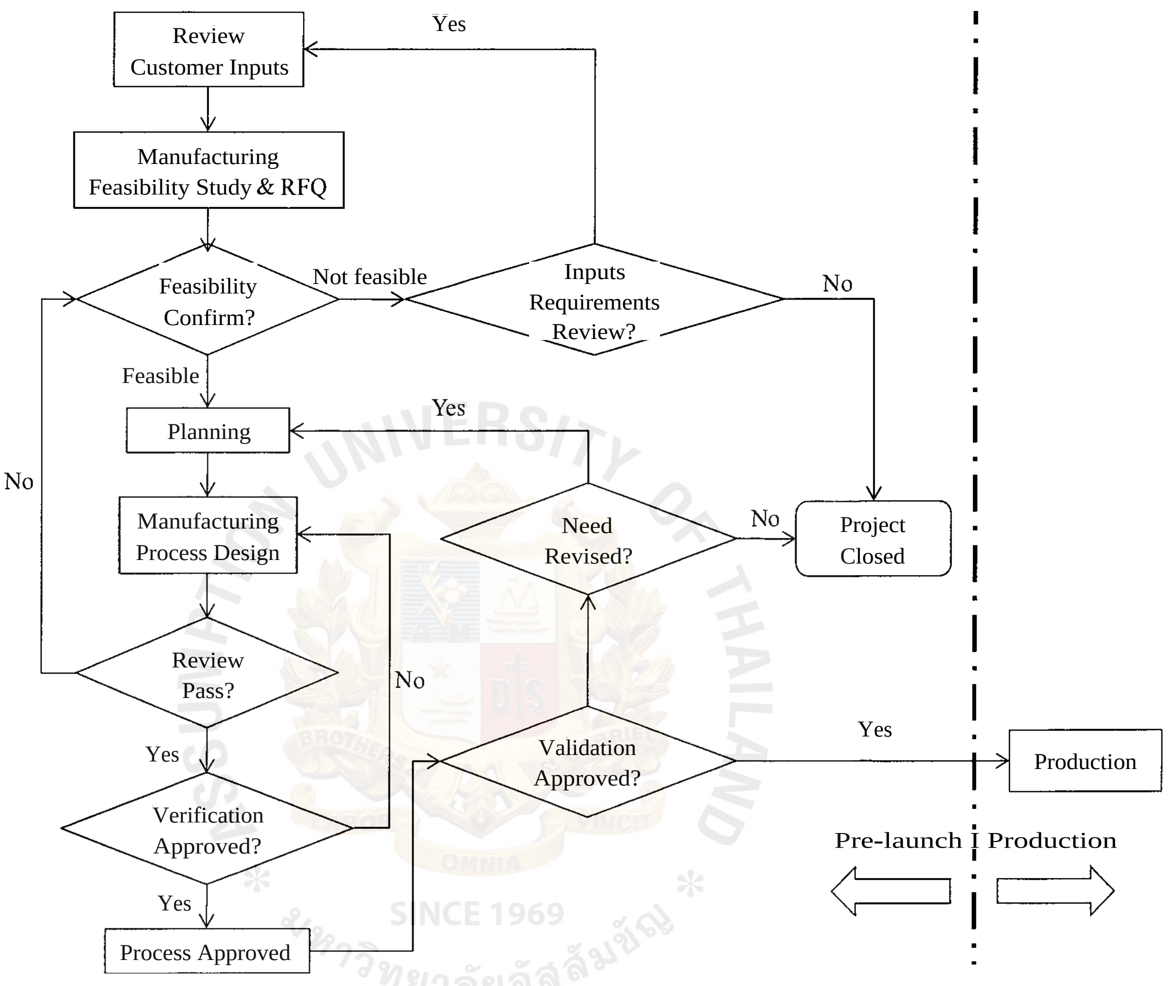


Figure 1.12 Business process flow chart

1.2.3 MED EQUIP Sale Revenue

For the first 2 years, the company generated revenue from the data mass storage devices segment with major support from Seagate, a major hard disk drive manufacturer. However, this became a minor company output and it faded out in 2004.	From 2001 to 2004, the company developed the fiber for optical market segment, and became well known for ECM for fiber optical products. The growth of optical products is considerably significant to the company since then, as shown in the Figure 1.13.

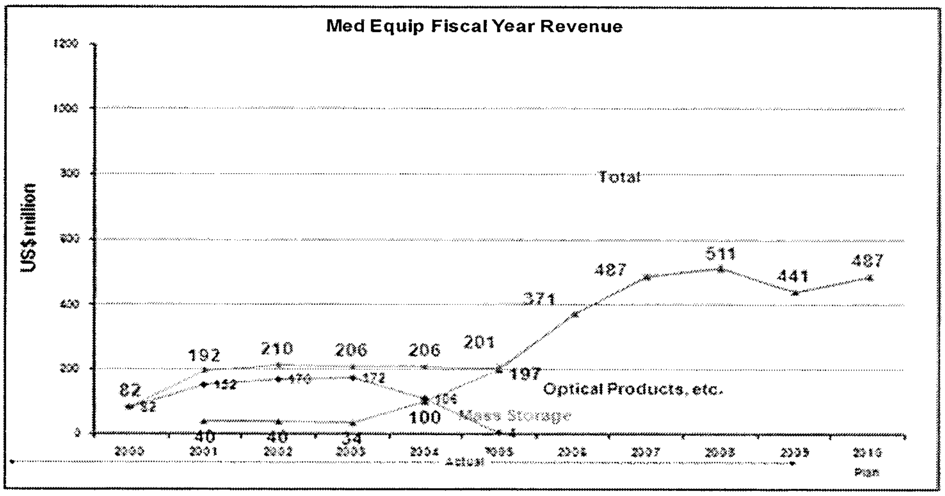


Figure 1.13 MED EQUIP revenue

1.2.4 Medical Business unit Sales Revenue

The sales revenue for the medical business unit is shown in Figure 1.14 and indicates that the medical division started the mass production since July 2008, the sales had gone up in the Q2 (October-December 2008), then decreased due to the 2009 global economic crisis, then it turned to ramp up again from July 2009. From the revenue projection, it shows that customers aim to increase the sales revenue by having more product varieties, while the units ordered for each model is still at a low quantity. Therefore, this became a topic of interest for research since it is impact and to find one which appropriate strategy show be applied to this kind of business environment.

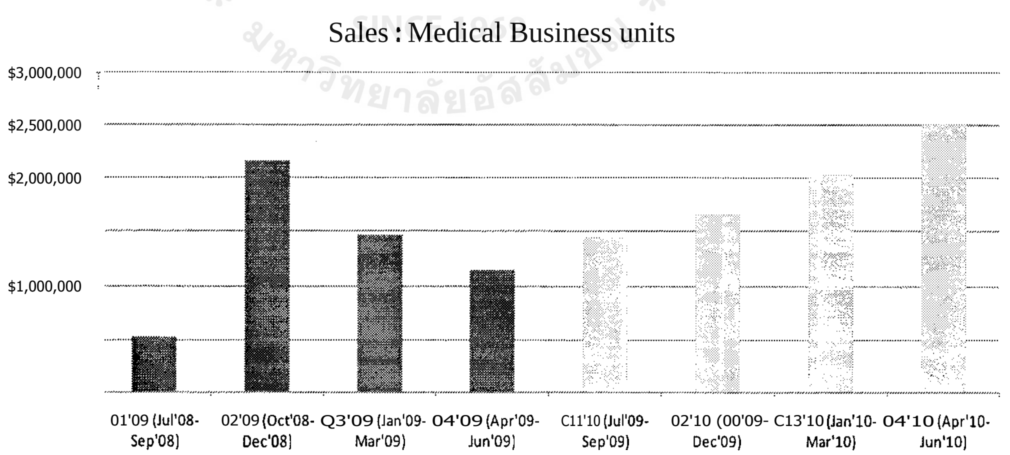


Figure 1.14 MED EQUIP Medical Business in 2008-2009 and projection

1.3 Statement of the Problem

Supply Chain Management is considered among the greatest challenges MED EQUIP faces. This is because nearly 90% of product cost is made up of materials used to manufacture the products. The company's growing product portfolio encompasses more than 23,000 top levels using over 36,000 components purchased from over a thousand suppliers located in different parts of the world. Many of the suppliers in the optics industry are small companies, with limitations in quality systems, reliability and overall maturity.

Thus with the high product verity, low volume demand in each product configuration with limitation on operations capacity and constraint on material lead times, it becomes a problem about what should be a suitable supply chain strategy for dealing with this kind of manufacturing environment. This is to achieve lower cost, better order fulfillment for customers, and help reduce forecast error from demand uncertainty, based on the performance of Medical business unit.

Yang and Burns (2003) see postponement as one of the tools to deal with demand uncertainty. They believe that two main ideas are behind the postponement concept. First, it is easier to forecast aggregate demand compared to forecasting demand of every finished product. And second, more accurate information (place, time and quantity) can be obtained during the delay period. By redesigning the business processes according to the postponement strategy, they believe that companies can get the missing information which is the reason for demand uncertainty.

This case study will focus on one business unit in MED EQUIP that has problems of low shipment delivery performance. This has been affected from long order fulfillment lead time and orders that are subjected to a seasonal demand pattern. The seasonal order pattern results in periods where the demand exceeds the nominal production capacity of the assembly operation. The customer demand will usually ramp up in the last month of each quarter, and occasionally in the last two weeks of each quarter. This leads to higher operating costs, especially on cost of overtimes. During some periods the orders are usually insufficient and there are idle capacity but number of operators is fixed each month and cannot be allocated to other business unit, due to "factory within factory" restriction.

Considering the situation and the concept above, these leads to the following research questions;

1.) How is it possible to improve order fulfillment lead times through the manufacturing postponement strategy?

2.) How is it possible to improve operation costs with the low volume high mix and seasonal demand pattern through the postponement strategy?

1.3.1 Shipment performance

The shipment delivery for on time performance is calculated from the last 12 months, ranging from July 2008 to August 2009. The average delivery is 80% for on time, even though the company had set the target at 95%. This is as illustrated in Figure 1.15. The measurement unit is the number of customer orders.

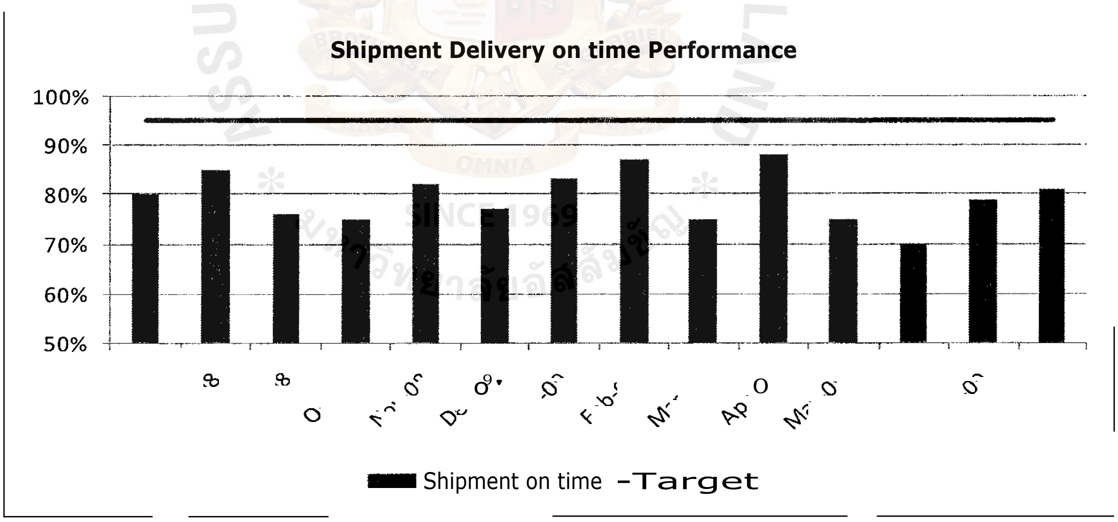


Figure 1.15 Monthly Shipment Performance

1.3.2 Shipment analysis by Product group

There are two groups of products that use the same manufacturing resources to support the customers. Figure 1.16 below shows a mixing ratio of units ship of 2 products groups. For the product, Group-1 consists of 25 finished goods (F/G) models and Group-2 consists of 75 F/G models. The product Group-1 is totally different in terms of materials and functional use from Group-2. Group-1 is the group on the Anesthetic Gas Analyzer and Automotive Gas analyzer. Group-2 are optical thermometry and optical process control solutions that serve the energy, medical and semiconductor industries by providing the most rugged solutions for the harshest electrical noise and chemical environments. There is a unique line of power transformer fiber optic instruments and probes for the rugged high voltage energy industries. The trend in Figure 1.16 also represents an increase in the product variation.

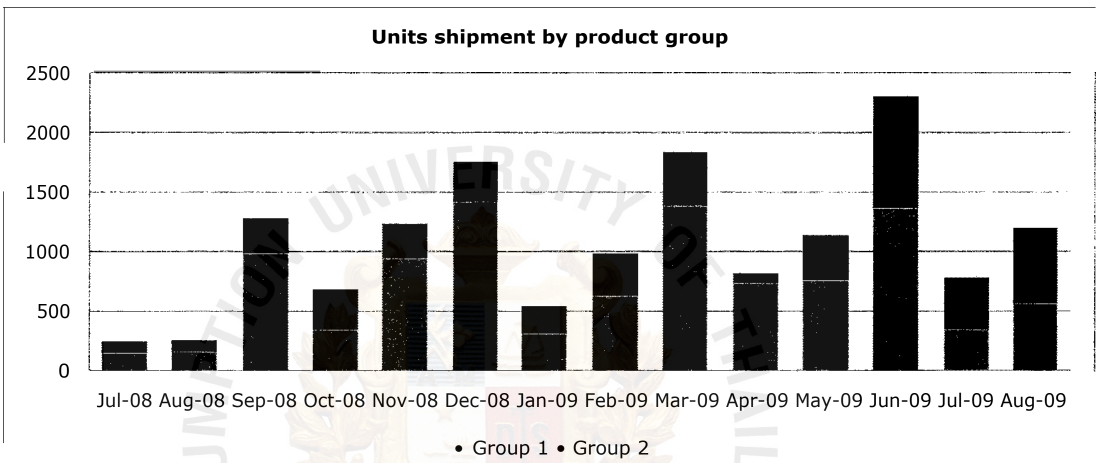


Figure 1.16 Monthly units shipment by product group

1.3.3 Shipment by sales value by product group

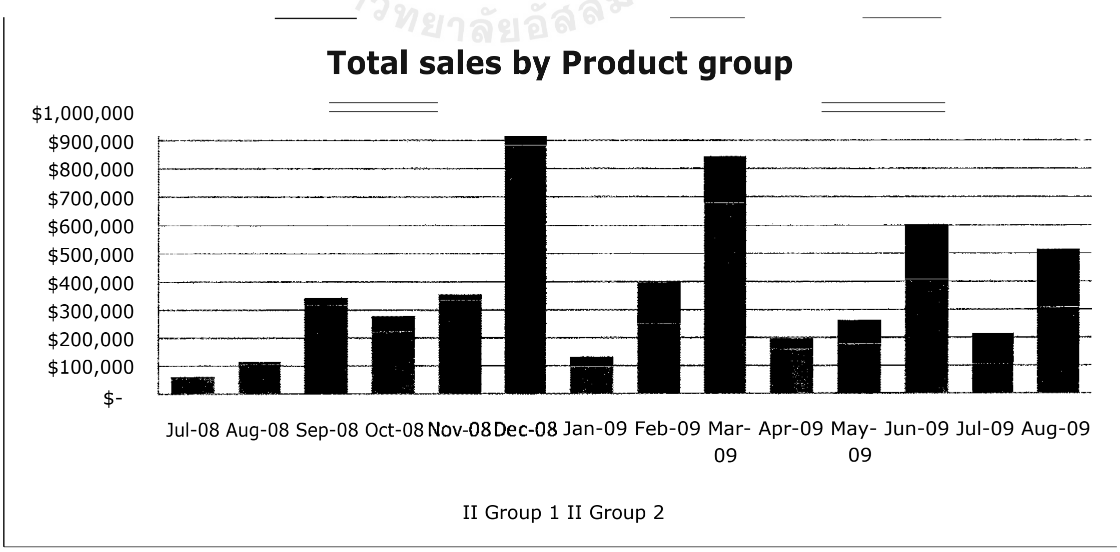


Figure 1.17 Total sales by product group

Figure 1.17 shows that during the last 6 months, the ratio for sales of product Group-2 has increased, which resulted in higher number of F/G top models being made. The pattern of the demand will increase during the peak season, on the 2nd quarter of fiscal year, from October-November. This business unit starts up from October-2007 and transfer to mass production phase on Group-1 products from August-2008. The Group-2 starts up mass production phase from January-2009.

1.3.4 Forecast accuracy

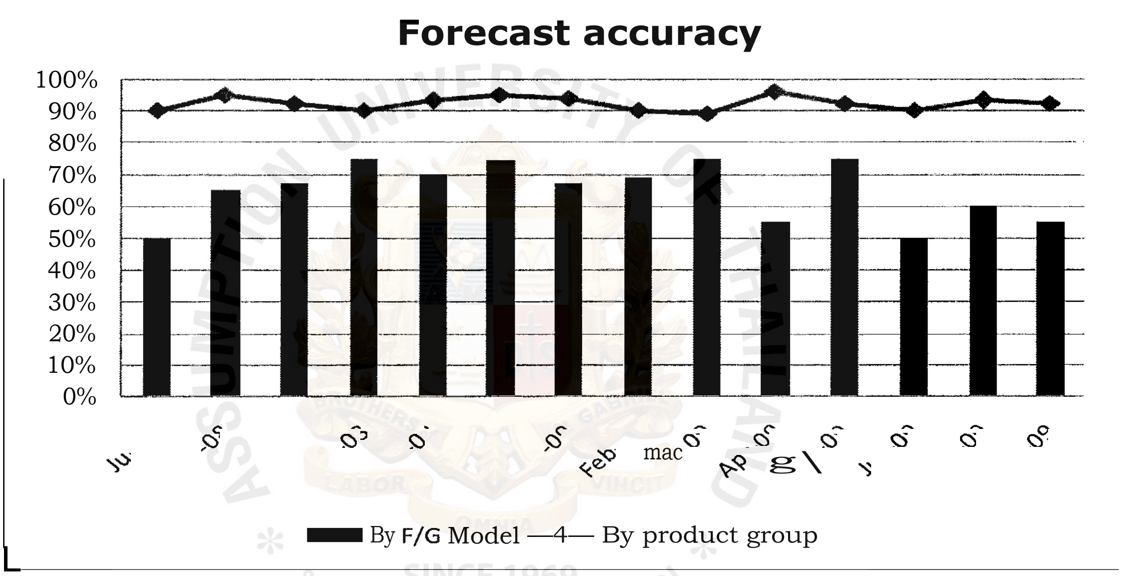


Figure 1.18 Forecast accuracy

Figure 1.18 shows a comparison between forecast accuracy of the product group and by the model, with the actual when customers actually requested the shipment. The forecast accuracy of the product group is more accurate than the forecast by the F/G model.

Information in Figure 1.16-1.18 indicates that when the variation of product types increase, the company has to improve its operating effectiveness and, probably more importantly, deliver with reliability. This research project will study the relevant parameters and factors, via the application of postponement approach.

