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THE DEVELOPMENT OF SHOP FLOOR MANAGEMENT SYSTEM IN LUBRICATING OIL MANUFACTURING INDUSTRY

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A Thesis Submitted in Partial Fulfillment of the Requirements
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คณิน แก้วอินทร์ : การพัฒนาระบบจัดการพื้นที่ผลิตในอุตสาหกรรมการผลิตน้ำมันหล่อลื่น. (THE DEVELOPMENT OF SHOP FLOOR MANAGEMENT SYSTEM IN LUBRICATING OIL MANUFACTURING INDUSTRY) อ. ที่ปรึกษา : รองศาสตราจารย์ ปารเมศ ชุติมา, 115 หน้า.

วิทยานิพนธ์ฉบับนี้มุ่งเน้นที่จะแก้ปัญหาการส่งสินค้าล่าช้าในโรงงานตัวอย่าง ซึ่งมีลักษณะการผลิตสินค้าแบบตามสั่ง (Make-To-Order) โดยได้นำเสนอแบบจำลอง ลีนและการปรับรื้อกระบวนการทางธุรกิจ (Lean & Business Process Reengineering) เพื่อประยุกต์ใช้ในการจัดการพื้นที่ผลิตอย่างมีประสิทธิภาพ แบบจำลองถูกพัฒนาขึ้นจากหลักการของการผลิตแบบลีน (Lean Production) และการประยุกต์ใช้การปรับรื้อกระบวนการทางธุรกิจในอุตสาหกรรมต่างๆ ซึ่งได้ศึกษางานวิจัยที่ผ่านมา แบบจำลองมี 4 องค์ประกอบต่างๆคือ ทีมงานที่มีบุคคลมาจากหลายหน่วย (Cross-Functional Team) การพัฒนาอย่างต่อเนื่อง (Continuous Improvement) การผลิตแบบตรงเวลา (JIT Production) และการสร้างเครือข่ายกับซัพพลายเออร์ (Supplier Integration) งานวิจัยนี้เริ่มตั้งแต่ การระบุกระบวนการ การวิเคราะห์กระบวนการ การประยุกต์ใช้แบบจำลองมาสร้างระบบ และการวัดผลที่เกิดขึ้นจากการประยุกต์ใช้แบบจำลอง

จากการที่ระบบจัดการพื้นที่ผลิตถูกพัฒนาขึ้นตามแนวทางของการผลิตแบบลีน (Lean Production) และได้นำไปประยุกต์ใช้ในโรงงานตัวอย่าง ผลการดำเนินงานพัฒนาระบบจัดการพื้นที่ผลิตพบว่า มีการลดลงของร้อยละของการส่งสินค้าสาย (ลดลง 95.24%) ร้อยละของการผลิตซ้ำ (ลดลง 96.73%) จำนวนของการทำงานล่วงเวลา (ลดลง 95.06%) และมีการเพิ่มขึ้นของอัตราหมุนเวียนของสินค้าคงคลัง (เพิ่มขึ้น 37.76%) และการใช้ประโยชน์ของคนงาน (เพิ่มขึ้น 68.14%) แบบจำลองลีนและการปรับรื้อกระบวนการทางธุรกิจได้พิสูจน์ให้เห็นว่าเป็นอีกหนึ่งแนวทางที่มีประสิทธิภาพ ในการจัดการกับปัญหาที่เกิดขึ้นในพื้นที่ผลิต ในโรงงานที่มีลักษณะการผลิตสินค้าแบบตามสั่ง และยังสามารถเพิ่มความคล่องตัวในการตอบสนองต่อความต้องการที่ไม่แน่นอนของลูกค้า

ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต	ลายมือชื่อนิสิต................................
สาขาวิชาการจัดการทางวิศวกรรม	ลายมือชื่ออาจารย์ที่ปรึกษา................................
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4871657921 : MAJOR ENGINEERING MANAGEMENT
KEY WORD: LEAN PRODUCTION / MAKE-TO-ORDER MANUFACTURING / SMALL TO MEDIUM-SIZED ENTERPRISE / OPERATIONS MANAGEMENT / CONTINUOUS IMPROVEMENT

KANIN KAEWIN : THE DEVELOPMENT OF SHOP FLOOR MANAGEMENT SYSTEM IN LUBRICATING OIL MANUFACTURING INDUSTRY. THESIS ADVISOR : ASSOCIATE PROFESSOR PARAMES CHUTIMA, 115 pp.

Manufacturers across many sectors increasingly operate in make-to-order (MTO) environment which has a negative impact on performance. This paper aims to present lean & business process reengineering (BPR) model for effective shop floor management, with the flexibility to position the organisation in MTO environment. Lean & BPR model combines the most common lean production with BPR principles found in the literature. Four elements of the model which contribute to improve the company's performance are cross-functional team, continuous improvement (kaizen), JIT production and supplier integration. The four phases of the model include identifying, analysing, implementing and evaluating.