1.4 Research Objectives

The objectives of the study are as follows:

1.) To review and study current parameters of operations processes such as assembly process and standard time, labor utilization, and bill of materials.

2.) To improve order fulfillment performance and operating costs by using the postponement approach.

1.5 Scope of the Research

The scope of this research is to study one business unit in MED EQUIP that the researcher currently works for. This business unit is the Medical Division. One customer is used in this study. The study focus on the internal operations processes from raw material inventory to final products that are ready to ship to the customer. The numbers of F/G model are 100 models with the 1,500 items of material. The data collection the for study is from July 2008 to August 2009.

1.6 Limitations of the Research

This research focuses mainly on the internal processes of the case study company, particularly on forecasting and inventory management. Although the researcher seeks to find a practical solution improvement for this high mix and low volume, it is understood that the implications of this research may be limited only for a number of manufacturing sectors.

1.7 Significance of the Study

The significance of the study is that it uses an opportunity for studying in on demand characteristics and finding suitable strategies for postponement strategy to be utilized which can optimize the value of the company and the end customer. The study will also give the researcher an opportunity to improve the firm's performance, while gaining more understanding of supply chain management concepts through practical problem-solving.

1.8 Definition of terms

Postponement

Postponement means delaying activities in the supply chain until customer orders are received with the intention of customizing products, as opposed to performing those activities in anticipation of future orders (Hoek ,2001).

Order fulfillment lead time

The total time from the shipment date request from the customers on confirmed order to the time the product is shipped out.

Low Volume-High Mix Demand

One style of order pattern where the quantity per order is low but the variety of products for order at one time is high.

Delivery Performance

The measurement to show the actual shipment date and quantity compared to the customers requirement date.

Bill of Materials (BOM)

BOM is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, components, parts and the quantities of each needed to manufacture an end item (final product).

Planning BOM

The BOM which is created to drive the material only not for production use to produce the products. This is specific only for MED EQUIP.

Drop-in demand

Drop-in demand refers to a concrete/firm order from a customer who did not provide forecast information earlier. In other words, it is an immediate demand from a customer.

Semi-assembly

The semi-finished or half-finished product unit is built in the form that is not ready to be a finished product.

Purchase Order (PO)

Purchase order is the formal document to notify or either issue a notice to suppliers start manufacturing the product.

Work Order (WO)

Work order is the document generated from Oracle ERP system to notify the production department to start activities from material preparation to producing of the product.

Hour per Unit (HPU)

Hour per Unit is the total time that is used to produce one unit of the product measured by the industrial engineer.

Earned Hours

The total hours required to use to produce the product by calculating HPU and quantity of products that customers order. Total earned hours is represented as the standard hours that generate the sales revenue for the company.

CHAPTER II

REVIEW OF THE LITERATURE

2.1 Increasingly Complex Demands

It is common knowledge that the closer the product specifications are to customer demand, the higher the value of it for the customer (Can, 2008). It is not a simple task to meet every individual need in today's turbulent and volatile market environment. Because the media, especially internet, now enables customers to reach any manufacturer that could produce exactly what he/she wants, it is not increasingly easy to survive without meeting exact demands of the customers (Can, 2008).

Internet began to reshape the world at the end of 1990s. According to Kumar (2004), internet had two significant impacts strategically: (1) entry barriers and (2) exit barriers disappeared. Companies which are good at all four priorities (cost, delivery, quality and flexibility) can easily penetrate any market in the world by just building a web-site with a small investment. Conversely, a company that has any competitive skills lacking can lose a big market share, and even disappear. The ubiquitous presence of Internet has, therefore, created an aura where companies can no longer afford to compete on just one priority; there is always someone who can compete on all four priorities and win the competitive battle (Kumar, 2004). Kumar (2004) also states that mass customization strategy, when thoughtfully implemented, would produce a winner in all competitive priorities, partly through product design (customization), partly through web-based customer interaction (customer satisfaction), and remaining through appropriate production systems associated with mass customization strategy (cost, quality, and delivery).

2.2 Postponement

Postponement or *delayed product differentiation* has been adopted by several companies as a strategic mechanism to manage the risks associated with product variety and uncertain sales, and as a powerful way to enable cost-effective mass customization (Shen, 2005). The concept of postponement is to re-design the product or production process so that the point of differentiation can be delayed as much as possible. In other words, postponement is to delay the commitment to a product's characteristics until more information is available, therefore the decisions about the product can be made more accurately (Shen, 2005).

The idea of postponement can be traced as far back as the 1920s and the first use of postponement as a manufacturing strategy as early as the 1950s (Paugh and Cooper, 1998). Early mention of postponement suggested that costs due to risk and uncertainty were a function of variety and that an efficient means of producing a product is to postpone changes in form and identity to the latest point in the marketing flow and postpone changes in inventory location to the latest point in time (Alderson, 1965).

There is a growing stream of publications on postponement in various disciplines (Feitzinger and Lee, 1997 in strategy; Garg and Tang, 1997 in operations research; Pagh and Cooper, 1998 in logistics). Taken together with the stated interest of managers, does the increased production of knowledge on postponement mean that, after 30 years of incubation, the principle has finally been integrated in managerial practice and academic research? The consistent reference to the value of postponement for logistics strategy and capability development (Bowersox and Closs, 1998) and the work on postponement (continued and published in the 1980s by Zinn and Bowersox (1988). Zinn (1990) suggests that the concept has not found a place in academic research. Bowersox et al. (1995) states that postponement has increased in application over the last few years. Morehouse and Bowersox (1995) predicted that it will increase in application, to the extent that by the year 2010 half of all inventory throughout the food and other supply chains will be retained in a semi-finished state waiting for finalization-based upon customer orders. Still, postponement is not new to the research agenda. The number of important journal articles published over the last two decades, including publications in the fields of logistics, marketing, and operations demonstrates this trend.

Feitzinger and Lee (1997) provide examples of postponement such as Hewlett-Packard, which adopted delayed product differentiation by re-designing the inkjet printers to maximize the value of common parts and postponing the localization of the products. Swaminathan and Tayur (1998) illustrate the computer-server assembly postponement practice by IBM through its "vanilla boxes" operation. In the fashion industry, Benetton improved its forecasting accuracy and reduced inventory and product shortage costs by reversing the process of dyeing and knitting (Dipiran, 1992). Whitney (1995) describes that product modularity enabled delayed customization of parts, such as radiators in the automotive industry. A summary of some successful applications can be found in Venkatesh and Swaminathan (2001).

Accordingly, product life cycles shorten, product variety increases, and customer demands escalate. Consequently windows of opportunity become narrower and more transitory. Then companies have to seriously consider manufacturing for and marketing to individual customers, as opposed to mass markets. As a result, frame-breaking strategies become a necessity (Achrol, 1991). Postponement is frequently presented as a strategy suited to this option to postponement. Its popularity in the international business community is significant, because it aims to combine an agile customization of products with lean production efficiency within one supply chain (Anderson and Narus, 1995; Kahn, 1998).

2.1.1 Postponement as a Concept

Postponement itself is an operational concept; however the motivations for adopting this practice are often at the strategic level, where critical business issues could be addressed by innovative applications of the postponement concept. On the other hand, these strategic issues are often the opportunities for implementing a postponement strategy (Shen, 2005). Below are key summary of the reasons for the case study to identify the primary strategic motivations for postponement.

1) Controlling Supply Chain Costs from High Product Variety

Postponement often becomes a highly effective strategy when companies encounter high supply chain costs caused by demand variability and explosion of product variety (Fisher, 1997). When product variety is high, the demand variability is low, and it often becomes impossible to accurately forecast the demand of each end product. For companies that make to forecast, this often leads to high market mediation costs. For Benetton, while its demand forecast for the total sales of each of its styles and sizes was not a significant problem, it continuously missed the forecast about which colors would catch the fancy of its fashion-conscious customers, while having to slash prices on out-of-favor colors (Gong, 2005). In this case it lost money. On the average, Benetton lost $27 for each unsold shirt, and it lost $9 on each shirt it had to mark down in its store or sell through discount channels (Dipiran, 1992).

In HP's case (Lee et al., 1993), selling printers in Europe means following each country's requirements for printer configurations: different labels, a country-specific power plug, and language-specific manuals. In the past, HP forecasted the demand for each European country and then manufactured the appropriate numbers for each country. Unfortunately, it is extremely difficult to forecast the demand for each country, for example, not enough printers for Denmark yet too many printers for Slovenia without any way to convert Slovenian printers into Danish ones (Lee et al., 1993). With six generic printers, the different country configurations meant that HP has 138 versions of the finished printers and a huge challenge to match the supply and demand (Lee et al., 1993). Table 2.1 shows a summary from the case study of each company on the primary driver of postponement and benefits.

Table 2.1 Primary drivers and benefits of postponement

Company	Primary **Driver(s)** of Postponement	Primary Benefits
GM	Inventory costs Product variety	Service levels Inventory reduction Maintenance costs
Honda	Product variety	Manufacturing cost reduction
Embraer	Reconfiguration costs	Service levels
Dade Behring	Inaccurate forecasts Inventory costs	Inventory reduction Service level Lead time reduction
Reebox	Inventory cost	Lead time reduction
Polaroid	Reconfiguration costs	Service levels Lead time reduction Reconfiguration costs
Bic	Inventory costs Long lead time	Service level Sales volume increase

McGraw-Hill	Product variety	More accurate forecast
Imation	Long lead time Price erosion Short product life cycles	Lead time reduction More accurate forecasts
Solutia	Reconfiguration costs	Reconfiguration costs Service levels
Xilinx	Product variety Short product life cycles	Service levels

Source: Rietze (2006)

2) Inventory reduction

Reduction in inventory under a fixed level of service is another benefit of postponement. When companies increase variety they increase the number of SKUs and hence must maintain what translates into higher inventory costs. Each SKU is subject to different forecasts and therefore requires different levels of safety stock. Safety stock buffers against sudden increases in demand. Holding safety stock ensures better customer service but is also expensive because of inventory holding costs. In a study of the effect of product variety on production-inventory systems (Rietze, 2006). Benjaafar and Kim (2004) found that inventory levels increased linearly with variety. They also found that cost was most sensitive to demand variability, capacity constraints, and set-up costs (assuming a fixed cost to switch the production line between products). This highlights the risk associated with having too much variety for products, especially those with high demand variability. Companies can mitigate this risk by standardizing parts, holding more work in process (WIP) inventory, and postponing customization.

3) More variety

Having variety allows for a closer match between customer preferences and offered products leading to increased sales and (sometimes) increased prices (Benjaafar, Kim, and Vishwanadham, 2004). The build-to-order strategy pioneered by Dell shows how manufacturing a product according to customer specifications is one way to offer a large variety in a cost effective way (Shen, 2005). Dell offers enough options for their Dimension 4600C desktop to build over 100 million different computers using combinations of the components listed in Table 2.2

Table 2.2 Component List and Options for Dell 4600C

Part	**Options**
Intel Pentium 4	5
Operating Systems	5
Productivity Software	6
Memory	8
Hard Drive	4
Floppy/Storage Device	4
CD/DVD Drive	6
CD/DVD Software	4
Storage Devices and Media	2
Keyboards	3
Mouse	4
Monitor	9
	Total Combinations 100 millions

Source : Shen (2005)

Dell does not stock each of the 100 million varieties (Rietze, 2006). Instead, they wait for customers to place an order before they build a machine. They have perfected this strategy so well that they are able to shape demand and produce popular combinations to forecast. Dell can offer discounts on combinations that are popular because of economies of scale and can carefully encourage customers to choose components that are in-stock using discounts. This strategy allows them to offer a quick turnaround and ensures that customers will not have to wait more than a week for a new product.

4) Better Forecast Accuracy

Postponement strategy is an effective way to address these issues through aggregation of end demands and shortening of forecasting horizon. The case study of Benetton is a good way to illustrate the benefits of postponement. To reduce the shortage and outrage cost, Benetton re-designed the process such that dyeing and knitting are changed and dyeing is carried out until more sales information is available (Shen, 2005).

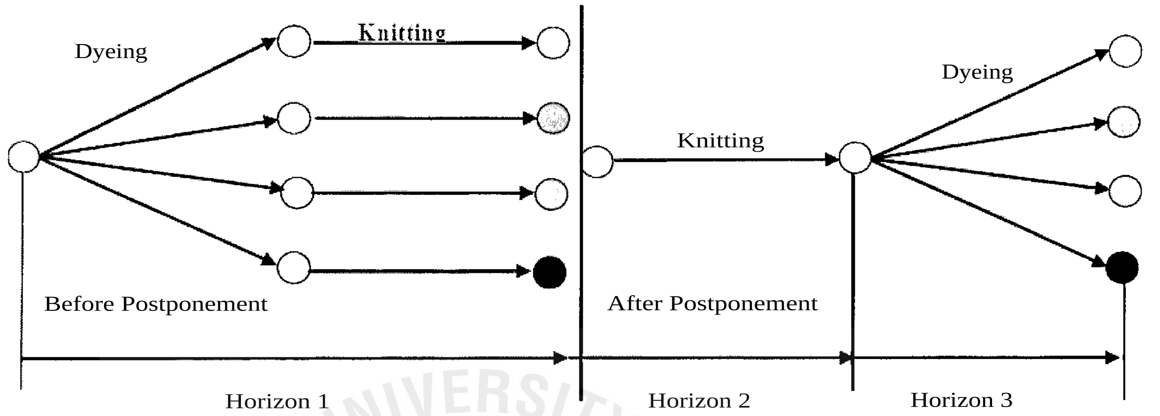


Figure 2.1 Operation process Improvement through Postponement

Source: Shen (2005)

Figure 2.1 shows before postponement, the company needed to forecast every colored garment over horizon 1. After postponement, it first forecasts the aggregated quantity of un-dyed generic garments over horizon 2. Once more demand information regarding color is available, it forecasts the different colored garments over horizon 3 with updated information. Therefore, postponement can improve forecast accuracy and thus reduce market mediation costs through reducing forecasting horizon, aggregating end products, and utilizing updated market information.

5) Achieving Make-to-Order

The business practices of make-to-order (MTO) have existed for centuries. The popularity of MTO has been increasing for several reasons (Shen, 2005). First, as we discussed, due to the trend of mass customization and competition of product variety, many companies have to offer a large variety of goods in order to stay competitive, and make-to-order is often a good way to deal with product proliferation. Customers' willingness to pay a premium for customization provides further incentives for MTO. Second, the growth of information technologies makes demand information far more accessible than before, therefore end customer demand can be transmitted to manufacturers within a few seconds via the Internet; the manufacturers could precisely make-to-order instead of holding excess inventory. Third, advanced manufacturing systems have improved the flexibility in producing different variety of goods and reduced setup costs, which had been one of the limitations on make-to-order before flexible computer-controlled manufacturing systems and lean production came along. The recent success of make-to-order companies, especially Dell, has also made many executives rethink their business strategies to consider the possible transition from make-to-stock to make-to-order (Toytay, 1998).

Postponement is an enabling mechanism for make-to-order. Regardless of the forms of make-to-order, such as configure-to-order, assemble-to-order, or engineer-to-order, every make-to-order model further differentiates products after the perfect or actual demand information is available. If we look at the supply chain timeline starting from product design, some stages are make-to-forecast, while the remaining stages are driven by the actual demand information. There could be multiple postponement points in the make-to-order supply chain process and demand information update at each point, but the actual customer demand is integrated into the supply chain at the last point of postponement, or the push-pull boundary. For configure-to-order, it is often the software or easily configurable features that are performed after demand uncertainty resolves. In the case of assemble-to-order, the primary assembly process is postponed while for engineer-to-order, the design process is also delayed until customers specify their preferences (Shen, 2005).

Companies can use a series of improved forecasts-imperfect demand information to trigger postponement points, but for make-to-order, there must be some steps postponed after actual demand information comes in, be it design, manufacturing, or packaging (Can, 2008).

6) Improved Customer Service Levels

Customer service levels are defined in terms of lead time; how long it takes an order to arrive, and item fill rate, how often orders are filled from inventory on hand. Providing customers with orders quickly can be the result of improvements in manufacturing processes or by repositioning inventory closer to the customer.

Customer's willingness to wait is a key factor when assessing a product for postponement and determining the location of the postponement point within the supply chain. If customers are willing to wait a long time for a product then there is no benefit from expediting orders or sourcing components or processes closer to the customer even if they can be done cheaper overseas. On the other hand, if customers are willing to wait for one week, then the supply chain must be structured therefore the finishing lead time and delivery time is less than or equal to one week. This breakpoint between initial and finishing lead time is called the decoupling point and separates production into two stages. The length of time for the first stage is not visible to the customer and therefore all options for achieving lower manufacturing costs can be exhausted. The second stage of the supply chain (from intermediate product to delivery) must be structured in a way that offers the customer the highest level of service without sacrificing cost (Zu, 2004).

2.1.2 Applying Postponement Strategy

In applying postponement, firms can customize and localize products according to customer demand and local market circumstances from a vantage point close to the market (which is especially relevant when a company operates in varied international markets) (Hoek, 2001). This enhances the efficiency of various operations, as they avoid uncertainty about the specification of orders and order mixes. In other words, the company can cope with complexity without having to lower product variety; in fact, they may decide to expand it (Hoek, 2001). Besides customizing (job shop) postponed operations, those activities that are not postponed (for example, up-stream activities) can be run (like a flow shop) in a mass production environment, thereby maintaining efficiency. Hewlett Packard has reported double-digit savings in supply chain costs by applying postponement in manufacturing and distribution (Hoek, 2001). Table 2.3 compares traditional approaches with the postponement approach.

Table 2.3 Postponement Opportunities in Operations

	Traditional operations	Postponement opportunities
Uncertainties	Limit operations; uncertainty about order mix and volume	Reduce risk of volume and variety mix by delaying finalization of products
Volume	Produce volumes (flow shop) with	Make batches of one (job shop for

	large economies of scale	customization, flow shop elsewhere)
Variety	Create obsolescence risks	Presume, customize, requiring flexibility
Lead times	Involve long response times	Offer accurate response, yet perform activities within order cycle time
Supply chain approach	Limit variety to gain efficiency advantages	Reduce complexity in operations, yet possibly add flexibility and transport costs

Manufacturing postponement is an extension of assembly postponement. The difference lies in the degree of final assembly that takes place at the distribution or finishing center. According to Zinn and Bowersox (1997), manufacturing postponement occurs when parts are shipped to the finishing center from more than one supplier. Manufacturing postponement has the greatest potential for cost savings in inventory because the value of the product increases through the addition of each successive component. Manufacturing postponement usually results in higher production costs. The increase is due to the capital cost of switching machinery between different types of variety and shipping them to different finishing facilities.

Time postponement occurs when finished products are shipped to centralized warehouses closer to the customer than the manufacturing location. The motivation is to increase customer service levels by decreasing customer lead time and to respond quickly to orders by placing inventories closer to the customer without committing to an individual order (Rietze, 2006). Table 2.4 shows a list of the postponement types and the firms which would benefit from implementing each type of postponement.