The new shop floor management system which was developed according to lean production principles was implemented in a case study company. Case results show significant decreases in the amount of drum delivery delays (94.25% decrease), reworks (96.73% decrease), overtime (95.06% decrease), as well as increases in inventory turnover rate (37.76% increase) and labour utilisation (68.14% increase). Lean & BPR model provides a comprehensive solution to a complex shop floor management problem in MTO environment where the company has to be able to respond to dynamically changing market conditions.

Regional Centre for Manufacturing Systems Engineering
Field of study Engineering Management
Academic year 2007

Student's signature..........................
Advisor's signature..........................

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This thesis would not have been possible without the kind support, the trenchant critiques, the probing questions, and the remarkable patience of my thesis advisor – Associate Professor Parames Chutima. Through his Socratic questioning, Associate Professor Chutima brought me closer to the reality I had initially perceived, eventually enabling me to grasp its rich complexity. His comments on chapter drafts are themselves a course in critical thought upon which I will always draw. His capacity to combine critique with an immediate empathy and commitment towards workers and others engaged in struggle will always inspire me. This study drew upon the knowledge and experience of managers, labour activists, engineers and other employees in the case study company, particularly metalworking lubricants section (MLS). Although too numerous to name, they are appreciated for their individual contributions. This research benefited particularly from the receptivity of workers, who shared their recent history with me in a variety of settings. Many thanks to all, especially general manager and plant manager who always remember to bring me news of everyone. Special thanks to Professor Sirichan Thongprasert for persuading me to pursue a postgraduate study and providing valuable feedback at both the initial and closing moments of this thesis. In addition, I remain indebted to my parents, family members in Bangkok, teachers and professors for providing me the means to learn and understand.

And now, the customary disclaimer: I take responsibility for the original insights, if any, of the thesis. These insights are a result of my decent intelligence and creative abilities. I am also responsible for the remaining portions of the thesis, which may seem intellectually unwarranted, mistaken, and incorrect – feces elements of the thesis, if you will, Highest Honours notwithstanding. These are a result of my limited understanding – incomplete digestion of the relevant concepts and literature on my part – and unjustifiable tardiness.

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CHAPTER I
INTRODUCTION

1.1 General Background

In recent years, the growing complexity of industrial manufacturing and the need for higher efficiency, shortened product life cycle, greater satisfactory of customer's expectation's, and lower cost have changed the face of manufacturing practice. A great challenge for today's companies is not only how to adapt to this changing business environment but also how to draw a competitive advantage from a means of which they choose to do so (Metaxiotis et al., 2002) As a basis to achieve such advantages, any company needs to become more responsive, customised and be able to meet the increasingly demanding customer requirements. In the lubricating oil manufacturing industry, many companies are facing a dilemma. On the one hand, customers are demanding that their orders to be fulfilled ever more quickly. On the other hand, they are demanding highly customised products and services. Manufacturing firms which mainly make customised products, competing for each order with other supplier companies on the basis of price, technical expertise, delivery time and reliability in meeting due dates are usually labelled as "versatile manufacturing companies" (Persona et al., 2004). This sector consists of those companies that manufacture high variety products in relatively low volumes and includes engineering-to-order (ETO) and make-to-order (MTO) companies, as they typically do not hold finished good inventory, being very difficult to predict customer requirements and specifications. After the customer order is received, the company is responsible for design and manufacturing activities according to the customer needs and requirements as stated in the sales order. Besides that, delivery, consultancy as well as after-sales services appear to be the norm for this type of company. Furthermore, this environment caters for sophisticated products that have different types and each product type has a small quantity order size. In such a context, each product is quite unique in terms of specification, manufacturing and technological requirements and precedence constraints. Consequently, the lead time required to complete all the types of job is high and routings processing times are highly uncertainty. Such uncertainty, added to that associated with customer orders, makes the production planning, management and control become a very difficult task. Since traditional, centralised manufacturing planning and control mechanisms were found insufficiently flexible to respond to the new situation of current competition, many manufacturing companies thus decided to adopt intelligent solutions. In fact, while large companies are capable of investing huge amounts of capital, manpower and time to modernise their information management systems, SMEs are constrained by limited resources to improve their technology. Hence, there is an increasing need for specific "tools" for small companies which have limited budgets and are looking for proper systems to integrate various activities related to the order to delivery cycle through robust information management and decision support systems.

1.2 Problem Statement

In the past years, the case study company has faced a growing number of customer complaints which can be classified in two aspects: lateness in delivery and quality problems. Figure 1.1 represents the proportion of the customer complaints during the period November 2005 to October 2006.

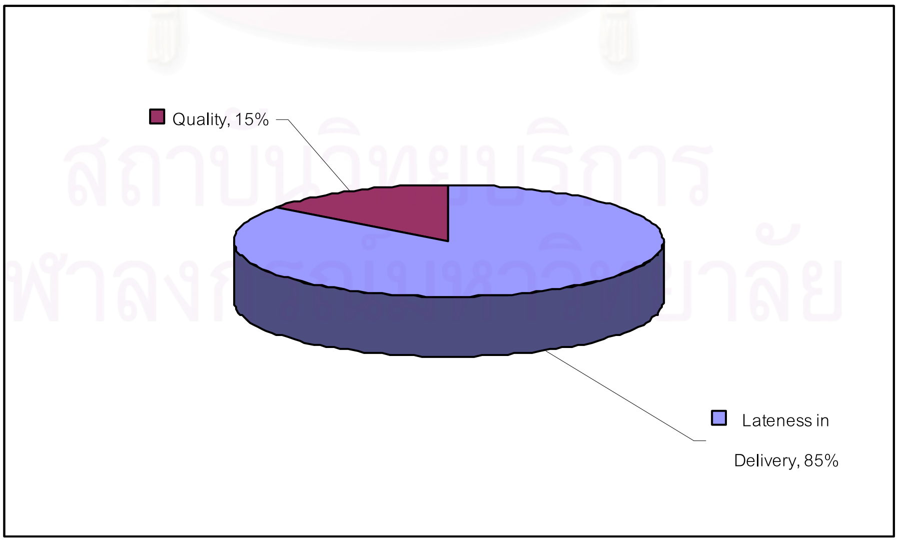

Figure 1.1 Pie chart shows the proportion of the customer complaints

From Figure 1.1, it was found that approx 85% of customer complaints were the case of the lateness in delivery. Table 1.1 represents the number of customer complaints during the period November 2005 to October 2006.

Table 1.1: The number of customer complaints

Month	Total number of Complaint	Lateness in Delivery	Quality
Nov-05	18	15	3
Dec-05	18	15	3
Jan-06	19	17	2
Feb-06	18	16	2
Mar-06	19	16	3
Apr-06	21	17	4
May-06	20	17	3
Jun-06	20	17	3
Jul-06	22	18	4
Aug-06	21	19	2
Sep-06	19	16	3
Oct-06	17	15	2
Total	**232**	**198**	**34**

Nevertheless, it was found that all customer complaints came from metalworking lubricants section (MLS). This section is one part of the case study factory and it was formed so as to produce products under company's own brand. Furthermore, a full make-to-order policy with guaranteed delivery dates and lead times has been applied to meet the gap in the marketplace. Hence, it would seem that the case study company has to deal with high variety, low volume (HVLV) environment. A common feature of MTO shops is that production takes place only on receipt of customer orders and the MTO production is typically in an exclusively job shop environment (Yeh, 2000).

In the make-to-order situation, production planning & control is complex because of the number of variables involved. There is often a high level of variability with respect to the routeings and processing times. It is thus difficult to predict how the work will be distributed among machine groups in the factory at any point in time (Babu, 1999). However, after pre-assessment was conducted, problems were classified into 5 major aspects as the following: order management; production planning, management & control; transportation management; and uncertainties.

Order Management

Indeed, this process has a major impact on the possibility of the firm securing the order because firms must maintain their promised lead times to remain competitive (Persona et al., 2004). It is thus important that any companies must be able to promise reliable delivery dates. For metalworking lubricant products, it is a company policy that customers can have their goods within five days after the orders have been placed. In general, the decision is usually made on the receipt of customer order, but it may be set by the customer and the salesman which no relation to the required processing time, availability of production capacity, and availability of resources. In this case, the salespersons may set due dates shorter than five days so as to satisfy their customers. It was found that the company however could not meet the committed due dates, and consequently it has lost those potential customers. It is therefore noted that lack of effective order management has led to the lateness in delivery.

Production Planning, Management & Control

Manufacturing firms which deal with products that are made-to-order, fall under the category of intermittent production systems that are geared to produce in batches or small lots (Babu, 1999). Although materials may be purchased and production is planned, manufacturing activities begin only after the customer order is received (Porter et al., 1999). Therefore, these firms typically do not hold finished goods inventory. In the general competitive situation, a company responds to customers' enquiries with price and delivery date even though sometimes either may be fixed by the customer. The values chosen for these two parameters clearly have a major impact on the chance of the firm securing the order. In the case study factory, there are two batches in each day (morning and afternoon) and two persons are responsible for the production. As mentioned earlier, manufacturing activities start when the invoice has been received and the sequencing of jobs used in the factory is First In, First Out (FIFO) which means what comes in first is handled first, what comes in next waits until the first is finished, etc. Nevertheless, it was proved that the sequencing of jobs was not so effective because there appears to be an increasing number of tardy jobs in the production lines which has led to the lateness in delivery. As a matter of fact, enquiries do not arrive in order of importance, it would be therefore necessary to re-schedule all the jobs each time when a high priority job arrives. As previously discussed, the company has used FIFO method for sequencing. It would seem that this method caused unacceptable delays to other jobs which lead to the job tardiness. From the pre-assessment, it was found that there has been no standard of performance for the activities being carried out in the manufacturing processes. As there has been no standard time for each process, it is therefore difficult to estimate any processing times. Consequently, the company will never know when a job is completed.