Table 2.4: Potential Utilization of Postponement

Postponement Type	**Potentially Interested Firms**
Labeling	Several brand names
	High unit value products
	High product sales fluctuations
Packaging	Variability in package size
	High unit value products
	High product sales fluctuations
Assembly	Selling products with several versions
	High volume incurred by packaging

	High unit value products
	High product sales fluctuations
Manufacturing	High proportion of ubiquitous material
	High unit value products
	High product sales fluctuations
Time	High unit value products
	Large number of distribution warehouses

Source : Zinn and Bowersox in Rietze (1988)

Wallace and Stahl (2005) propose a framework for implementing postponement by classifying products according to two factors; product complexity (the number of product varieties) and speed (the time from customer order to delivery). This results in four levels of differentiation as shown in Figure 2.2.

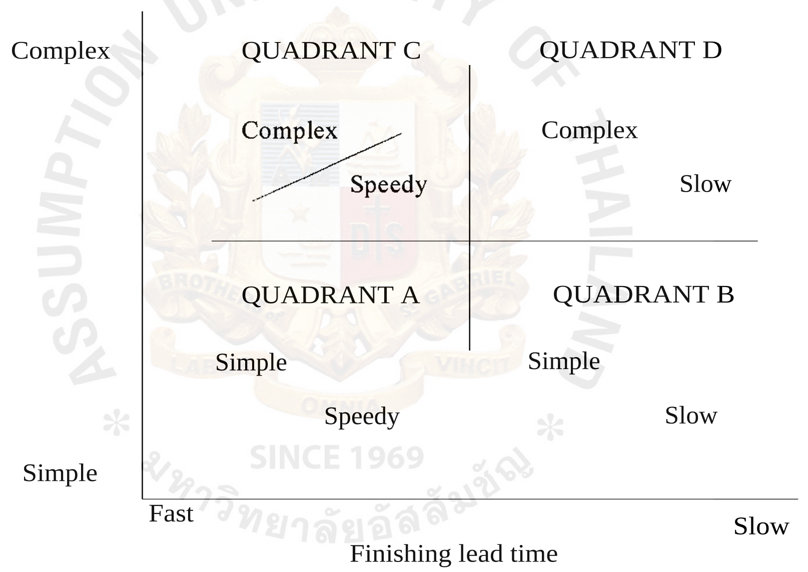


Figure 2.2 Product characteristic (Source: Rietze, 2006)

Companies in each of the four quadrants have different challenges when adopting a postponement strategy. For example, a company in Quadrant-B produces a product that has very little variety but takes a long time to produce and deliver to the customer. Wallace and Stahl suggest that a company in this quadrant focuses on speed by reducing the lead time from suppliers and expedites the delivery to the customer. Companies can accomplish this by implementing lean manufacturing initiatives, improving the work flow, and reexamining the location of their suppliers in terms of distance to the customer (Wallace and Stahl, 2005). This dilemma illustrates the trade-off between cost and service level. One way to take advantage of distant suppliers and still achieve fast delivery is to decouple the production process and hold inventory of intermediate product locally. Wallace and Stahl (2005) argue that not all of the manufacturing process needs to be highly speedy, only the part where the options are added.

Swaminathan and Lee (1998) identified the factors which influence the costs and benefits of postponement as market factors, process factors, and product factors. Market factors refer to characteristics of demand and uncertainty. Process factors refer to characteristics of operating policy within the firm as well as the external supply chain, such as managerial support and the location of and relationship with suppliers. Product factors refer to the design and characteristics of an individual product such as integral versus modular and inventory carrying cost. They also highlight enablers of postponement such as process standardization, process re-sequencing (redesigning the assembly process to move value-added processes closer to the customer), and component standardization. Redesigning products with these characteristics makes postponement possible and reduces the risk to the manufacturer by eliminating redundant processes and designing products to be modular and component interfaces to have standard ports for easy assembly.

2.1.3 Change management

The case studies on the implementation of postponement (Feitzinger and Lee, 1997; Van Hoek, 1997, 1998a) center largely on the managerial processes - from feasibility studies to the actual implementation of postponement. Central to the managerial process is the change management, O'Laughlin et al. (1993) state that proper change management in logistic reconfiguration programs may be the single most critical success factor in such programs. Van Hoek et al. (1998) use the O'Laughlin change management action plan as a framework for studying the implementation of postponement). The literature deems relevant to the change management process, following the environment - strategy - structure - performance contingency framework. First of all, Dröge et al. (1995) point out the importance of IT as a driver of organizational change and its role in enabling postponement by speeding up customer information and making it transparent in the chain (contributing to customer responsiveness). Secondly, Van Hoek et al. (1998) identified deregulation as a second driver of supply chain reconfiguration. It can be expected that deregulation enables companies to establish postponement operations in major markets, while globalizing primary production instead of duplicating factories nationally. The notion that a trade relation is imperative to the supply chain structure. Dröge et al. (1995) explain that market turbulence is a relevant driver of the growing attention for postponement. In international markets, a general move towards customization of products on a cost-effective basis is accompanied by residual differences in local markets. These differences require the localization of strategies, products, and operations, all favoring postponement. Market turbulence is expected to be the new demanding context in which postponement can prove to be an effective solution. The reason why postponement is receiving more attention might be that the operating environment did not facilitate or require postponement in the past, whereas it now does. Apart from the new technologies and the new market context, new organizational forms are also expected to influence the application of postponement. In particular the literature refers to geographical restructuring within the service window and the role of operating characteristics in favoring or disfavoring postponement. Finally the organizational heritage may exert a moderating influence on structure development through its impact on the time-line, the structure, and the nature of the change process. Ultimately, the implementation of postponement, within the proper operational and strategic context, should affect performance levels. The literature is predominantly concerned with improvements in operational (cost) performance. (see Lee et al., 1993 and Zinn, 1990).

2.1.4 Push-Pull Based Supply Chain

Levi et al. (2008) explain each one of the strategies. Push-Based Supply Chain, production and distribution decisions are based on long term forecasts while Pull-Based Supply Chain, production and distribution are demand driven, therefore they are coordinated with true customer demand rather than forecasted demand. Thus Postponement, or delayed differentiation strategy will be appropriately applied in the Push-Pull boundary point between push-pull supply chain. This is illustrated in Figure 2.3.

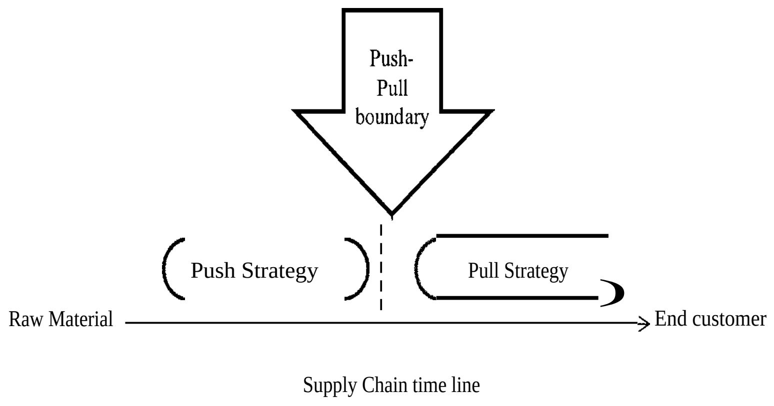


Figure 2.3 Push-pull Supply Chain (Source : Simchi-Levi et al., 2008)

2.1.5 The impact of Lead Time

Levi et al. (2008) describe the impact of lead time on the supply chain strategy. Intuitively, the longer lead time, the more important it is to implement a push-based strategy. It is rather difficult to implement a pull strategy when lead times are long and it is difficult to react to demand information. In Figure 2.4 it considers the impact of lead time and demand uncertainty on the supply chain strategy.

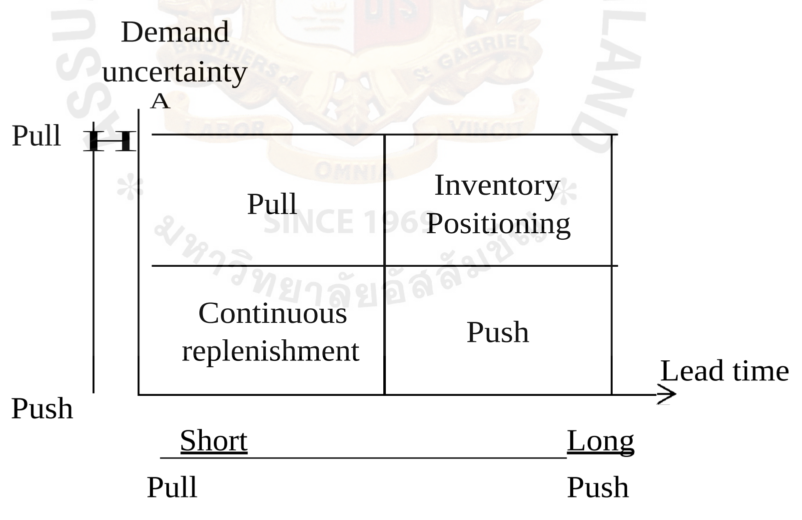


Figure 2.4 Matching supply chain strategies with products

(Source: Simchi Levi et al., 2008)

Quadrant Pull represents the situation that, for materials with short lead time and high demand uncertainty, suggesting pull strategy should be applied as much as possible. Quadrant Push represents items with long supply lead time and low demand uncertainty, so for this case the appropriate supply chain strategy is push. Quadrant

Continuous replenishment is suggested for the materials with short supply lead time and high predictable demand. While Quadrant Inventory Positioning is the most difficult to manage in the supply chain with the long lead time and high demand uncertainty.

2.2 Developing an Action Plan for Postponement

Ting Shen (2005) suggests that there are 3 steps for formulating and implementing a postponement strategy.

Step1: Identifying the Source of Demand Variability

The strategic motivation of postponement explains before all centers about the variability of demand. Therefore the first step is to identify the sources of demand variability - product features and associated demand patterns that drive demand variation or variety explosion. Such features could include color, language, option combination, or software content. If we look at demand variability, there are typically two sources: variance of individual demands and the number of individual demands resulting from the variety a company offers. These two sources are inter-related as offering more variety could increase the uncertainty of each end product.

Step2: Re-design Products and Processes for Postponement

Once the sources of variability are identified, the next step is to re-design the products and re-arrange the processes to enable postponement. To reduce demand variability, postponement strategy needs to work on both sources. Parts commonality can often reduce unimportant varieties and thus variability of demand. Instead of having a separate braking system for each vehicle line, communizing these systems across all vehicle lines usually will not reduce consumers' value from the vehicle (Shen, 2005). Product modularity is an effective way to control combinatorial explosion of varieties by providing common product architecture. Process standardization often accompanies parts commonality to reduce the intermediate or end varieties produced. Process re-sequencing provides the structure therefore the most variable features can be added on later. From a forecasting perspective, parts commonality and process standardization create the demand risk pooling effect. Product modularity imposes independences among different features and ensures that a parsimonious set of basic features can create the maximal number of end varieties, which also create the demand risk pooling effect at the component level (Shen, 2005). Process re-sequencing on the other hand allows the shortening of forecasting horizon and updating of new demand information (Shen, 2005).

Table 2.5 Benefits of product and process changes in postponement

	Demand Risk Pooling	Shortening of forecasting horizon
Part commonality	X	
Product modularity	X	
Process standardization	X	
Process re-sequencing		X

Source : Shen (2005)

Most of the successful postponement applications have these four elements (Shen, 2005). In many well-developed industries, such as apparel, paint, and computer, products already have modular structure and high degree of parts commonality and processes are standardized (Shen, 2005). In these cases, process re-sequencing is often the mind-shifting part that enables companies to reap the low-hanging fruits of postponement. For example, Sherman Williams moved the paint-mixing process into retailer stores and therefore re-sequenced the distribution and mixing process. Although the company needed to develop new process and technology for mixing paint at stores, the accrued benefits far exceeded the cost of change. Benetton, the international apparel company, reversed the process of knitting and dyeing and significantly reduced the market mediation costs.

Besides the above four approaches, supply chain steps that generate high product varieties, such as software customization and assembly, are nature candidates to be postponed. Due to the nature of information goods, software customization could generate unlimited variety and therefore variance. Xilinx and General Motors have successfully postponed software customization until the end of supply chain process (Shen, 2005). In Xilinx's case, customers also have the option of customizing by themselves after sales. Combination of a few feature options could generate varieties at multiplicative rates, therefore assembly process is also a nature candidate for postponement if the lead-time is acceptable. For National Bicycle, color is also the one that drives the most variety, so it leaves painting as the processes until customers configure their orders (Shen, 2005). In a make-to-order (MTO) setting, option combination is the one generates the largest combination and is therefore left until after orders come in as in Dell's case (Shen, 2005). Postponement can be enabled by a combination of product and process changes. Depending on the operations that are postponed, there are different forms of postponement, such as labeling, packaging, assembly, and manufacturing.

Postponement can also be enabled by simply adding more forecast update points, which might or might not incur product and production processes changes at all. Japanese automobile makers manage manufacturing and distribution in two monthly stages (Asanuma, 1991; Whang and Lee, 1998). At the beginning of the first stage, sales-dealers provide aggregate orders, which are used to generate orders for components with critical parts, such as engines and chassis, with long lead times. Subsequently, at the beginning of the second stage, and with additional visibility to recent sales trends, the sales-dealers provide data for features in each car line, which helps make the final decision of feature selection and product mix of the vehicles being manufactured. This reduces the risk of misjudging the vehicle specification and hence reduces the risk of manufacturing and stocking vehicles that are not in current demand. In this case, Japanese automobile makers could have increased commonality, modularity, and standardization through the lean manufacturing thus gaining additional benefits by simply increasing forecast points.

With the enabling techniques discussed above, will be discussed the critical steps that determine the structure and form of postponement.

Step3: Determining the Postponement Points

The third step is to determine the postponement points, i.e., which processes will be carried out after more demand information is observed or demand is realized. It is important to note that there could be multiple points for postponement. First consider the following sequential and parallel postponement cases are considered, and then dynamically adjusting postponement points in a product life cycle and determining the specific postponement points with cost benefit analysis are discussed.

In summary, postponement enables forecasters to make better predictions about end product demand over time, since the standard module is built-to-forecast and the finished product is built to a better forecast or even built-to-order.

2.3 Relevant Research

Pagendarm (1991) studied a use of strategic buffer of in-process inventory and delay in final packaging of end-items at Kodak Company, by selecting placement on inventory in the process. The result was that Kodak reduced manufacturing costs, maximized the ability to respond to consumer demand patterns, both daily and the seasonal demand patterns.

Cooper (1993) distinguishes four types of mid-to-down-stream postponement applications, based upon different combinations of operating characteristics that favor certain types of postponement applications. He gives examples of companies that fit into that classification.

Hoek (1997) expands the classification into a framework of four categories. These are based upon technology, processes, products, and market operating characteristics that do or do not favor specific postponement applications.

Feitzinger and Lee (1997) used HP as a case study in the other publications by Lee on postponement. These other works by Lee used a different method to assess the feasibility of postponement.

Van Hoek et al. (1998) provided a cross-case comparison of postponement practices to allow for generalization. Statistical and mathematical generalizations are made on the basis of the final two methods used, modeling and surveys.

At hlstroÈm and Westbrook (1999) report the results of a survey conducted to explore issues surrounding mass customization and in particular its implications for operations management. The findings cover the market changes driving customization, the positive and negative effects of customization, and the difficulties of implementation. These are shown to have important implications for operations management in a strategy of mass customization. The survey has indicated, companies perceive mass customization not only as something which is currently happening but also as something which will be even more important in the future.

Ritetze (2004) highlights some of the leading companies who are pioneers of postponement and includes case studies of additional companies who have followed their lead. For many case studies Postponement is a strategy that allows businesses to take advantage of the offshore capacity and labor for manufacturing in addition to local finishing centers for final assembly, packaging, and distribution. Ritetze also point out the tangible benefits of lower inventory costs, quicker response time, better forecasts, and more variety as well as the intangible benefits of better customer service and the coordination and integration of manufacturing, sales, and marketing functions.

Can (2008) studied the relationship of the four strategies which are postponement, mass customization, modularization and customer order decoupling point and used the pair-wise relationships of these strategies. The research model was built accordingly and explored it in Autoliv Electronics. He states that postponement creates more agile supply chains on behalf of mass customization. For the postponement strategy, it is not possible to separate and delay any operation without achieving process modularity.

Zu (2004) studied two approaches to buffer inventory against demand uncertainty. The first approach is make-to-anticipated-order as a pull and postponement and the second is a commonality strategy to lower demand uncertainty which can optimize multi-stage inventory placement with the minimum holding cost of total safety stock.

2.4 Contract Manufacturing

Electronic Contract Manufacturing (ECM) is a term generally used for companies that offer contracts for electronic assembly for another company. For instance, instead of attempting to manufacture complex circuit boards themselves OEM (Original Equipment Manufacturer) companies often outsource their manufacturing operations to ECM companies. In effect, contract manufacturing providers do not post their brand name on any product, and both design and brand name belongs to the OEM (Mahoney, 2007).

The tide of constant innovation, changing market paradigms, competitive dimensions and rising customer expectations has transformed the hi-tech and electronics industry into one of the most competitive industries (Gill, Lopus & Camelon, 2007). Challenges in dealing with mass customization, rapidly shrinking product life cycles, rapid inventory depreciation, and handling complex multi sourced supply chains have required the use of very sophisticated tools and strategies for meeting the rising expectations of customers in a cost-efficient manner. Among other approaches, the electronics industry has tackled this problem through a focus on core competencies, outsourcing of non value-adding activities, multi-stage manufacturing and built-to-order strategies.

Increasingly the OEM are focusing on the high-value design and marketing aspects of the business, while outsourcing the manufacturing of their products to contract manufacturers who have core-competencies in large-scale production of mass customized products. Thus, outsourcing of activities ensures that each business within the supply chain is focused on certain products and services delivering highest revenue to them, while employing the least amount of capital and resources.

Furthermore, instead of storing huge amounts of expensive and rapidly depreciating inventory the supply chains are designed such that the contract manufacturers produce the goods only when the customer orders them. This postponed production allows the customization of the product to the precise requirements of the customer. The key however to the success of these outsourcing, postponement and customization strategies is close coordination between the OEM, the contract manufacturer and the component suppliers. Close coordination between the various participants allows the electronics supply chain to quickly react to changing market requirements.

23 Theoretical Framework

From the literature review, it may be summarized that, postponement, or delayed configuration, is based on the principle of seeking to design products using common platforms, components or modules. The final assembly or customization does not take place until the final market destination and/or customer requirement is known.

Therefore, in this research, the challenge is to use postponement approach to matching demand with supply at the appropriate time where so that it could be possible to improve order fulfillment performance and operating costs. The flow of product up to the decoupling point, which is the point that key postponement decision made, may well be forecast driven; after the decoupling point it should be demand driven. There may be two decoupling points for postponement. The first is the one already referred to, e.g.. the material decoupling point where strategic inventory is held in as generic a form as possible. This point ideally should be further downstream in the supply chain and close to the final market place as possible. The second decoupling point is the "information" decoupling point. The idea is that this should be far upstream in the supply chain as much as possible.

From the key points discussed earlier in this chapter, the researcher proposes a theoretical framework of this project, as shown in Figure 2.5.