Transportation Management

Typically, make-to-order companies have a few standard products. They tender a quotation including the price and delivery lead time for a particular job in response to a customer's enquiry. Hence, if they are to maintain competitive, they must maintain their promised lead times (Babu, 1999). Indeed, there are sufficient resources for products delivery. Nonetheless, in case that the ordered volume is small (less than 1,000 litres) and the customer is not located in the delivery route of that day, the delivery may be slightly delayed because of uneconomical transportation costs. However, to solve the problem, the company has recently discussed with its customers about the possibility for paying an extra charge in this case.

Uncertainties

It has been generally agreed that the planned or expected performance of production units often deviates from the actual performance. In the make-to-order situation, the finite nature of the manufacturing resources creates in evitable conflicts of delivery priorities, which are made even more difficult by machine breakdowns, labour absenteeism, delays in the delivery of materials and components etc. (Babu, 1999). On the shop floor, there have been many disturbances that affect the manufacturing performance. Stoop and Wiers (1996) divided these disturbances into three categories: disturbances regarding the capacity (machine breakdowns, illness of operators, and unavailability of tools); disturbance related to orders (unavailability of materials and drawings, fulfilment of sequencing rules, extra orders caused by scrap or rework, and rush orders); and disturbances related to the measurement of data (differences between pre-calculated and actual processing time, and capacity efficiencies). In the case study factory, it has been recognised that uncertainties such as added job, cancelled job, increased order, decreased order, material shortage, worker absent, shift due date forward and shift due date backward occur at any times and there is no certain solution to approach these uncertainties. It could be therefore noted that the lateness in delivery may be a result of uncertainties which occur during the operations.

To give customers a responsive service and ensure a reliable delivery date for customer orders, MTO production requires detailed, realistic, and flexible operational plans, along with a control mechanism for easy track of production status of customer orders (Yeh, 2000). As a result, there is a need to develop production planning approaches designed specifically for MTO production. It is therefore vital to develop a customer-focused approach to effective planning of MTO production for accommodating varying needs of individual customer orders. This approach will be developed particularly for the jobbing production environment where small orders are placed by a wide variety of customers.

1.3 Research Objectives

1. To improve the effectiveness of shop floor management system for metalworking lubricant products

2. To introduce the new system model in order to decrease level of the lateness in delivery

3. To be a pilot project for further development for the engineering business unit

1.4 Scope of the Research

This research focuses on the order to delivery cycle of metalworking lubricant products.

1.5 Expected Benefits

It is expected that the development of the new shop floor management system would help the company achieve many of the following aspects.

1. meet customer due dates

2. minimise job lateness, response time, cycle time, overtime and other unplanned costs

3. reduce inventory

4. maximise machine and labour utilisation

1.6 Research Approach

In order to tackle the research objectives, the study has been carried out in seven steps as the following.

1. Study the related materials and the characteristics of the order to delivery cycle management in the case study factory

2. Analyse and summarise the significant problems that have led to the lateness in delivery

3. Conduct the work study of each process and set up standards of performance for the activities being carried out

4. Develop a new shop floor management system which can be particularly suitable for the case study factory needs

5. Implement the new system and evaluate the performance

6. Analyse, discuss and summarise the results and make the suggestion for further improvement

7. Write the thesis report and prepare for thesis presentation

CHAPTER II
LITERATURE REVIEW

Literature review was conducted to capture the main idea (i.e. problems, approaches and solutions) from previous researches on the order to delivery cycle management in the versatile manufacturing (VM) context.

Achanga et al. (2006)

The aim of this research paper is to present the critical factors that constitute a successful implementation of lean manufacturing within manufacturing SMEs. Several critical factors that determine the success of implementing the concept of lean manufacturing within SMEs are identified.

Amaro et al. (1999)

This research presents a new taxonomy for the non make-to-stock sector to enable a like-with-like comparison, arguing that existing taxonomies within the literature are inadequate for strategic research purposes. It also presents empirical evidence which has been collected from 22 companies in three European countries: the UK, Denmark and The Netherlands. The data support the structure of the proposed new taxonomy and provide insights into competitive advantage and customisation issues in the non make-to-stock sector. In this research, two new labels for this sector of industry are proposed. “Versatile manufacturing company” is used to describe those manufacturers which are involved in a competitive bidding situation for every order which they receive, customisation by individual order. In contrast, the “Repeat business customiser” may only be in this position for the first of a series of similar orders from a particular customer, customisation by contract.

Appelqvist and Lehtonen (2005)

This paper presents a successful application of simulation for schedule validation in a complex and demanding environment. Nevertheless, an approach is presented where only the main constraints are included in the scheduling algorithm. The schedule is thus validated using a discrete-event simulation model that includes additional detail. In doing this research, the combined approach is utilised for production scheduling in a steel mill in Finland and consequently the case implementation was a success that increased production without making trade-offs with other production goals.

Armistead et al. (1995)

This purpose of this article is to examine the concepts and techniques of the field which might have application for BPR.

Armistead and Machin (1997)

This paper introduces the concepts of business processes and business process management, and reports findings from interviews in four organisations which are continuing to develop their approaches to managing processes.

Arnheiter and Maleyeff (2005)

The purpose of this research is to eliminate many misconceptions regarding Six Sigma and lean management by describing each system and the key concepts and techniques that underlie their implementation.

Ashayeri and Selen (2005)

The authors provide a unified approach for effective capacity management, with the flexibility to position the organization across differing market-orientations, anywhere from produce-to-stock to purchase-and-produce-to-order. This unified planning system combines capacity management with the external market through the customer order decoupling point (CODP). The approach starts by determining the CODP, using commonality and effect-cause-effect analysis. The resulting CODP information is then used to determine the optimal master production schedule (medium-term), as well as the detailed schedule (short-term) at the bottleneck resource, using mathematical programming; to support decisions across different planning horizons in an integrated fashion. In this research, this unified approach was applied to an electronics manufacturing company in the Netherlands. Findings show that the structured unified approach provides a comprehensive solution to a complex capacity management problem, in competitive environments where organizations have to be able to respond to dynamically changing market conditions, given the process choices within which they are operating.

Babu (1999)

This paper relates to make-to-order (MTO) manufacturing environment. Initially, the various issues of concern and problems encountered in relation to typical MTO systems are presented to emphasize why agility is required in such systems. The need to have better performance measures is discussed. How some of the problems related to typical MTO systems were dealt with in the past is discussed, by highlighting the salient features of some selected contributions made towards enhancing agility in MTO systems. However, an outline of the system presently being developed by the author for concurrent and integrated management of MTO manufacturing organisations, which is conceived mainly as an agile management system for MTO environment, is also presented.

Bramham et al. (2005)

This paper presents case analysis of the quotation processes from manufacturers operating in high-variety environments. Qualitative process modelling tools have been developed to allow representation of process complexities and informal process elements. The generic model developed by this research offers insight into the functioning of the core process elements of the quotation system. Reviewing an organisation's structure and the information systems infrastructure supporting these decision centres should lead to the identification of potential system or reorganisation improvements.

Buxey (2005)

The paper reports on the ramifications for production planning when monthly sales exhibit predictable seasonal highs and lows. The literature first acknowledged and dealt with the (aggregate planning) problem 50 years ago. Nevertheless, there is neither evidence that industry has adopted any of the mathematical techniques that were subsequently developed, nor a convincing explanation as to why not. Hence this research sets out to discover the methods manufacturers use to cope with seasonal demand, and how germane the published algorithms really are. In doing this research, forty-two case studies were compiled by interviewing senior managers and then conducting plant tours. Nonetheless, no prior assumptions were made and the list of questions covered the gamut of production planning. The main finding is that manufacturers select a straightforward production strategy, right from the outset, so the fundamental cost-balancing format is not relevant. The majority pick a "chase" strategy, since most organizations subscribe to a "just in time" ethos. Whenever a different strategy is preferred the rationale springs from skilled labour considerations or binding facilities constraints.

Davis and Kanet (1997)

This project developed an interactive computer graphics approach to construction and modification of schedules for a work centre. The system handles problems involving sequence-dependent setup times for products of the work centre and penalties for both early and late completion of jobs. A schedule of jobs is displayed as a Gantt chart. Jobs appear as colour-coded bars whose lengths represent setup and processing times. The user can manually revise a schedule by "drag and drop" manipulation of the job icons and can invoke built-in routines to automatically reschedule. The system displays a number of quality measures and other schedule implications to aid the user in evaluating schedules.

De Toni and Tonchia (1996)

In this article, the authors show that the pursuit of excellence and the organisational change required by lean production leads to a management-by-process organisation, and that management by process influences the performance measurement system (PMS). The study provides a detailed analysis of the organisational change and its effects on performance measurement.

De Toni and Tonchia (2001)

This research presented results of a survey conducted in 115 medium and large sized Italian manufacturing firms operating in three main industries. Principal components analysis was carried out with the aim of describing the dimensions and the actual state of these systems. The majority of performance measurement systems (PMS) models are of the “frustum” type: the traditional cost performances (the production costs and the productivity) are kept separate from the more innovative non-cost measures (quality, time and flexibility). To make the most of the potentialities of these systems, formalisation and integration with other firm systems are of prime importance, while greater space should be given to the consideration of human resources.

Emiliani (2000)

This paper utilises the principles and tools of lean production to decode the CEO’s mandate and deliver practical, solutions-oriented tools to employees to help achieve stretch business goals. This creates an effective bridge between the language of the CEO and engineering, manufacturing, purchasing, quality, and finance functions.

Fowler (1998)

This paper has argued that systems-thinking and continuous-system simulation potentially provides a highly illuminating framework within which to implement major change initiatives such as BPR. A number of operations oriented models have been presented as a potential basis for this approach and it has been suggested that important advantages can accrue, at several levels, by developing theses as a perceptional framework.

Gargouri et al. (2002)

This paper identifies and characterises specificities of agro-food production systems. The authors focus on the features which represent hard constraints that must be met by the scheduling problem. Thus synchronisation with the stock state must be integrated. Next, they suggest a real time scheduling approach based on some preference and priority rules that allow them to take into account the majority of constraints and to consider the unforeseen events that can eventually occur. The two main objectives of the generated scheduling are the minimisation of the cost of expired products and the minimisation of the time interval between the finishing date and the expedition date in order to handle storage cost and avoid the discount imposed by the distribution sector.