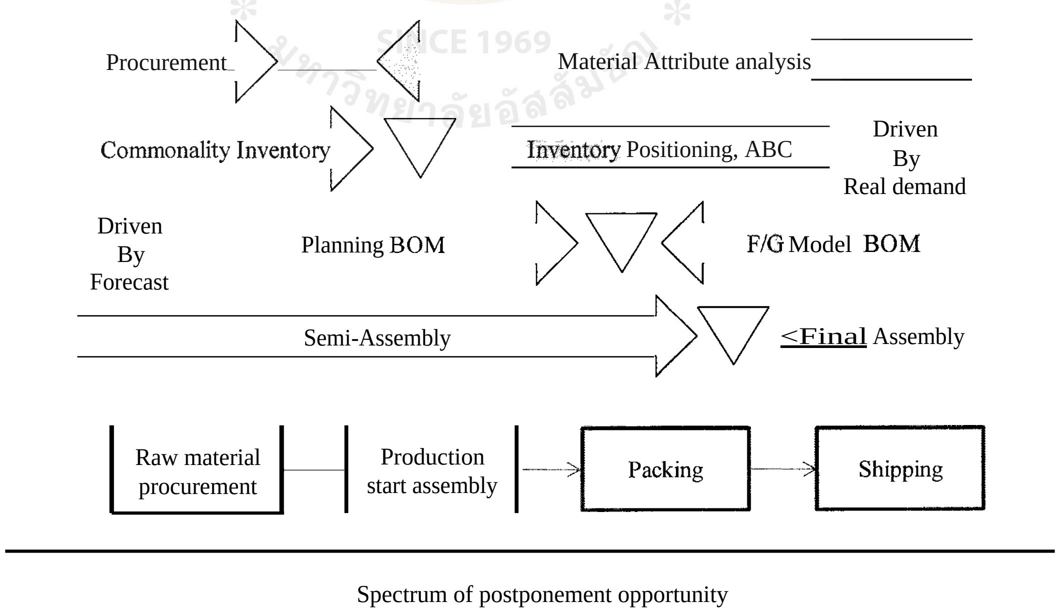


Figure 2.5 Theoretical Framework

Figure 2.5 shows the inter-relationship among many factors in this case study, all of which are concerned with improving operations effectiveness. Procurement and commonality inventory would play an important part in analyzing a planning BOM and proposing "semi-assembly" approach. At the same time, analyses on materials attribute, inventory positioning, finished good model BOM, and final assembly, would highlight some constraints and opportunities to improve operations. This framework is limited to activities from raw materials procurement, production, packing, and shipping.

In this chapter, the researcher has discussed relevant concepts in managing inventory complexity, while aiming to optimize delivery reliability, as well as proposing the theoretical framework for this research project. In the next chapter, the researcher will explain the methodological approach for undertaking this project.

CHAPTER III
RESEARCH METHODOLOGY

In this chapter, the researcher will explain relevant methodological concepts and methodologies for undertaking this research. First, the researcher will examine how a research is viewed, as well as how it should be undertaken, given the circumstances surrounding this case study. Then, the researcher will outline an approach for this research.

3.1 Methodological Framework

Research is an important aspect for economy and society, since it is the process which leads to new knowledge. Leedy and Ormrod (2001) argue that research is a systematic process of collecting and analyzing information, in order to increase our understanding of the phenomenon about which we are concerned or interested. In order to perform a research project, a systematic way of working, or methodology, is required in combination with a theoretical foundation and a thorough analysis and discussion. Regarding this, it can be assumed that the desired outcome – the kind of knowledge that wants to be learned – determines the research methodology which is most effective.

The purpose of the report is to test this assumption and to deliver useful information to managers who want to make decisions concerning these subjects. Since it was assumed that these three main subjects are related to each other, a decision to use a qualitative, interpretive research design was made.

Like shown in Figure 3.1, indicates a methodology flow chart which is a process by which a researcher is able to return to a previous step when it is considered interesting to do so. For this project this is desirable, because while analyzing the results new knowledge about separate subjects might be required. However, every research project starts with defining a topic of interest. For this project, the definition of topic had been done at the end of January 2009. This was partly influenced by the fact that the company was forced to reduce inventory. At first, different ideas were generated without limitations. Subsequently, several items were combined and the topic was selected. Finally, a brief literature review was studied to find existing literature about the subjects.

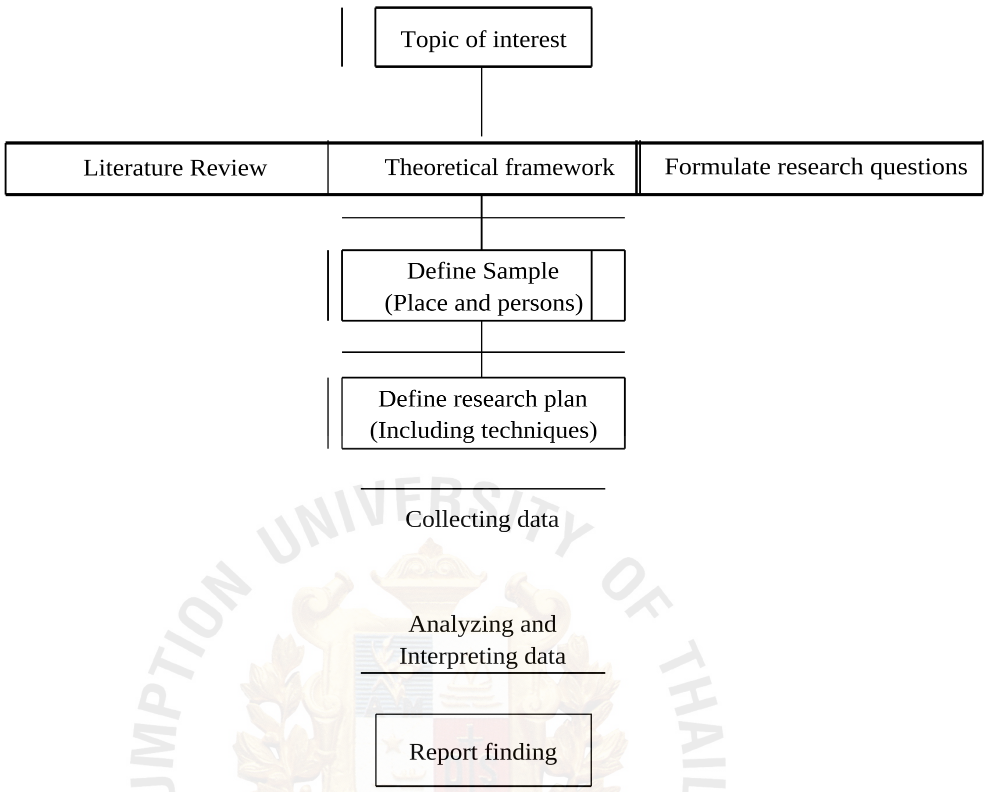


Figure 3.1 Research Methodology (Source: Williamson, 2000)

3.2 Generic Approaches on Data Collection and Analysis

According to Yin (1994), there are five major methods for handling research. They are experiments, surveys, history, archival analysis and case studies. Selection of a method can be done based on type of research question, researcher's control on event of interest and focuses on contemporary events. Saunders et al. (2003) suggest that a survey is a strategy for a descriptive approach, where data is collected from a large population by questionnaires. The researcher has more control over research in this strategy. However, in the case of a qualitative study data may not be in a wide range (as sample size is small), and hence there are restrictions for qualitative research by this strategy. In this research, one business unit in the company was selected which does not represent a large number of population whiles still remaining rich in information to be analyzed. Hence, the survey method was considered inapplicable for this research.

3.3 Definition of Data and Sample

The researcher collected data for a period of eight months, from October 2008 to July 2009, from the Medical business unit of MED EQUIP Co., Ltd. The data was included in the BOM, Shipment historical data of units shipped, customer PO request date shipped and actual date shipped. The Medical unit in MED EQUIP has about 100 F/G models, with 1,500 items of materials.

3.4 Definition of Research Plan

For this research project, the researcher plans has 7 steps as shown in Figure 3.2 below.

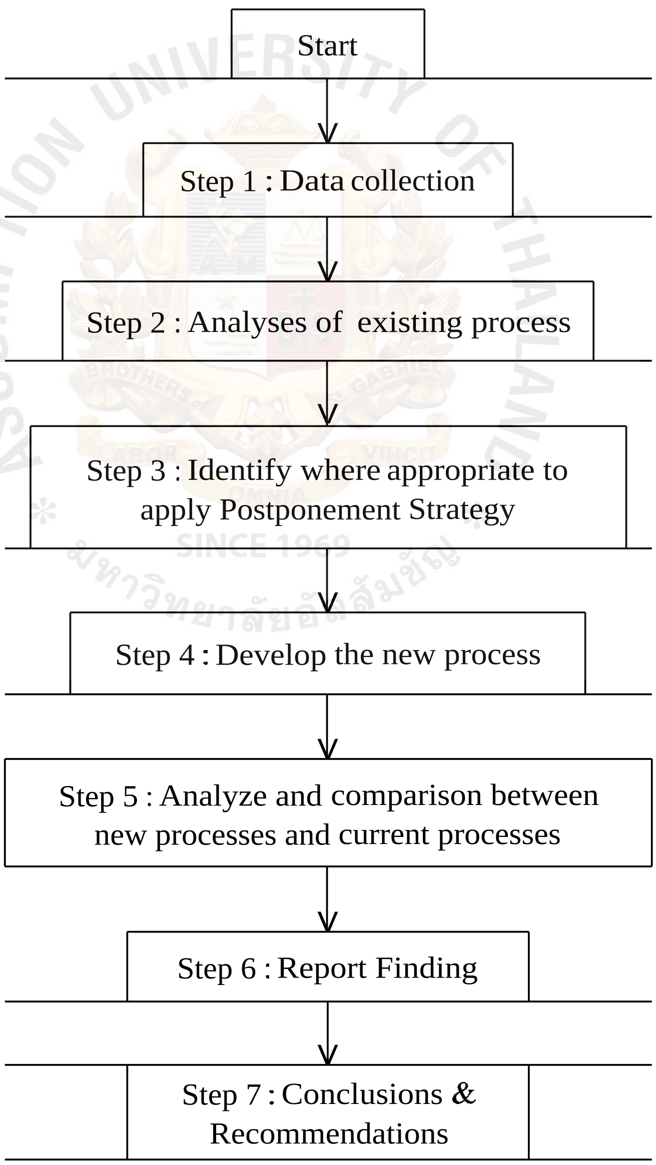


Figure 3.2 Research Plan and Steps

Step 1 Data collection

Below are the historical data that was collected between October 2008 and July 2009.

1. The operations cost gathered from monthly financial reports is the portion of the labor cost and overtime spending costs for each month.

2. Earned hour is the amount of hours that the company uses to generate revenue from each unit produced. This is calculated by the standard time multiplied with the units produced in one period.

Earned Hours = HPU x Units built

3. Total attended hours are the total working hours of operators who come to work each day. Total standard working hours per day is 7 hours multiplied by the number of operators.

4. HPU : Hour Per Unit is the total time that is used to produce one unit of the F/G model, which is set up by an industrial engineer who is works as the centralization supporting group. This group will support every business unit to collect and monitor the production process and come out with the standard HPU, in order to have the same method and measurement in the company.

Table 3.1: Sample of total Earned hours calculation sheet

Product group	Part No.	A : Unts build	B : HPU (Hour/Unit)	C : Earn Hour = AxB
1	Al	2,777	0.6400	1,334.40
1	A2	650	0.6400	512.00
1	A3	1,536	0.6400	1,134.08
1	A4	10	0.6400	12.80
1	A5	20	5.6000	156.80
1	A6	4	5.6000	56.00
1	A7	90	6.4000	800.00
1	A8	40	6.4000	384.00
1	A9	40	5.6000	252.00
1	Al 0	320	8.0000	4,000.00
1	All	1,125	0.7093	1,028.49
1	Al2	16	1.2800	20.48
1	A13	92	0.9700	145.50
1	A14	40	0.9700	63.05
1	A15	320	0.9700	436.50
1	A16		0.6400	0.00
1	A17	4	2.3500	9.40
1	A18	24	2.4855	2,234.46
1	A19		2.4820	186.15
1	A20	30	2.4820	0.00
1	A21		2.4820	0.00
1	A22	-	2.4820	0.00
			Total Earn hours	12,766.11

Table 3.2 Sample of HPU detail by operations

F/G Model : A10

Operation	Machine group	Man cycle time Prime			Machine time			Batch size	Unit per hour
		Hr	Min	Sec	Hr	Min	Sec		
Kitting and Material Preparation (Approximately)	1	1	30	0	0	0	0	10	7
Wiring Assembly (Sub-Assembly)	1	0	10	0	0	0	0	1	6
Tubing Assembly (Sub-Assembly)	1	0	30	0	0	0	0	1	2
Manifoild Leak Test (Material)	1	0	5	0	0	0	0	1	12
Leak Drop Test	2	0	1	7	0	0	10	1	44
Pneumatic Assembly	3	0	18	47	0	0	0	1	3
Label Printing	4	0	0	14	0	0	0	1	257
Manifoid Leak Test	5	0	12	31	0	0	0	1	5
Thermistor Assembly (Sub-Assembly)	7	0	11	0	0	0	0	1	5
Thermister housing cleaning in ultranonic bath with IPA	7	0	0	41	0	5	0	20	211
Thermistor Baking (Sub-Assembly)	7	0	1	48	12	0	0	20	2
Lamp Assembly (Sub-Assembly)	7	0	11	0	0	0	0	1	5
Lamp Baking (Sub-Assembly)	7	0	0	18	12	0	0	20	2
Lamp Burn-in	7	0	1	48	8	0	0	20	2
Source End Cap. Assembly (Sub-Assembly)	7	0	0	54	0	0	0	1	67
0-ring cleaning in ultranonic bath with IPA	7	0	0	41	0	5	0	100	1,056
Source End Cap. 0-Ring Baking	7	0	1	6	2	0	0	100	50
Source End Cap. Baking	7	0	1	6	12	0	0	24	2
Slit End Cap. Assembly (Sub-Assembly)	7	0	4	30	0	0	0	1	13
Slit End Cap. 0-Ring Baking	7	0	1	6	2	0	0	100	50
Slit End Cap. Curing (Sub-Assembly)	7	0	1	30	0	0	35	5	144
Grating Motor Assembly (Sub-Assembly)	8	0	11	43	0	0	0	1	5
Grating Motor Baking (Sub-Assembly)	8	0	1	6	2	30	0	20	8
Sample Cell Assembly	9	0	6	7	0	0	0	1	10
Housing Grinding	9	0	6	0	0	0	0	1	10
Housing cleaning in ultranonic bath with IPA	9	0	0	41	0	5	0	20	211
Housing Baking	9	0	2	30	8	0	0	40	5
Sample Cell Leak Test	9	0	1	13	0	0	0	1	49
Optical Head Assembly	10	0	45	1	0	0	0	9	12
Grating Mirror Baking	10	0	1	6	8	0	0	30	4
Optical Head Baking	10	0	2	42	7	30	0	9	1
Pre-Amp PCBA Assembly	11	0	29	37	0	0	0	1	2
Optical / Pre-Amp PCBA Assembly	12	0	6	10	0	0	0	1	11
DIR Head Test	13	0	0	56	0	15	0	1	4
Main PCB Test	15	0	7	11	0	0	0	1	9
Reworked Main PCB (Assume)	16	0	3	6	0	0	0	1	18
4850 Chasis Assembly	17	0	33	36	0	0	0	1	2
System Bring up Test	19	0	17	48	0	0	0	1	3
System Calibration	20	0	55	20	18	0	0	16	1
4850 Final Enclosure Assembly	21	2	0	0	0	0	0	1	1
Hi Pot Test	22	0	0	32	0	4	10	1	13
System Verification	23	0	42	2	0	0	0	1	1
Out of Box Audit	24	1	8	52	0	0	0	1	1
Packing	25	0	12	37	0	0	0	1	5

5. BOM : Bill of material explosion and detail of every model, extracted from the Oracle ERP system.

Table 3.3 Example of BOM (Bill of Materials)

Level	Item	Type	UOM	Usage Quantity
1	- 00-13564-04	Make Item	EA	1
2	- 01-13802-01	Make Item	EA	4
3	02-13839-01	Direct Item	EA	1
3	02-13840-01	Direct Item	EA	1
3	02-13842-01	Direct Item	EA	1
3	07-12803-01	Direct Item	EA	1
3	- 07-13841-01	OutSide Processing	EA	1
4	47-1179	Direct Item	EA	1
3	- 08-13853-01	Make Item	EA	1
4	43-437	Direct Item	EA	1
4	28-13853-01	Reference item	EA	0
3	30-12804-01	Direct Item	EA	1
3	35-13802-01	Reference item	EA	0
3	46-614	Direct Item	EA	1
3	90-1256	SubDirect	ML	0.5
3	90-1257	SubDirect	GR	0.5
3	90-2019	Direct Item	EA	1
3	90-2138	SubDirect	ML	0.02
3	90-2178	Direct Item	EA	1
3	90-2183	SubDirect	GR	0.1
3	95-1043-06	Direct Item	FT	0.0425
3	97-1857-3X5	SubDirect	EA	1
3	- 98-1360	SubDirect	EA	1
4	28-14235-01	Reference item	EA	0

6. Forecast details by product group, F/G model and quantity extracted from the Oracle ERP system.

7. Order fulfillment time from the promised date to the delivery date extracted from the Oracle ERP system.

8. Material attributes by extracting data from the Oracle ERP system.

Step 2 Review and Study of current parameters of the existing operation processes

After collecting **all** information and data from step 1, the researcher analyzed existing business processes, starting from receiving forecast from the customers until shipping out the finished products to the customers.

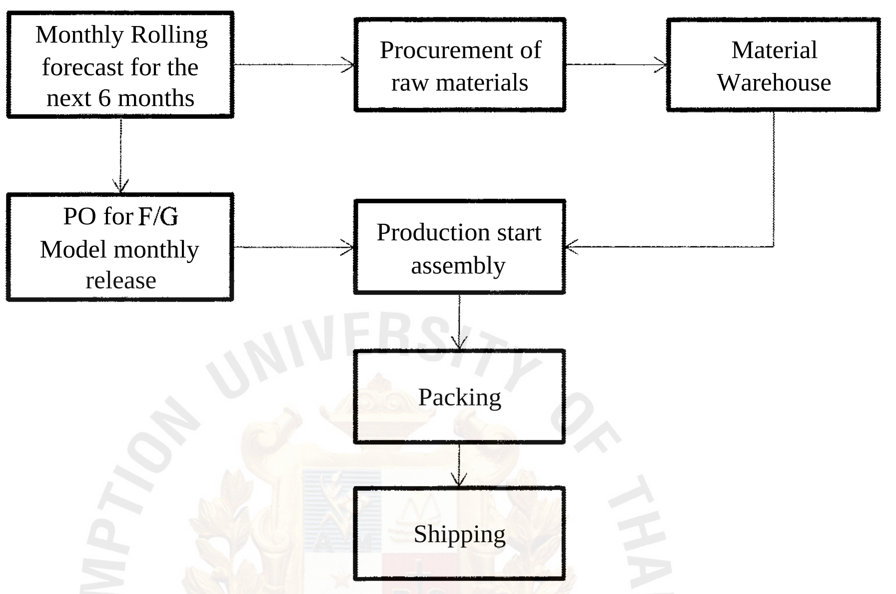


Figure 3.3 Current Operations Processes

2.1 Customers provided demand forecast for the next six months at the third week of the current month. This forecast was input into the Oracle ERP system and MRP (Material Requirement Planning) schedule was run every Thursday night. Then the system would generate the MDS (Master Demand Scheduling) plan of each item.

2.2 Material Procurement started from running MRP, which was scheduled every Friday night. Starting every Monday, the buyer retrieves the MRP suggestion report and process is the activity to push out or pull in current purchase order or generate new purchase order of materials that MRP in Oracle system had calculated of the shortage. The buyer would consider the other attributes such as material lead time, minimum order quantity, and multiple quantities per order and suggest the appropriate quantity and delivery time of each item to create a purchase order.

2.3 The master production loading would be triggered from customer confirmed orders released which can come in any time, regardless of whether forecast had been provided or not. Sometimes there were drop-in demands. Customers just placed the purchase order (PO), and demanded the products in a very short period of time. All of these confirmed order release. The planner would schedule the production, and the company would release work orders for production to start manufacturing the products.

2.4 After the production is finished, the product would go to the packing station, and then would be shipped to the customers. The MED EQUIP control inventory, usually do not keep F/G model in stock over one week.

2.5 Data analysis on operations costs and materials

2.5.1 Overtime spending hour in each day

2.5.2 The labor efficiency which can be calculated is as the given ratio below;

$$\text{Labour Utilization} = \frac{\text{Touch time or Earn hour}}{\text{Total attended hour}}$$

2.5.3 Review and analysis of Material attributes that are set up in the Oracle.

2.5.4 Use ABC analysis to separate group of materials

2.5.5 Analysis of BOM structure map with the HPU of each unit.

2.5.6 Analysis of each material by BOM matrix map with the commonality group in each semi-assembly

Step 3 : Developing new processes

At this step an analysis of the relative capacity of the various process steps within the assembly operation is performed to determine the applicability of a postponement strategy in order to address the seasonal concerns. It could be used to enable the company to alleviate seasonal capacity concerns and reduce their overall manufacturing costs while improving customer order fulfillment lead time. The researcher will review on the data collection and analyze data in the process and BOM identifies where the operation that use the same materials to assembly will be define as sub-assembly level.

3.5 Operations Processes

The concerned operations processes in this case study are indicated in Figure 3.4.

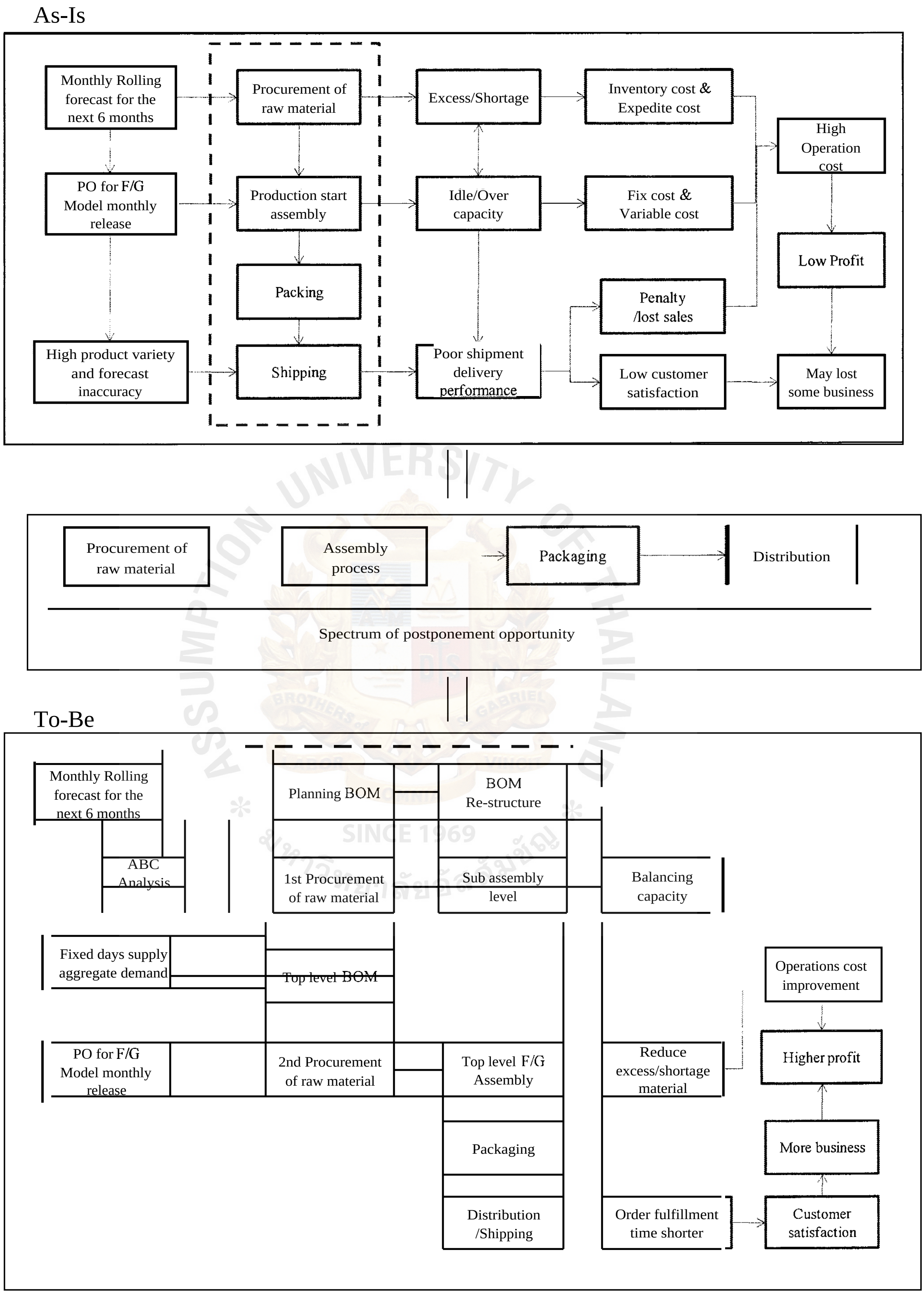


Figure 3.4 Project model

Figure 3.4 on the As-Is box shows the current process flow starting from receiving the 6 months rolling forecast from the customer. The forecast is the key information to drive all materials to prepare for production building. At this stage, production will not start assembling the product until they receive the PO from customers. Then after analysis the production process flow and BOM is used to find the sub assembly commonality that will set a planning BOM level to reduce the variety of materials and pre-build sub assembly. After planning BOM, will undertake ABC analysis of materials, and material lead time to use fix days supply to aggregated demand on the common materials. The common materials will be identified on the semi assembly production phase. It will delay ordering other materials that are not common and those with short lead times, until receiving the PO from customers. It can reduce the manufacturing lead time by using the sub assembly that is pre-built in advance to final finish products following the customers purchase order.

Planning BOM will help to reduce excess or obsolete materials. This is because the company will order only the materials that are common in each product group, and delay to order the unique materials until receiving the PO.

Building common sub-assembly products will help balancing production capacity where the demand pattern is seasonal. This would enable the company to aggregate demand of each low volume and high mix of product configuration, by using previously idle capacity to make sub-assembling, while enabling reserve capacity to build the final product on the peak demand period.

The 2nd procurement approach is to postpone ordering of unique materials that have short lead time such as packaging, labeling or the materials that are used in the process close to the final process.

3.6 Define time line

For this project, the researcher planned specific periods to work on each step as shown in Table 3.1. After the topic of interest was defined on June 2009, the data collection would follow. The overall timeline for undertaking this project is around 5 months.

Table 3.4 Project timeline

Task	Jun	Jul	Aug	Sep	Oct
Step 1: Data collection	■				
Step 2: Analyze exiting process		■			
Step 3: Identify where appropriate to apply postponement Strategy		■	■		
Step 4: Develop the new process				■	
Step 5: Analyze and compare between new process and current process				■	
Step 6: Report Finding					■
Step 7: Conclusion & Recommendation					■

Summary

In this chapter, the researcher has discussed the methodology used for research purpose. The researcher will analyze the data collected and measure, and interpret the results by comparing the result As-Is with To-Be, for better understanding and detailed explanation of a phenomenon.

CHAPTER IV

FINDINGS AND ANALYSES

In this chapter the researcher will present analyses of variables, both independent and dependent, followed by comparisons between As-Is and To-Be, after the application of postponement concept.

4.1 As-Is Analysis of Existing Processes and Parameters

4.1.1 Analysis Of Capacity Planning

Current capacity planning will be done every 3 months starting from the time that customer gives the 6 months forecast to order by model of units. This research will focus on the DL (Direct Labor) resource which is the position of an operator.

The working assumption for each operator is as follow;

Working hours per day 7 hours

Working days per week 6 days (Monday — Saturday)

Working weeks per quarter = 13 weeks to follow company calendar

Total earned hour required = Total forecast units * HPU

Therefore, the number of operators required= Total earned hour required / (7 hour * 6 days * 13 weeks)

Table 4.1 Total number of operators required per day per quarter

Period forecast	Total Earned Hours required	Number of Operators require per day
FQ3'09 Jan-Mar'09	5,993	11
FQ4'09 Apr-Jun'09	6,529	12
FQ1'10 Jul-Sep'09	8,638	16
FQ2'10 Oct-Dec'09	10,913	20

The number of the total earned hours and the number of operators in Table 4.1 is the result of the calculation method that company used to hire operators in each quarter. It shows the requirement of operates increasing from FQ3’09 TO FQ2’10 by 50% according to the total earned hours increasing. The total HPU and earned hours required will be reviewed and accepted by customers. If the actual order in each quarter is higher than the agreed total earned hour customers will pay the additional overtime cost based on the contract. All products are made to order (MTO), therefore no production can be made before an order has been released.

4.1.2 Labor Cost

The researcher will put assumption on the labor cost as a baseline for calculation and analysis as below since the actual data is treated as confidential data of the company;

- Each operator will receive the daily wage = $7 based on 7 hours regardless of whether there is any work done.

- Overtime cost will be 1.5 times of normal hourly rate paid = $7÷7 * 1.5 = $1.5 per hour and each operator is not allowed to do overtime of more than 36 hours per week based on the Thai labor law.

4.1.3 Labor Efficiency Analysis

The analysis on the labor efficiency can be done by considering the following parameters;

- *Operator Attendance hours* means the actual working hours per day including overtime hours. (clock-in & clock-out time excluding leave and holiday)
- *Earned hours* means number of hours to produce 1 product unit measured by the industrial engineer at optimum condition.

The meaning of labor efficiency is the ratio of total hours that generate the out put based on the HPU with total hours that company pays to each operator. For example if the operator gets paid for = 100 hours, and has the output = 10 units, the HPU 9.63 therefore, labor efficiency = (9.63*10) ÷ 100 = 96.30%. The higher labor efficiency will result in the lower idle hours which mean better capacity utilization. The formula to calculate labor effectiveness is as below;

$$\text{Efficiency} = \text{Earned hours} - \text{Operator Attendance hours}$$

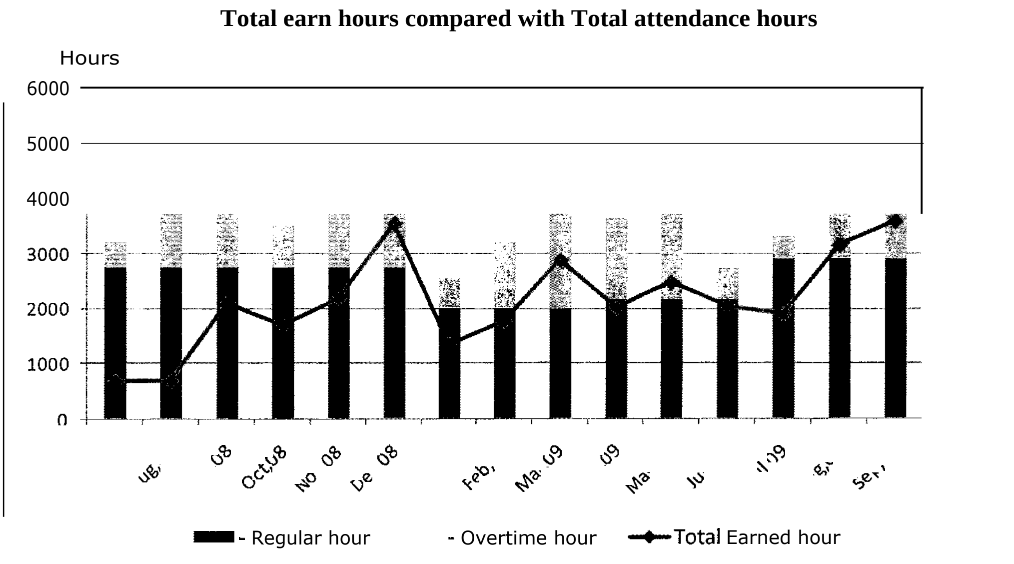


Figure 4.1 Total Earned hours compared with total attendance hours

Figure 4.1 shows the total hours usage compared with the total earned hours. The total hours usage shows a different between regular hours and overtime hours. The graph shows the actual hours usage is higher than the total earned hours which indicate that there are idle hours in the manufacturing line. The total earned hours is the hourly rate that customers will pay for including the unit price of the product. Thus any, excess or over hours usage has direct impact to the overhead cost of the company. At this point we will use postponement strategy to help to reduce the over hours usage.

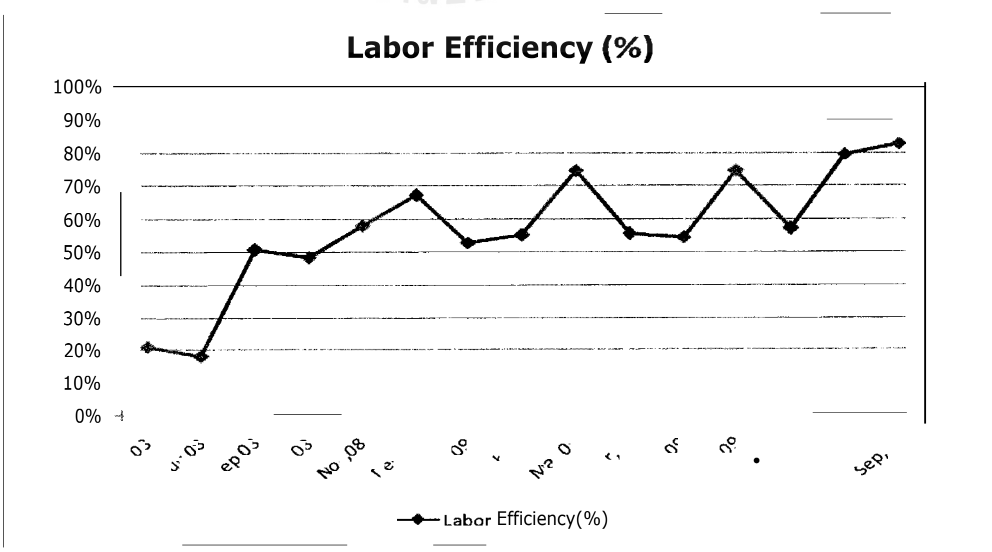


Figure 4.2: The labor efficiency

Table 4.2 The labor cost analysis compared with the total earn hour

	⊐an,09	Fe	Mar,09	Q3'09	^pr.	a,,09	Jun,09	Q-'09	ul,09	09	Sep,0	Q1'10
Total Earn hour required (A)	1345	68	28 0	5 92	1	247	2 45	5529	1894	31 5	3 8	8628
- Regular hour (B)	2002	02	20 2	6 6	8	216	2 84	6552	2912	29 2	2912	8736
- Overtime hour (C)	543	0	1856	3 9	5	2345	563	4361	4 7	5	1432	2904
TotalAttendance Hour (D)	25 5	12	3858	9 5	3	4529	2747	10913	3319	3977	4344	11640
Regular hour paid 1$ hour (E)= (B*$1)	$ 2,002	$ 0 2	$ 2,002	$ 6,0 6	$ 2 81	$ 2 184	$ 2 184	$ 6 55	$ 2 912	$ 2 912	$ 2,912	$ 8,736
Overtime hour paid $1.5 hour (F)=(C*$1.5)	$ 54	$ 2 0	$ 1 856	$ 3 6 9	$ 1 5	$ 2,345	$ 563	$ 4 36	$ 407	$ 1 065	$ 1 432	$ 904
Total labor paid (G)= (E)+ (F)	$ 2,545	$ 2 2	$ 858	$ 9,6 5	$ 3,637	$ 4,529	$ 2,747	$ 0 913	$ 3 319	$ 3 977	$ 4,344	$ 11 640
Labor utilization (H)=(A) / (D)	53%	5 %	75	62%	5	5 %	74%	60%	57%	79%	83%	74%
Cost of laborunutilization (G)-(A)	$ 1 200	$ 4 4	$ 978	$ 3 6 2	$ 1 2	$ 2 0 9	$ 702	$ 4,384	$ 425	$ 622	$ 755	$ 3,002

The result of lower labor utilization can be seen when the labor cost is higher than the standard as shown in Table 4.2. If we consider the quarterly performance Q3'09, it can be seen that the standard hours required (total earned hours) to build the products is a total of 5,993 hours which calculates at 11 operators working everyday without overtime required. However, in reality both actual regular hours and overtime hours are higher than total standard hours required. This means the company has to pay for higher labor cost than should be. The labor utilization is only 62%. In Q4'09 the total standard earned hours required is 6,529 hours and 12 operators but total actual hours used is 10,913 hours. Q1'10 actual hours used is 11,640 hours while standard earned hours required is 8,638 hours. This results in labor utilization of 60%. Significantly improvement on Q1'10 increases the labor utilization to 74%.

During the demand pattern analysis, it was found that daily demand of the product and volume varies as shown in Figure 4.3. During a 38 days period, there are 67 products that were ordered in various quantities from 1 up to 300 units per line item.