Grunberg (2003)

In this paper, a number of improvement methods, together with their aims and implementation processes, are discussed. Furthermore, a performance factor model and a measurement model designed to fill the gap in literature are desbribed.

Gunasekaran et al. (2000)

A case study conducted in a British company on reengineering business processes is presented. This case study ought to contain information that readers can use in replicating the experiences gained and lessons learnt in future endeavours under similar settings.

Hines et al. (1999)

This paper describes the application of a new variant of process benchmarking called value stream mapping to the development of a supplier network around a prominent distributor of electronic, electrical and mechanical components. This involved mapping the activities of the firm, identifying opportunities for improvement and then undertaking with the firm an improvement programme.

Houghton and Portougal (2001)

This research presents an analytic framework for processing planning in industries where fixed batch sizes are common. The overall optimum processing plan is shown to be located on an envelope between the optimum JIT plan and the optimum level plan. These concepts provide the framework for understanding the overall optimum plan, and the framework leads to an efficient heuristic. The approach is practical, illustrated by a case study from the food industry, which shows the place of overall optimum planning within the company's planning system and its implications for company performance.

Jina et al. (1997)

This article proposes approaches which feasibly can be considered when implementing lean manufacturing principles within a typical high variety, low volume (HVLV) situation.

Kaighobadi and Venkatesh (1994)

In this article the literature on definitions of Flexible Manufacturing Systems (FMSs), reasons for change from conventional systems to FMSs, installation and implementation issues of FMSs, application issues, and finally problems of FMSs, were reviewed. The FMS related problems were categorized into two major areas: managerial and technical. Both managerial and technical problems are discussed along with the earlier research. There is a vast source of materials on the subject, although the interest and the technology of the field are relatively recent. Furthermore, there are a number of predictions and forecasts in regard to the future of FMSs.

Khan et al. (2007)

This paper fulfils an identified need of SMEs to achieve WCM status and offers a novel/practical framework and PAM tool which are timely because the DTI is promulgating the need for SMEs to become world-class. This study advocates a planned and integrated approach for the gradual achievement of WCM in SMEs by a strategy of BPI through continuous improvement and structured training.

Kondakci and Gupta (1991)

In this study, an interactive scheduling approach is developed for a dual-constraint dynamic job shop production environment. The approach is used by a number of subjects in an experiment. The performance of the subjects is compared with that of dispatching rules based on tardiness and other measures relevant to the job shop environment. The results indicate that the subjects outperform the dispatching rules in general.

Kritchanchai and MacCarthy (1999)

This paper discusses evidence from field studies undertaken to investigate the responsiveness of the order fulfilment process in a number of companies. The evidence is analysed in the context of the literature on responsiveness and related areas such as time-based competition. Similarities and differences are analysed across a number of industrial sectors with respect to order fulfilment processes and the interpretation and significance of responsiveness. Generic factors that influence different types of companies are identified. The field and case study evidence allows the development of more precise definitions and descriptions of each of these components. In addition, the study also allows a generic responsiveness framework to be developed that incorporates both strategic and operational viewpoints.

Kumar and Harns (2004)

This paper reports learning and application of a few significant techniques to improve basic business practices in a company, with manufactures large volume, high quality optical thin film coatings. The study demonstrates measurable results realised through use of process mapping tools, kaizen blitz activities, formalised and documented work instructions and work measurement tools.

Kumar and Narendran (1997)

This article has proposed an algorithm to sequence PCBs with consideration to due-dates. Recognising the dominant role of component change-overs in the make-span, the algorithm exploits the similarities among the PCBs in terms of their component requirements and seeks to minimise the make-span as well as the tardiness. When compared with several popular despatching rules used for single machine scheduling with due-dates, the proposed algorithm is found to perform distinctly better, particularly under conditions of tight capacity.

Little et al. (2001)

This research is aimed at developing novel planning and scheduling reference models for industrial sectors where the MRPII paradigm is not appropriate. It outlines the process mapping approach adopted for data capture within the case study companies and the use of ARIS, Scheer's enterprise modelling tool, for the production of sector reference models.

Mathaisel and Comm (2000)

This paper presents the findings of the investigation from aerospace industry. It explores the relevance and value of the lean concepts to the US defence launch vehicle, spacecraft, and space operations industries, and it ascertains if there is interest within space industry firms in establishing a lean initiative similar to that of the automotive industry.

Metaxiotis et al. (2002)

The authors propose an expert system, which uses the prevailing conditions in the industrial environment in order to select and “fire” dynamically the most appropriate scheduling algorithm from a library of many candidate algorithms.

Meybodi (1995)

This article presented the hierarchical production planning (HPP) model which extends current HPP models and incorporates a simple and realistic scheduling routine into the model. The scheduling routine schedules the jobs with the objective of minimising both lateness and earliness, a JIT concept. The Gantt chart schedule generated from the scheduling routine is a practical tool which enables the scheduler actually to schedule the jobs and then monitor the progress of jobs through the work centres. Unlike the existing HPP models, the present model provides detailed information regarding job tardiness, bottleneck work centres, number of set-ups, inventory, shortage and capacity. This information is critical for day-to-day shop floor management. The experimental results indicate that the performance of the present model is better than the existing models in general; however, the model is truly superior under tight capacity conditions.

Motwani (2003)

The author discussed the most important elements of lean manufacturing (LM), the strategy used by the company for implementing LM and the significant benefits that were accrued in manufacturing operations. Moreover, the critical factors involved in the implementation of LM utilising a business process change framework were described.

Motwani et al. (1998)

The purpose of this paper is to examine and classify the current BPR literature into four different streams and to suggest research areas that need to be addressed, under each of these streams, in the future.

Papadopoulou and Ozbayrak (2005)

This article highlighted the evolutional orbit that leanness has followed over the years and serve as a herald of the current state of this evolution, which will be discussed further, in a separate paper.

Persona et al. (2004)

The research presented in this study is included in a wide cross-disciplinary project which involved seven research centres. In particular, this paper aims at identifying the general requirements and guidelines for the definition of an integrated model of the order to delivery cycle in a VM environment, which can particularly be suitable for the small-medium enterprise needs. A number of guidelines emerged, mainly in the areas of customer requirements definition and commercial configuration of customer order, supply and production planning, and intermediate and final project evaluation.

Petroni (2002)

The author dealt with the implementation process of material requirements planning (MRP) within small and medium-sized firms. This study identified the elements of MRP implementation that are required to ensure successful implementation. Consequently, criteria were selected as measures of the level of implementation success. The analysis revealed that only a few of the identified elements were indeed required for successful implementation. Among these are management support, level of functional integration and data accuracy.

Pibernik (2006)

The paper provides a consistent formal approach to modelling order promising mechanisms, introduce new and innovative order promising mechanisms and provide valuable insight into their performance through numerical analysis. The results obtained from this analysis provide guidelines for manufacturers, retailers, and vendors of supply chain software on how to design and utilise order promising systems.

Porter et al. (1999)

The authors first set out some common manufacturing classification systems, then attempt to map them against accepted paradigms for production planning and control approaches. Analysis confirms the need for a more rigorous approach to software selection, and the need for a complete understanding of the drivers of the production control process before this can be achieved. The paper goes on to discuss a method for mapping these drivers, with the aim being to create a series of reference models for production planning and scheduling.

Rawabdeh (2005)

This paper aims to investigate the waste in a job shop environment and proposes an assessment method aimed at helping companies to identify root causes of waste. The simplicity of the matrix and the comprehensiveness of the questionnaire contribute to the achievement of accurate results in identifying the root causes of waste.

Ramesh and Devadasan (2007)

The purpose of this research is to review on the literature and contribute a comprehensive model that would identify the criteria for attaining agility and suggest a procedure to successfully implement it in manufacturing.

Rogers (1989)

The study proposes a computer based interactive graphical aid which can provide data of computational analysis in forms more compatible with the needs and environment of the production scheduler.

Sanchez and Perez (2001)

The authors develop and test an integrated check-list to assess manufacturing changes towards lean production. Using the results from a survey to manufacturing plants located in the Spanish region of Aragon, analyses which lean production indicators are more used to assess the company's improvements in their production systems, and the determinants on the use of these indicators.

Sorlano-Meler and Forrester (2002)

This research focused on clarifying the concepts of lean manufacturing and what it comprises. The authors also commence with a review of the lean production literature and, specifically, existing models that identify the variables and component elements of lean production firms.

Stoop and Wiers (1996)

This article revealed the complexity of scheduling in practice which often results in disappointment by shop floor management and schedulers themselves. A number of causes have been given why scheduling techniques often do not work in practice. Moreover, the authors also propose a means of tackling this difficulty.

Sweeney and Szwejczewski (1996)

This study was aimed to use manufacturing performance measures to create manufacturing strategy groups, examine the manufacturing policies of the firms in these groups and compare their standards of performance.

Taj (2005)

This paper offers a practical and easy to use assessment tool to help manufacturing managers to make their manufacturing operations more productive. A spreadsheet-based assessment tool is used to evaluate nine key areas of manufacturing.

Ulusoy and Ozdamar (1996)

In this paper, the authors propose a framework for an interactive project scheduling system under limited resources. The framework includes a modelling module (MODEL) and a scheduling module (SCHEDULER). An important feature is that the project plan can be updated by performing the least modification of future commitments. It is possible to freeze the activities already scheduled in the near future while admitting the changes in the activity/network information.

Westbrook (1994)

This article is concerned with the major background finding of the research, which concerns the nature of operations management itself as carried out in the collaborating companies. Computer systems are typically founded on formal planning and control models but such models were either absent from, or resisted in, every company. The aim of this article is to consider why traditional manufacturing planning and control (MPC) systems seemed inappropriate in these contexts, and to analyse the approach to managing operations which these companies actually used. That approach, which is here called priority management, has been neglected in management literature. Several perennial problems in management studies seem to relate to it, yet it has never been explicitly identified before. Accordingly, it can perhaps be claimed as an innovation in theory.