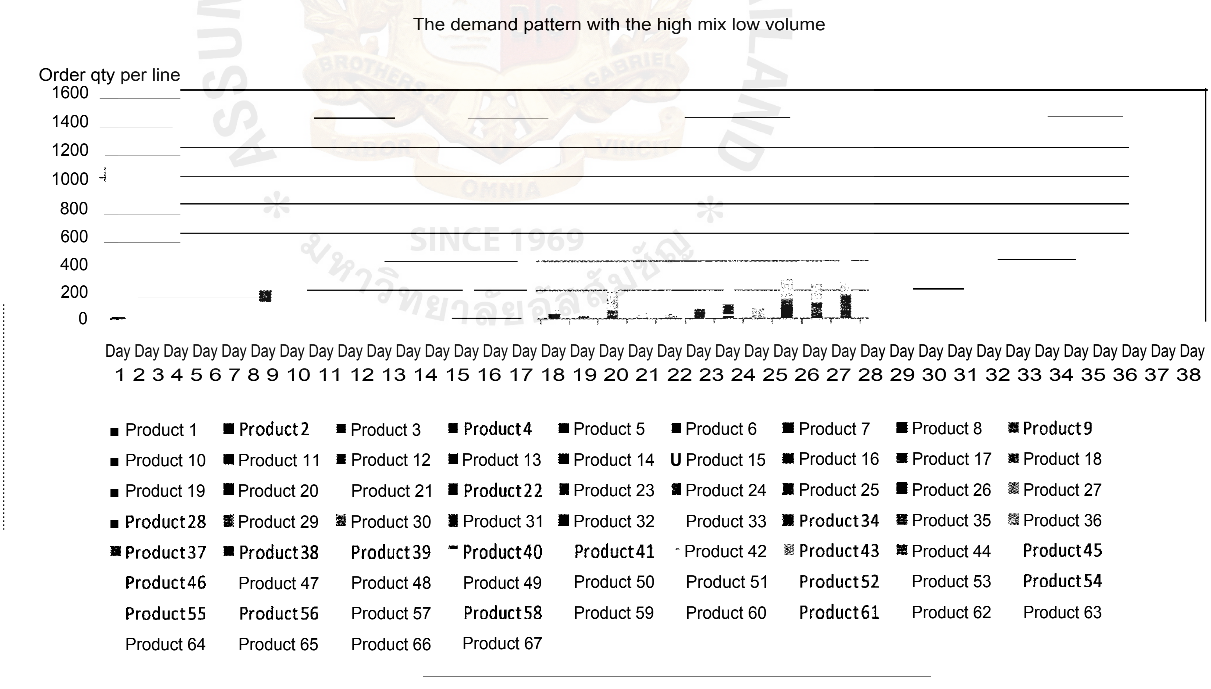


Figure 4.3 The demand pattern

4.1.4 Order Fulfillment Lead Time

The order fulfillment lead times by product group is shown in Figure 4.4. It indicates high fluctuation, and on average takes 12 days from order request date to actual shipment date.

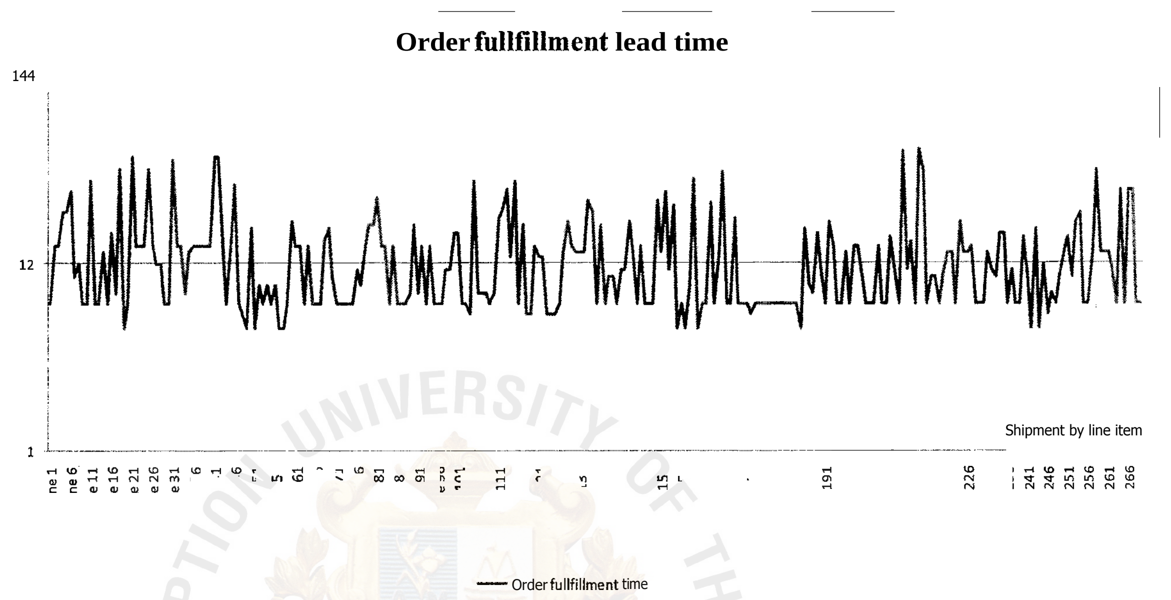


Figure 4.4 Order fulfillment lead time

4.1.5 As-Is BOM structure

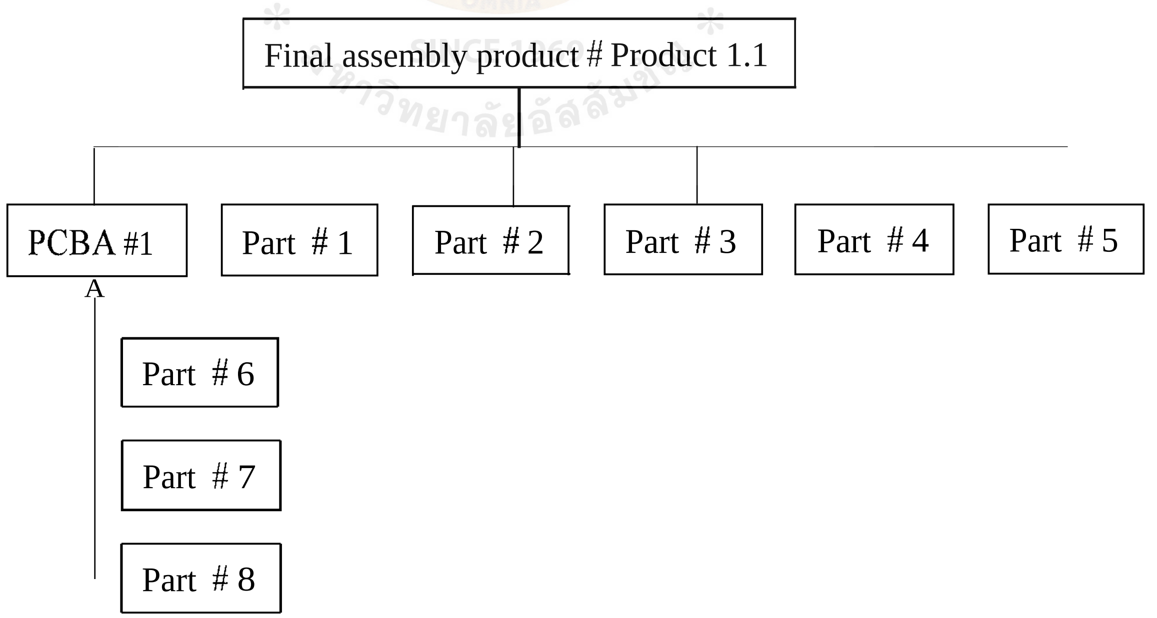


Figure 4.5 As-Is BOM structure

Figure 4.5 shows most of the models have individual BOM and consist of 2 levels. The 2^{nd} level is the PCBA (Print Circuit Board Assembly) is assembled into the 1^{st} level to be the final product. There is no semi assembly level. The final assembly product # Product 1.1 refer to PCBA # 1 to make items to produce in the SMT line and raw materials Part # 1 to 5 are direct items ordered from suppliers. PCBA # 1 refer to raw materials Part # 6, 7, 8 as direct items. When the demand of Product 1.1 into the Oracle system, it will calculate the quantity to order of raw materials of Part # 1 to Part # 8, and generate plan order for PCBA # 1, if there is no on-hand quantity available. This BOM structure can help the planner to creates work orders to the shop floor, and it will generate the material picking list to withdraw material from the inventory at the same time, to start production from the first process to the last process for final product.

4.1.6 HPU and Process Analysis

The detail of HPU has been analyzed following the work instruction of each process and the results are shown in Table 4.3. It can be explained that if we have 1 operator and start producing 1 units, it will take total 9.63 hours to complete every process starting from Process 1 to Process 15.

Table 4.3 HPU per process : Product group Al

Manufacturing process	**HPU (Hour per unit) to complete each process**
Process 1	0.17
Process 2	0.50
Process 3	0.68
Process 4	0.19
Process 5	0.19
Process 6	0.02
Process 7	0.08
Process 8	0.30
Process 9	0.22
Process 10	0.09
Process 11	0.74
Process 12	1.16
Process 13	3.04
Process 14	0.87
Process 15	1.40
Total HPU required	**9.63**

4.1.7 BOM Matrix

The BOM matrix table is shown in Table 4.4 to help identify common materials in each product group. For example from the matrix, it shows that raw materials Part # 9 is commonly used with all final Products 1.1 to Product 1.8, therefore it likely that for the material Part # 9 will be set in the Planning BOM if it is also used in the common semi-assembly.

Table 4.4 BOM matrix table

Material part number	Product 1.1	Product 1.2	Product 1.3	Product 1.4	Product 1.5	Product 1.6	Product 1.7	Product 1.8
Part # 1	1	1						
Part # 2	1	1						
Part # 3	1	1						
Part # 4		2						
Part # 5	1	1						
Pan # 6	1	1						
Part # 7	4							
Part # 8	2							
Part # 9	1	1	1	1	1	1	1	1
Part # 10	1	1	1	1	1	1	1	1
Part # 11								
Part # 12								
Part # 13								
Part # 14	1	1	1	1	1	1	1	1
Part # 15	1	1	1	1	1	1	1	1
Part # 16	1	1	1	1	1	1	1	1
Part # 17								
Part # 18								
Part # 19								
Part # 20								
Part # 21								
Part # 22	1	1	1	1	1	1	1	1
Part # 23	1	1						
Part # 24								
Part # 25	1		1	1	1	1	1	1
Part # 26					1			
Part # 27			2			2		
Part # 28	1	1		2			2	1
Part # 29								

4.1.8 Material lead time

Raw material lead time distribution is shown in Figure 4.6. This information will help to identify the procurement strategy when calculating the planning BOM. This is done by identifying a point of purchasing that postpones or delays a purchase of some materials that have short lead times and are unique. The orders are processed only when confirmation release order of final product is received. It can help to reduce the exposure on obsolete materials and help to reduce the holding cost of that material.

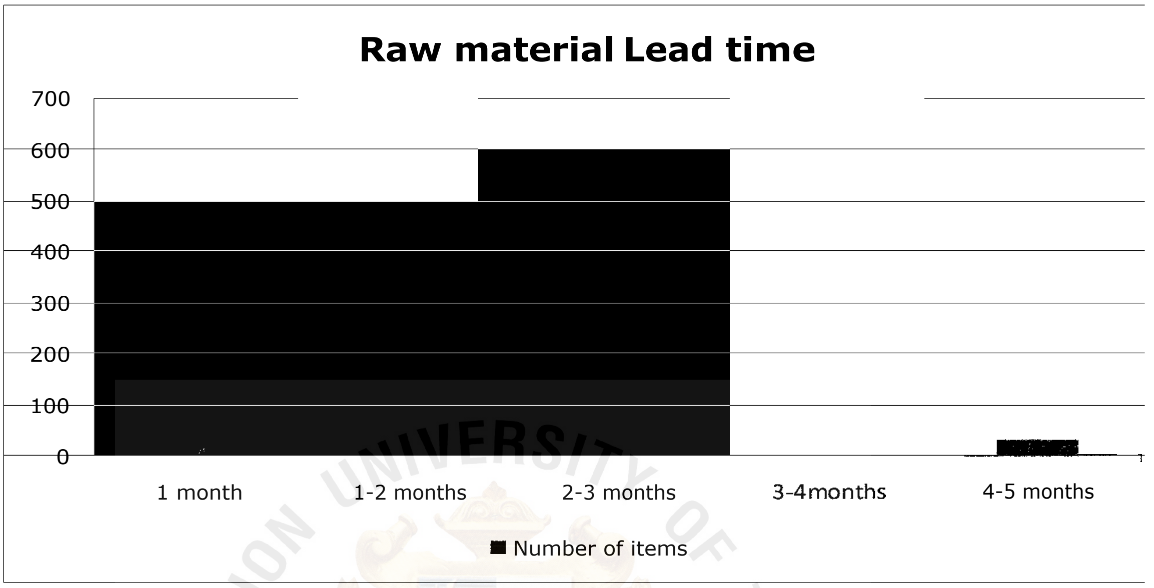


Figure 4.6 Raw material lead time distribution

4.1.9 Material ABC analysis

The ABC concept is derived from the Pareto's 80/20 rule curve. It is also known as the 80-20 concept (Svensson and Wood, 2006). The total Dollar value of each individual inventory item is calculated on quarterly consumption basis. Thus, applied in the context of inventory, it is a determination of the relative ratios between the number of items and the currency value of the items purchased / consumed on a repetitive basis.

The 10-20% of the items ('A' class) accounts for 70-80% of the consumption the next 15-25% ('B' class) account for 10-20% of the consumption and the balance 65-75% ('C' class) account for 5-10% of the consumption. Therefore, these are classified as high value (A), intermediary value (B), low value (C). It provides a sound basis on which to allocate funds and time A,B & C, all have a purchasing / storage policy - "A", most critically reviewed, "B" little less while "C" still less with greater results as shown in Figure 4.7.

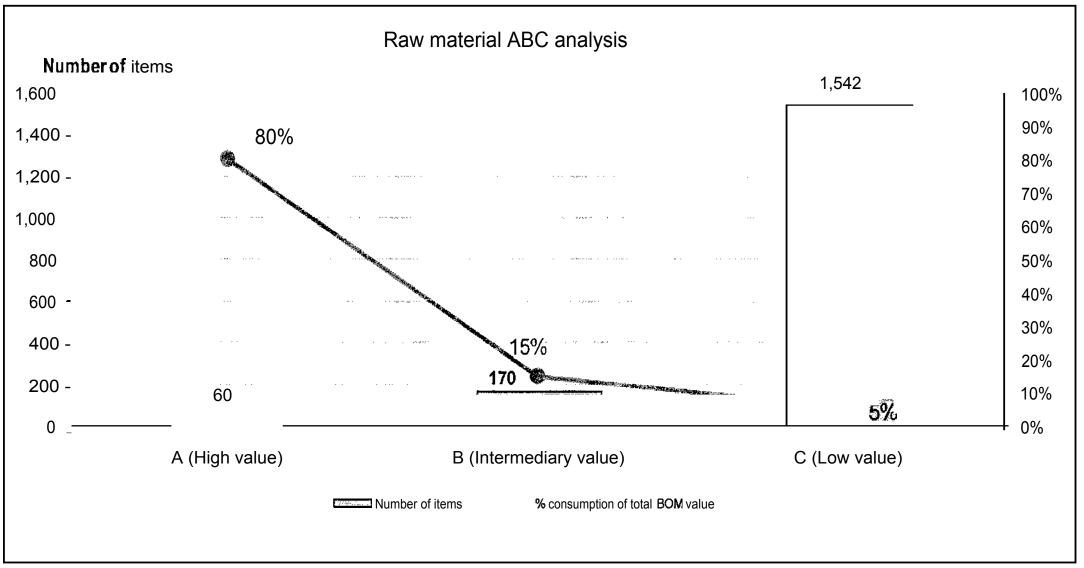


Figure 4.7 Raw material ABC Analysis

4.2 Identify where appropriate to apply postponement strategy

Postponement may correspond to details of certain attribute(s) not of the whole order. Generally, the logic behind the concept of postponement is:

(1) The overall demands (the number of aggregate items) are relatively easy to accurately forecast.

(2) Accurate information on demand for every product variation in every sales location (further details about other order attributes) is available in the delay period. In theory, the DP (Decoupling point) does not have to be the same point at which postponement is applied in theory (Van Hoek. 2000a). In addition, to correspond to several attributes of the demand, there might be several postponement points in the same supply chain.

After analyzing the As-Is data, the relationship between the raw material usage per BOM and the process is calculated. The planning BOM is created at this process on the points that have the most commonality of materials and processes, so the material preparation and the manufacturing can start to produce semi assembly during the period with idle capacity. In this research, the researcher will present the result in the 2 area of postponement strategy where it applies.

1.) Manufacturing postponement : Products in semi assembly forms which can be customized quickly in production facilities

2.) Purchasing postponement : Delay purchasing of unique item, and expensive parts that have short lead time.

4.2.1 Manufacturing postponement

After reviewing work instruction of the product and monitoring the actual process in the production line is identified the point where the process that makes the difference to the final product. The concept is the point of postponement in manufacturing process. Figure 4.8 shows the final process trees, the production start from process 1-5, which start producing the semi assemblies that can be produce parallelly. Process 7 is the testing and programming process which depends on the final product configurations. Process 6 is to produce another semi-assembly to assembly with the semi-assembly 1 and 2. Process 8, 11, 12 is the semi assembly process while process 9, 10 and 13 to 15 is the process that has different material usage and at this point process 13 will be determined as the point of postponement. Therefore, the real demand from actual orders received **will** drive the process and material at this point to upstream level.

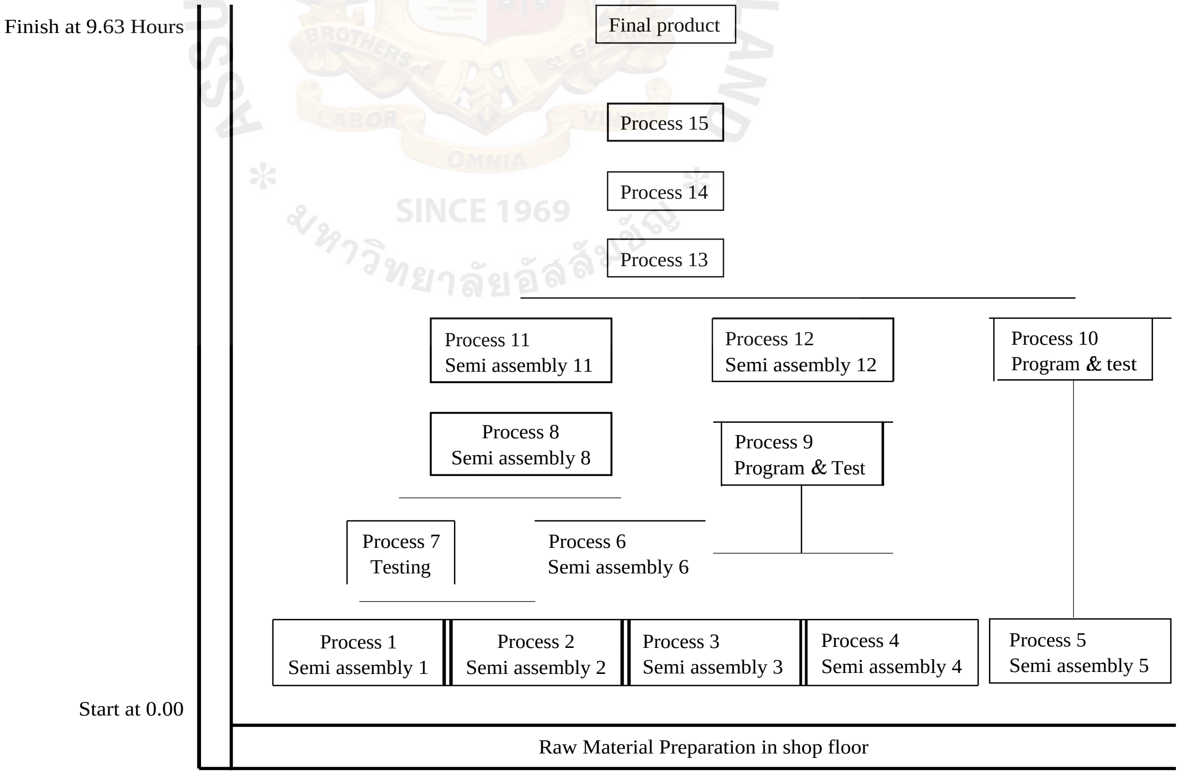


Figure 4.8 Process tree

4.2.2 Purchasing postponement

After defining and setting up a group of common processes and semi assembly, the semi assembly is combined and explored in detail of material used to identify the material in each group and find out if it is common use or unique to the final product. After identifying common materials, then it is classified into 4 groups which are Pull, Continuous replenishment, Push and Inventory Positioning which is related to the lead time of each material by using the push-pull strategy and by matching the lead time of the materials with the degree of demand uncertainty. In this case, this means the common materials will have lower demand uncertainty than the unique materials. ABC analysis also used to determine the purchasing strategy at this point. Figure 4.9 shows To-Be BOM structure when receiving the forecast from the customer to the Planner who will input the forecast quantity of the Semi assembly 1 to Semi assembly 6 and semi assembly 8, 11 and 12 to run MRP on the material Part # 1 to Part # 10 as 1st time procurement. When get the real PO released from customer the Planner will input the order qty of Final product to run MRP on the material Part # 11 to Part # 18 which is the 2nd procurement which means raw material Part# 11 to Part # 18 is delayed to order until receiving the real demand from the customer.

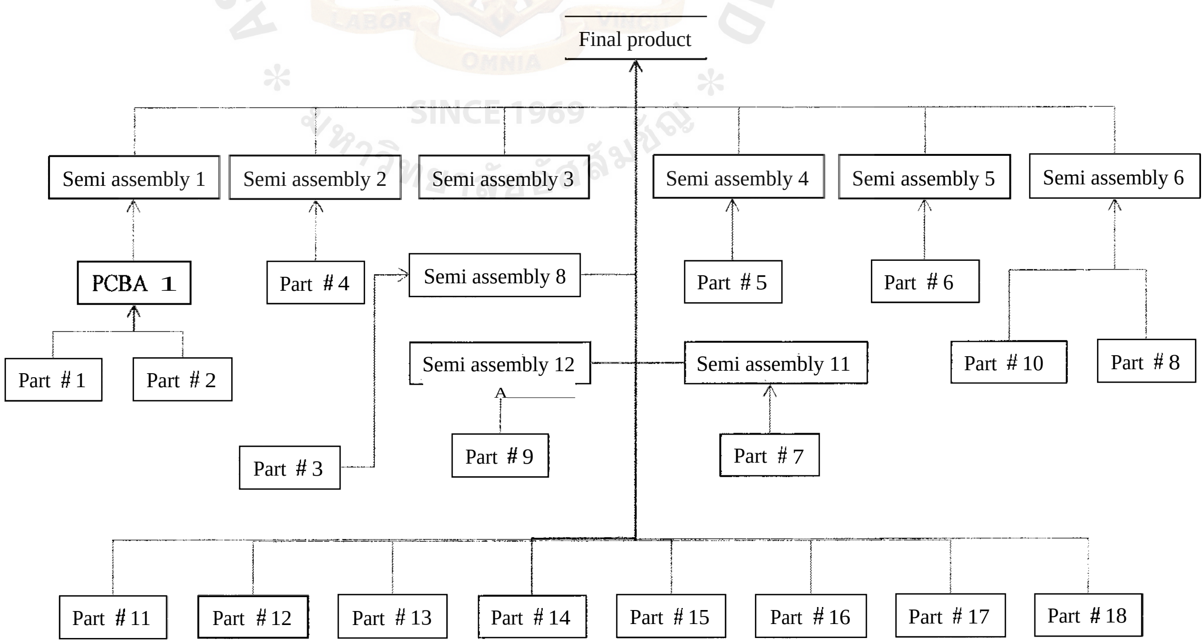


Figure 4.9 To-Be BOM structure

Table 4.5 shows the material attributes with the BOM details to define the part that can apply postponement purchasing activity until receiving the real demand driven.

The material attribute analysis by product group

Material part number	Lead time (week)	BC	m on	Where use	P nn'og BO	Product 1.1	Product 1.2	Product 1.3	Product 1.4	C od	Fio tc b	P o c 7	Product 1.8
Part 4t	1		Yes	Sub assembly 1	es	1	1			1	1	1	
Part# 14			e	Subassembl 1	Ye					1	1		
Part# 15			s	Subassembl 1	Y s					1	1		
Part 4t9	14	C)	es	Sub aosn by 1	Yes	1	1	1	1	1	1	1	
Part # 10	12	C)	es	Sub assembly 1	Yes	1	1	1	1	1	1	1	
Part # 1CO	1	C	s	Sub assembl 1				1	1	1			
Part # 2		C		Subassembl 1				1	1	1	1		
Part # 2			0	Process 12	0			2					
Part 4t2	co	C	0	Process 12	0								
Part 3t3	3	C	0	Process 12	0	1	1						
Part# 4	8	C)	0	Process 12	No		2						
Part 4t11	10	A	0	Process 13	0					2			
Part 7t		03	0	Process 13					2				
Part #			0	'Process 13	0								
Part 4tCO	8		0	Process 13	No								
Part 4t7	5	C)	0	Process 13	0	4							
Part 4tCO	2	C	0	Process 13	No	2							
Part# 17	t	A	0	Process 14	0			1					
Part # 1	2		0	Process 14	0					1			
Part 4t20			0	Process 14	0								
Part 4t21			0	Process 14	0								
Part 4t23	4	co	0	Process 14	0	1	1						
Part # 13	co	C)	0	Process 14	0			2					
Part 4t1CO	on.	C	0	Process 14	0				1				
Part 4t2CO	1	A	0	Process 15	No				1		1	1	
Part 4t24			0	Process 15	0							1	
Part 4t26		C)	0	Process 15	0								
Part 4t2CO	1	C	0	Process 15	No		1		2				1

4.3 Develop the new process

After analysis and identifying the point of postponement the new process through review and setting up of attributes to align with the process and semi assembly products is developed. Selecting one product group as the first group for pilot run and follow up the result is planned. This product group consists of product 1.1 to 1.8, where is the sales value of this product group contributing 60 % of total sales.

4.3.1 Manage Supply to meet Demand through Planning BOM

In order to drive the incoming material to match with the process and semi assembly defined the attribute in the MRP running which will be called "Planning BOM" is set up. It is the one type of feature in Oracle MRP system which can help to input the demand in the model number that sets up the attribute BOM Item Type as Planning. In the Planning BOM sets up what it needs to input other material attributes in order to drive the right material to come in the right time and right quantity. The key attribute to input such as purchasing lead time, manufacturing processing time and fix days supply to aggregate demand of C items and commonality part. Figure 4.10 shows the common process and common semi assembly in the boxes that are highlighted with gray color which are all processes of 1-6.

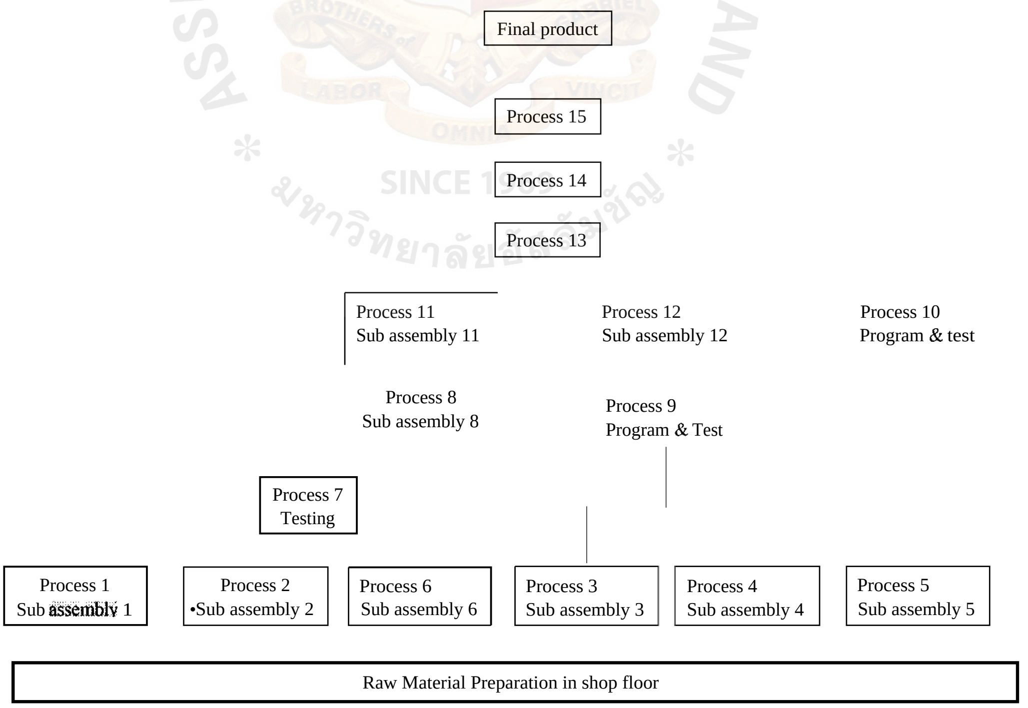


Figure 4.10 Define the process and sub assembly to be Planning BOM

Table 4.6 Identify on the part to apply purchasing postponement strategy

			Forecast quantity	10	20	5	40	70	45	25	30	245
Material part number	Lead time (week)	Where use	Planning BOM	Product 1.1	Product 1.2	Product 1.3	Product 1.4	Product 1.5	Product 1.6	Product 1.7	Product 1.8	
Part # 1	12	Sub assembly 1	Yes	1	1	1	1	1	1	1	1	Order through Planning BOM, Aggregate demand
Part # 14	12	Sub assembly 1	Yes	1	1	1	1	1	1	1	1	
Part # 15	7	Sub assembly 1	Yes	1	1	1	1	1	1	1	1	
Part # 9	14	Sub assembly 1	Yes	1	1	1	1	1	1	1	1	
Part # 10	12	Sub assembly 1	Yes	1	1	1	1	1	1	1	1	
Part # 16	10	Sub assembly 1	Yes	1	1	1	1	1	1	1	1	
Part # 22	7	Sub assembly 1	Yes	1	1	1	1	1	1	1	1	
Part # 27	7	Process 12	No			2			2			Purchasing postponement on the part that has short lead time
Part # 2	6	Process 12	No									
Part # 3	3	Process 12	No									
Part # 4	8	Process 12	No		2							
Part # 11	10	Process 13	No					2				
Part # 12	10	Process 13	No				2					
Part # 5	7	Process 13	No	1	1							
Part # 6	8	Process 13	No	1	1							
Part # 7	5	Process 13	No	4								
Part # 8	2	Process 13	No	2								
Pad # 17	4	Process 14	No			1						
Part # 19	24	Process 14	No									
Part # 20	10	Process 14	No						1			
Part # 21	4	Process 14	No									
Part # 23	4	Process 14	No	1								
Part # 13	6	Process 14	No			2						
Part # 18	3	Process 14	No				1					
Part # 25	1	Process 15	No	1		1	1	1	1	1	1	
Part # 24	1	Process 15	No							1		
Part #26	2	Process 15	No					1				
Part # 28	1	Process 15	No	1	t		2			2	1	

Table 4.6 shows the matrix of the Planning BOM and the final product BOM. Planning BOM will run MRP to drive the raw material by using the forecast but for the final product BOM will use the real demand from the firms order released to put it in MRP to drive for the short lead time items. The long lead time items on the others hand still need to use the forecast in order to get material otherwise it will affect in the long order fulfillment lead time.

4.3.2 Capacity Balancing

A simple capacity balance on the assembly operation was used to determine where the breakpoint occurred. The procedure entailed aggregating the demand for total hours require to build the final product by using the balance capacity from building final product to produce semi assembly products which is the sub set part of final product. As a guidance for this case study the balance capacity has been formulated for use in this case study which is as follows:

$$C_b = C_t - Cr$$

Where C_b = Balance capacity to build semi assembly

C_r = Total daily capacity per period of time

C_r= Reserved capacity for final assembly of product

Figure 4.11 shows the capacity allocation per day in one week. On day 1 total capacity per day is 140 hours, therefore the first priority of 100 hours will be planned to produce the final product while the balance 40 hours will be planned to produce the semi assembly. On day 2, 80 hours are reserved to produce final products, while 60 hours were planned to build semi assembly products. Up to day 6, all 140 hours have to be used in producing the final product so on this day operations cannot build semi assembly. The planning time fence is also needed for setting up smoothing production line. In this case study we set up one week frozen window which means during the current week the capacity plan for next week have to be generated and reflected on the delivery shipment to customers. Therefore, changes were allowed during next week with regard to order quantity or model. The planner will issue WO for production to withdraw the material in the current week to prepare for the next week production. In this situation it is not permitted to issue WO if any material shortage occurs in each WO.

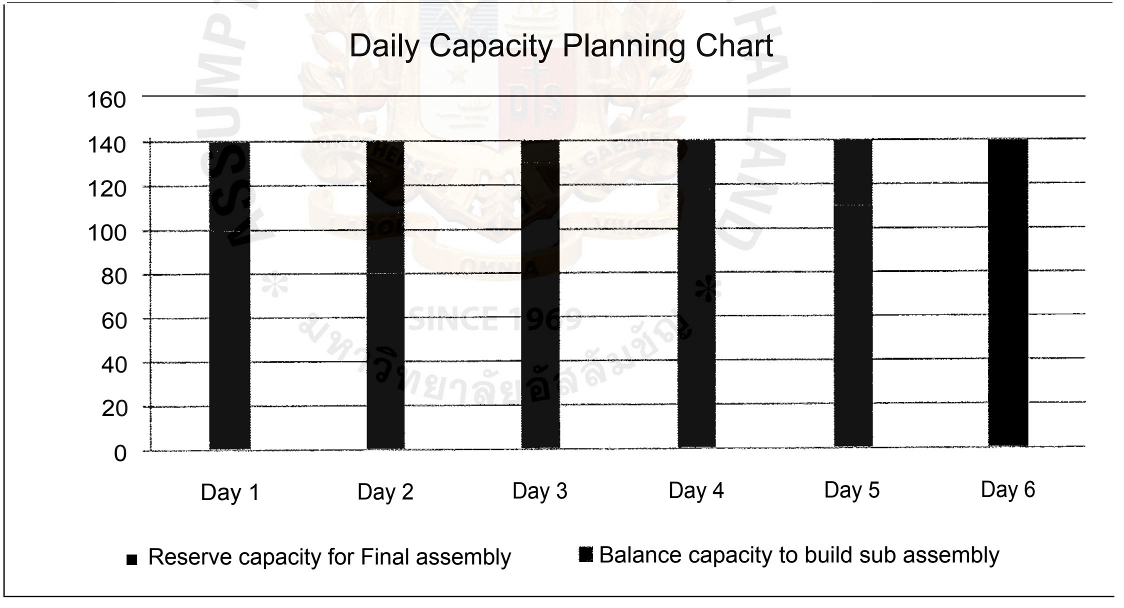


Figure 4.11 Daily capacity planning chart

4.3.3 Implementation

Successful implementation of any project requires effective change management within the organization. The method of initiating and conducting change needs to fit the company's strategic, political and cultural identity and work through key personal for the best results. Understanding the corporate organization with its strengths and weaknesses should drive strategic decision making and the mode of execution. Since to the researcher is a business unit manager, (September, 2009) the researcher performed the following steps for a period of 1 month which are as follows;

- Presented all data and send a proposal to the higher management (Operations Director) to get approval to this trial run.
- Communicated to customers on the product group selected to start a trail run. Explained what is the current BOM and what is the new BOM structure and the benefits of this implementation and how much order fulfillment lead time can be reduced with the risk associated in case there are changes in product design during the trial run. At this stage, it is very important to get customers approval since MED EQUIP is a contract manufacturing, thus any change in the manufacturing process must get the ECN (Engineering Change Notice) signed off before implementation.
- Presented all data and the problem analysis to the team. (Engineers, Planners, and Supervisors)
- Worked with IT and specified the cut off date data in Oracle to upload the new BOM structure into system.
- Recorded daily output and total hours used by work order. Shift start up daily meeting to follow up with the team.
- Presented the results and plans to extend this methodology to other product groups where applicable.

4.4 Analyze and compare between As-Is & To-Be

After the trial run period was completed the data was summarize and the key benefits of the postponement strategy on the manufacturing and purchasing was described as following;

4.4.1 Order Fulfillment Lead Time Reduction

The result from the trial run period is shown in Figure 4.12. It is significant that the order fulfillment lead time can be improved from 13.76 days to 8 days from the time firm receiving orders from customers which is 10 units based on HPU = 9.63.

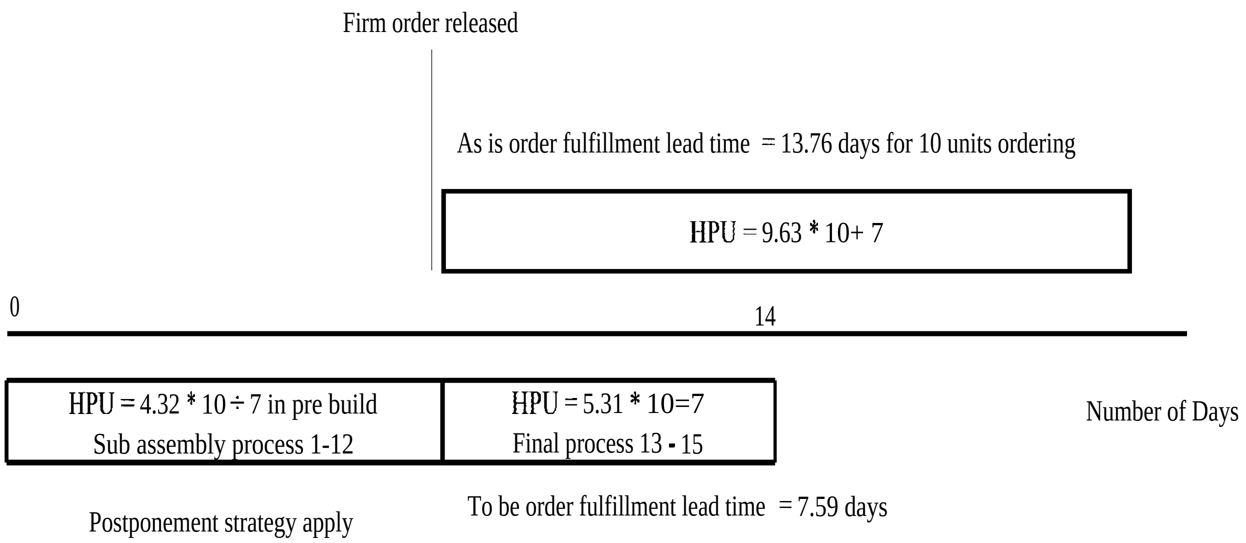


Figure 4.12 Order fulfillment lead time comparison As-Is and To Be

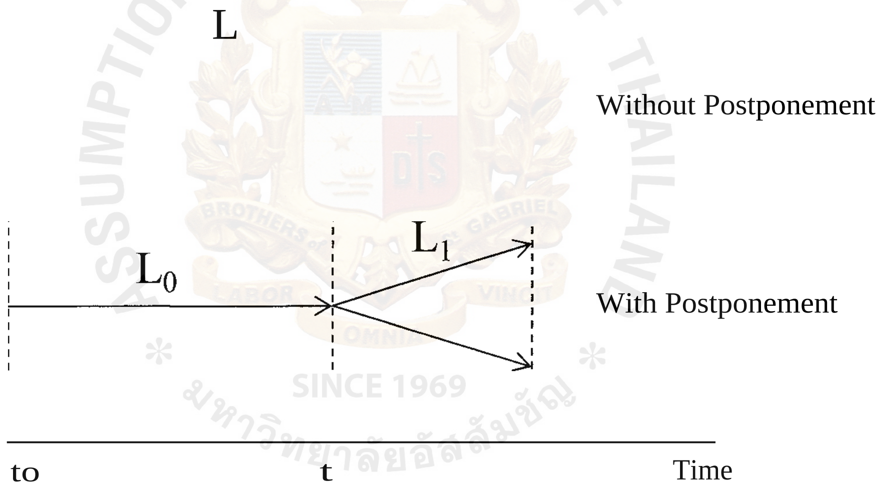


Figure 4.13 Overview of production process postponement. v.s. non-postponement

Figure 4.13 shows the overview on how order fulfillment lead time can be reduced by the application of manufacturing postponement. Without postponement, the products are different at the beginning of the entire production process. With postponement, the production process is separated into two stages: during the first stage, only those operations that are common to all end products are carried out, and product differentiation decisions are made at the beginning of the second stage. It is assumed that the total production lead time with and without postponement is the same. The second stage production lead time (in the postpone production setting) for the different final products are the same, and there is no capacity constraint for both the semi product and final product with and without postponement. Let L be the total production lead time, L_o and L1 be the stage one and stage two lead times with postponement (L = L1 + L2). Let to represent the point in time L periods before the demand realization time, and ti be the point in time L1 period before the demand realization time. Then under the above assumption it is optimal to make production decision at to without postponement and at time to and ti when postponement is implemented. So, the L1 will be used as the fulfillment lead time which explain as the reduction by (L1 ÷ L).

4.4.2 Better Labor Utilization

As show in the capacity planning method that $C_b = C_t - C_r$ therefore, the labor utilization will increasing up to the summary of the C_b when the $C_r < C$. and the C_b time can be eliminated. The idle capacity by produce semi assembly has added value for cost semi assembly rather than doing noting when there is no demand call out for final product in that period.

Table 4.7 shows the labor utilization and the labor cost spending comparison between using postponement strategy to reduce idle time and without using postponement strategy. In trial run the assumption will be as follows;

- The HPU = 7
- Total order quantity = 24
- Total earned hours = 7*24 = 168hours.
- No material shortage in any process to effect waiting time in production
- No machine down time in any process to effect in waiting time in production
- Fix 4 operators, and allow them to work overtime for 5 hours per day per operator.
- All 4 operators have the same multi skill level to meet the HPU of each process.

  On time shipment delivery performance measured by delivery in full quantity on each PO line item.
- There is no set up time in any process since most of the process is labor intensive.

Table 4.7 Labor utilization and Labor cost spending

			Postponement			Without Posteponement						
Working day	Customer order request (units)	Daily capacity (hours)	Reserved capacity for final assembly product	Balance capacity to build semi assembly	Shipment schedule	Idle capacity	Daily capacity (hours)	Overtime	Shipment schedule	Daily capacity (hours)	No Overtime	Shipment schedule
Day 1	2	28	14	14	2	14	28	0	2	28	0	2
Day 2	1	28	7	21	1	21	28	0	1	28	0	1
Day 3	2	28	14	14	2	14	28	0	2	28	0	2
Day 4	4	28	28	0	4	0	28	0	4	28	0	4
Day 5	7	28	49	-21	7	0	28	21	7	28	0	4
Day 6	8	28	56	-28	8	0	28	21	7	28	0	4
Day 7							7	0	1	28	0	4
Day 8										21	0	3
Total	24	168	168	0	24	49	175	42	24	217	0	24
Labor untilization					100%				77%			77%
Shipment delivery performance					100%				83%			67%
Labor cost normal hours					$ 168.00				$ 189.00			$ 217.00
Labor cost overtime hours					$ -				$ 60.00			$ -
Total labor cost					$ 168.00				$ 249.00			$ 217.00

Based on the assumption as stated before it can be seen that the result on the 100% labor utilization due to the idle capacity (hours) are utilized to produce sub-assembly product, while without postponement the labor utilization is 77% since there is idle capacity of 49 hours when the demand on that day is less than total hours available.

4.4.3 Labor cost

Table 4.7 also shows the result of the lower labor cost spent is $ 168 which effects higher utilization. This will result in the overhead cost reducing. Without postponement strategy, the company has to spend more in order to get the same output.

4.4.4 Shipment delivery performance

The result shows that in Table 4.7 when the shipment delivery performance applies production postponement strategy it is better. One key driver on this achievement is from the order fulfillment lead time reduction and the higher labor utilization.

4.4.5 Lowering obsolescence risk

Since there are groups of materials for which purchase orders can be delayed, until receiving confirm on order of the final product. The company can reduce the excess and obsolete material by not ordering this group of materials according to the forecast. In summary from this case study the business unit performance shows significant good result on higher labor utilization to a reduction of operations costs. The order fulfillment lead time has also been reduced while the shipment delivery performance is better through the application of postponement concept.

CHAPTER V

SUMMARY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

In this chapter the researcher will summarize the results of this project with the conclusions and recommendations for further study.

5.1 Summary of the Findings

Successful postponement implementation improves customer satisfaction while minimizing inventory costs. By improving the order fulfillment lead time, the medical business unit at MED EQUIP was better able to compete on time, while remaining cost competitive. This paper measures the labor utilization because better utilization will result in the lower labor cost. The summary of the key benefits in this research is given below;

- Order fulfillment lead time has significant improvement by 12.7% and from average 13.76 days to 7.59 days. By using manufacturing postponement framework to re-sequence the process to pre build semi assembly products the firm order release processing time will be shorter as we already have some stock in the semi sub assembly level.
- Improving labor utilization and operations cost results in overtime cost reduction from the capacity planning to utilization and help with idle capacity with the schedule to build sub-assembly. Operators have a full job working schedule each day. In the peak period overtime can be reduced due to the processing lead time reduction by counting from the point of finishing semi assembly to the point of final assembly product only. Table 5.1 shows the overtime reduce from 38% in Q3'09 to 25% in Q1'10 and labor utilization improvement significantly from 62% in Q3'09 to 74% in Q1'10.

Table 5.1 Labor utilization and Overtime percentage

	Q3'09	Q4'09	Jul,09	Aug,09	Sep,09	Q1'10
Total Earn hour required (A)	5993	6529	1894	3155	3589	8638
- Regular hour (B)	6006	6552	2912	2912	2912	8736
- Overtime hour (C)	3609	4361	407	1065	1432	2904
Total Attendance Hour (D)	9615	10913	3319	3977	4344	11640
Labor utilization (H) = (A) / (D)	62%	60%	57%	79%	83%	74%
% Overtime	38%	40%	12%	27%	33%	25%

- Enables better planning and allocation of resources by reducing the forecasting horizon by using the Planning BOM. The basic principle is that aggregated demand is more stable that disaggregated demand. Namely, forecast of aggregated demand is more accurate than that of disaggregated demand. Thus, a common semi assembly instead of various individual final assembly product in the same product family acts as master planning schedule in Planning BOM, The demand of the common semi assembly will represent the aggregated demand of all individual final assembly products and more accurate forecast can be made based on the demand of the semi assembly products. The configuration of customized demand is postponed to the time period that actual orders are received. In effect, by implementing postponement and commonality strategy, the push-pull boundary from the stage of assembly and testing to the stage of common semi assembly production can be changed and it leaves more demand uncertainty to the pull part of the system.
- The design and implementation of this strategy as the first stage is a complex task requiring an intimate understanding of the fundamental production planning process capability and product characteristics. This research develops a series of management tools derived from these principles to assist with an implementation in a complex, highly constrained system. Nonetheless, these tools alone are not sufficient for a successful implementation. Successful implementation requires a series of complementary proficiencies. These include, but are not limited to, systems level perspective, solid analytical skills, high level from customer buy-in and team support, effective leadership, and, most importantly, the ability to continually adapt and follow up the results.
- Shop floor supervisors are forced to micromanage both the production schedule and resource allocation. At the same time, operator utilization is considered a vital metric. When time is lost, it cannot be recovered by applying more resources. If this strategy is extended to every product family, it will require all operators to be trained and certified to have multi skills on every process.

5.2 Discussion of Results

Based on a case study of a business unit in MED EQUIP, this research has presented the approached to use postponement strategy for low volume high mix demand patterns.

First the study focused on production postponement and the results from the trial run period for one product group can help improve the labor utilization and reduce the operations cost by utilizing idle capacity in the low volume demand to pre build sub assembly units and also help to reduce the order fulfillment lead time. The Planning BOM has been created to drive the materials by using the BOM matrix table to identify the group of materials that are commonly used in the semi assembly levels since the demand of final product assembly is relatively stable and its future demand can be forecasted in terms of a certain demand on semi assembly level.

Based on the study, to consolidate the demand of all individual final product in a final product family, a common semi assembly is designed and act as a pre-build base product that can be further configured to customized final products according to customer's firm order demand Thus, the common semi assembly is produced based on aggregate forecast and customization of common semi assembly and postponed to the time when the actual firm order is received. Low volume high mix demand uncertainty therefore can be buffered by the safety stock of the common semi assembly instead of just keeping this safety stock in the form of individual materials.

The purchasing, postponement strategy approach is delayed to buy materials that are unique and for high demand uncertainty at the point when the actual demand is received, so it can help to reduce the material obsolescence and can lower the holding cost of total material stocks in the supply chain.

Clearly some level of inventory is necessary for an optimal process. Some of the rationale for holding inventory includes the following;

1. Inventory can be used to buffer against demand or process variability resulting in stable manufacturing shop floor operations and production outputs.

2. Customer or market conditions may require rapid order fulfillment. That, combined with manufacturing limitations, may necessitate holding inventory at some stage.
3. Inventory may be cheaper than capacity; therefore, a pre-build of inventory may be justified as opposed to providing adequate capacity to handle peak or seasonal demand.
4. The workforce size may be fixed due to unique skill requirement or labor regulations; therefore, during low demand periods rather than having idle time, production may be schedule in excess of actual demand resulting in a sub assembly inventory build. If labor is a significant part of cost of goods, a semi assembly build may be justified.

Finally, there is no single strategy for determining postponement potential that extends across all industries. The decision must be made at the product level according to specific metrics measuring demand, inventory costs, turnover, and lead time constraints. Different companies are better able to make a transition to a postponement strategy if their product is modular and they can see the benefits in total delivered cost instead of total unit cost. A truly robust framework of this nature is not possible without accurate and adequate data of product characteristics and data quantifying the costs and benefits of both successful and unsuccessful attempts at postponement.

5.3 Conclusions

In this research the researcher studied current parameters of operations processes such as assembly process and standard time, labor utilization, bill of materials which aim to improve order fulfillment performance and operating costs by using the postponement approach.

By studying the current parameters of operations, processes the researcher understands the product characteristics, the standard time, labor utilization and bill of material which are important. This is done to find the relationship of these parameters and identify the point of postponement.

The result from this case study after implementing one product groups shows that there is a significant improvement on order fulfillment lead time by 12.7% and the labor utilization increases from 60% to 74% which resulted in the overtime spending reduce from 40% to 25%. In summary at the step of review and analysis of current parameters is an important step to analysis whether the product and process characteristics are suitable for applying the postponement strategy or not. It may be argued that the more we can separate the common products or processes, the more upstream point of postponement strategy can be applied in the supply chain. This will reduce the demand uncertainty.

5.4 Recommendations for Further Research

It is highly recommended that this project be extended to other product families, by following the step-by-step analysis and execution explained in Chapter 4. However it is necessary to have more fully cross trained operators when not only leveling volume, but also to move around to where the work is for any particular product mix between the product family groups. The inventory analysis defines the group of common materials, by making use of the forecast of demand distribution of the common semi assembly products. Further analyzes of safety stock policy of the semi assembly to buffer demand uncertainty should be studied in detail. This is to apply the right strategy to manage these materials by considering the level of continuous replenishment which is the ROP (Re-order point), inventory positioning to satisfy the customer demand based on customer service level agreement. The EOQ (Economics Order Quantity) model analyzes and sets up the optimal order quantity of each material to minimize the total inventory cost.

This research is focused on the internal supply chain from raw material purchasing to finished good product delivery only. Further research should study the external supply chain at the supplier site by collaborating with supplier by using a postponement strategy aiming at delaying some supply chain activities until true customer demand is revealed in order to maintain both low cost and fast response for the customers.

BIBLIOGRAPHY

Achrol, R.S., (1991). Evolution of the marketing organization: new forms for turbulent environments. *Journal of Marketing,* Vol.55, 77— 93.

Alderson, W. (1950). Marketing efficiency and the principle of postponement, *Cost and Profit Outlook,* 3, 15-18.

Anderson, J.C., & Narus, J.A., (1995). Capturing the value of supplementary services. *Harvard Business Review of vol. 73,* 75-83.

Business Week. (2002). A Mass Market of One. December 2, 68-72.

Bowersox, D.J. and Closs, D.J. (1998). *Logistical management.• The Integrated Supply Chain Process.* McGraw-Hill : New York.

Brown, A., Lee, H. and Petrakian, R. (2000). Xilinx Improves Its Semiconductor Supply Chain Using Product and Process Postponement, *Interfaces of vol. 30,* 65 – 80.

Bucklin, L. P. (1965). Postponement, speculation and the structure of distribution Channels. *Journal of Marketing Research,* Vol. 2, 26 – 31.

Can, K. C. (2008). *Postponement, Mass Customization, Modularization and Customer Order Decoupling Point: Building the Model of Relationships.* Master Thesis, Department of Management and Engineering, Linkoping University.

Comstock, M. 2004. *Production Systems for Mass Customization: Bridging Theory and Practice,* Linkoping Studies in Science and Technology Dissertation No.894, Linkoping, Sweden.

Dröge, C.L., Germain, R.N., & Spears, N., (1995). Form postponement as a strategic initiative affecting organizational design. In: Proceedings of the American Marketing Association Summer Educators' Conference. Washington, DC, 3 Aug, 1995. pp. 263-269.

Feitzinger, E. and Lee, H.L. (1997). Mass customization at Hewlett-Packard: the Power of Postponement. *Harvard Business Review,* Vol. 75, 116 – 121.

Garg, A., and Tang, C.S., (1997). On postponement strategies for product families with multiple points of differentiation, *IIE Transactions,* Vol 29, 641— 650.

Gill H., Lopus M., & Camelon K.(2007). Overcoming Supply Chain Management

Challenges in a Very High Mix, Low Volume and Volatile Demand Manufacturing Environment. Retrieve July 15, 2007, from : http://www.fabrinet.com/white paper.html.

HlstroÈm,P. and Westbrook, R. (1999). Implications of mass customization for operations Management An exploratory survey *Journal of Operations & Production Management,* Vol. 19 No. 3, 262-274.

Jiang, K., Lee, H.L., & Seifert, R.W. (2004). *Satisfying Customer Preferences via Mass Customization and Mass Production.* Graduate School of Business, Stanford University.

Kahn, B.E., (1998). Dynamic relationships with customers: high-variety strategies. *Journal of the Academy of Marketing Science,* Vol. 26 (Winter), 45-53.

Kumar, A. (2004). Mass Customization: Metrics and Modularity. *The International Journal of Flexible Manufacturing Systems,* Vol. 16, 287 – 311.

Lee, T., and Ormrod, J. (2001). *Practical Research-Planning and Design.* Upper Saddle River, NJ, USA:Prentice-Hall, Inc.

Mahoney R.M. (2007). High-Mix, Low-Volume Manufacturing Paradigms. Retrieved August 7, 2007, from: http://www.holonyx.com/operations/holonics-3.pdf.

Morehouse, J.E., Bowersox, D.J., (1995). *Supply chain management, logistics for the future.* Food Marketing Institute, Washington, DC.

Pagendarm,S.M. (1991). *The Use of Strategic Inventory and Packaging Posponement to Address Daily Demand Variability and Seasonal Demand Patterns in a Demand Flow Environment.* Master Thesis, Massachusetts Institute of Technology.

Pagh, J.D., and Cooper, M.C., (1998). "Supply chain postponement and speculation strategies: how to choose the right strategy". *Journal of Business Logistics,* Vol 19 No.2, 13-34.

Rabinovich, E. and Evers, P.T. (2003). "Postponement Effects on Inventory Performance and the impact of Information Systerms", *The International Journal of Logistics Management,* Vol. 14 No. 1, 33 – 48.

Rietze, S.M. (2006). *Case Studies of Postponement in the Supply Chain.* B.S. Master Thesis, Massachusetts Institute of Technology.

Simchi-Levi, D., Kaminisky, P., & Simchi-Levi, E. (2008). *Designing and Managing the Supply Chain : Concepts, Strategies, and Case Studies.* New York : McGraw - Hill Irwin. 3rd edition.

Swaminathan,J.M., and Tayur, S.R. (1997). Managing design of assembly sequences for product lines that delay product differentiation.

Swaminathan,J.M., and Lee, H.L.(1995). Managing broader product lines through delayed differentiation using vanilla boxes. Graduate School of Industrial, Carnegie Mellon University, Pittsburgh.

Shen,T. (2005). *A Framework of Developing Postponement Strategies.* MIT Center for Transportation and Logistics working paper.

The Economist. (2001) Mass cutomisation - A long march. July 14th, pp 67-69.

Time. (2002) Have It Your Way. December 23, pp42-43.

Van Hoek, R.I. (2001). "The Rediscovery of Postponement: a Literature Review and Directions for Research", *Journal of Operations Management,* Vol 19, 161-184.

Williamson, K. (2000). Research methods for students and professionals. Wagga NSW : Centre for information studies.

Yang, B. and Burns, N. D. (2003). The Implications of Postponement for the Supply Chain. *International Journal of Production Research* of vol. 41, No 9, 2075 — 2090.

Yang, B., Burns, N. and Backhouse, C.J. (2004b). "Management of Uncertainty through Postponement". *International Journal of Production Research,* Vol. 42, No. 6, 1049 – 1064.

Xu, Z (2004). *Two approacheds to buffer management under demand uncertainty : An analytical process.* Master Thesis, Massachusetts Institute of Technology.

Zinn, W., (1990). " Developing heuristics to estimate the impact of postponement on safety stock". *The International Journal of Logistics Management of vol. 1, 11-16.*

Zinn, W. and Bowersox, D.J. (1988). "Planning Physical Distribution with the Principle of Postponement", *Journal of Business Logistics,* Vol. 9, 117-136.

Appendix A: List of Abbreviation

BU Business Unit

F/G Finish Goods

BOM Bill of Materials (BOM)

CM Contract Manufacturing

DL Direct Labor

ECM Electronic Contract Manufacturing

EOQ Economic Order Quantity

ERP Enterprise Resource Planning

FA First Article

FQ Fiscal Quarter

HPU Hour per Unit

IE Industrial Engineer

IT Information Technology

MDS Master Demand Scheduling

MRP Material Requirement Planning

MTO Make To Order

NPI New Product Introduction

OEMs Original Equipment Manufacturing

PO Purchase Order

ROP Re-Order Point

SCE Supply Chain Engineer

SKU Stock Keeping Unit

SMT Surface Mount Technology

SQE Supplier Quality Engineer

WIP Work In Process

WO Work Order