Yeh (2000)

This article presents a customer-focused approach to effective planning of make-to-order production, in which production activities are driven by customer orders and all products are made to customers' specifications. The approach plans, schedules and co-ordinates production activities are based on the needs of individual customer orders. In particular, an integrated bill of material and routeing data structure is used to effectively organise production data in response to product specifications of customer orders. It facilitates the creation of production jobs with varying routeings and material requirements. A job-oriented finite capacity scheduling system is used to effectively accommodate specific needs of individual customer orders. It allows for realistic setting of delivery dates and negotiation of order changes. Key features of the approach presented show its effectiveness in planning multi-item customer orders and multi-level products.

Yeh (2005)

The paper addresses the need for effectively coordinating production jobs of varying routings on the shop floor, which cannot be met by existing scheduling techniques or shop dispatching practice. It provides manufacturing practitioners with a structured approach for managing shop floor operations. Specific features of the approach are presented and illustrated with a numerical example. It enables production jobs to be run in the best possible way at individual work centre. Various options of implementing the approach in practical applications are discussed.

Zairi and Sinclair (1995)

In this article, the authors outlined a new approach to the management of processes which, it was claimed, was producing radical improvements in performance. It was quickly followed by a number of articles describing the benefits to be gained from BPR.

CHAPTER III
PROBLEM ANALYSIS

The case study company is a traditional company, with a hierarchical structure and the many handovers, and consent signatures within processes that inevitably come with this. In a hierarchical structure, each department has its own workspace, and interaction usually occur intra-departmentally (Armistead and Machin, 1997; Emiliani, 2000; Gunasekaran et al., 2000). Nevertheless, it had been found that within a company whose structure is of such a traditional form much of the work being executed is non-value-adding (Armistead et al., 1995; Gunasekaran, et al., 2000). Furthermore, the company had always relied upon day-to-day and on-the-job solutions to its problems. It had operated primarily from a position of honesty and trust. As a medium-sized company, it managed well under this format and its growth over the past 20 years has proven that. However, in today's ever-changing, increasingly demanding business environment, it is a necessity to provide continuity, responsibility and consistency in handling day-to-day operations. As mentioned earlier, metalworking lubricants section (MLS) is a part of the case study factory established in 2004. This section has operated 8 hours a day, 5 days a week, and produces high quality make-to-order metalworking lubricants for both metal forming processes (e.g. drawing, forging, sheet-metal forming, etc.) and metal cutting processes (e.g. drilling, milling, tapping, reaming, turning, etc.). Nonetheless, there have been a considerable number of customer complaints since it was formed. It was found that 85% of the complaints were the lateness in delivery. Hence, the purpose of this chapter is to analyse and discuss any significant problems which lead to the lateness in delivery within the order to delivery cycle. In the first instance of the analysis, information regarding metalworking lubricant products and sales will be described and analysed.

3.1 Products and Sales Analysis

One of the purposes of metalworking processes is that of creating a new shape. Usually the processes bring into contact two solids: the tool and the work piece. The contact involves either the plastic flow of metals (metal forming processes) or the creation of a new shape by controlled removal of excess material (metal cutting processes). The creation of new shapes by metalworking processes involves high friction, high temperatures and tool wear. Consequently, metalworking lubricants influence both the effectiveness of these processes, and the overall efficiency of the manufacturing operation (Mortier and Orszulik, ed., 1997).

Figure 3.1 Application of metalworking lubricant (water soluble type)

In general, there are four basic types of metalworking lubricants used in metal forming and metal cutting operations. They include: neat oils, soluble oils, semi-synthetic oils and synthetic oils (Mang and Dresel, ed., 2001). Neat oils have been available longer than the others. They include mineral oils, napthenic and paraffinic oils, and animal and vegetable oils, such as lard and castor oil. Additives are often blended to the base oils to improve “extreme pressure” (EP) and anti-weld. They typically offer excellent lubricating properties with only minimal heat transfer or “cooling”. Soluble oils were developed to offer the lubricating properties of oils with the cooling properties of water. Soluble oils perform well on ferrous and nonferrous metal. One drawback of soluble oils is their tendency for biodegradation. Semi-synthetic oils are basically water solutions with small amounts of oil micro-emulsified for improved lubricity while offering the cooling properties and cleanliness of synthetic oils. Synthetic oils are non-petroleum based materials that offer varying degrees of lubricity with excellent cooling and cleanliness. Synthetic oils are biodegradable, less likely to become rancid, and generally do not cause dermatitis. They also make filtering and recycling an easier possibility. In the case study company, metalworking lubricant products can be classified in two categories: water soluble (soluble oils, semi-synthetic oils and synthetic oils) and neat oils. The following figures represent metalworking lubricant sales during the period November 2005 to October 2006.

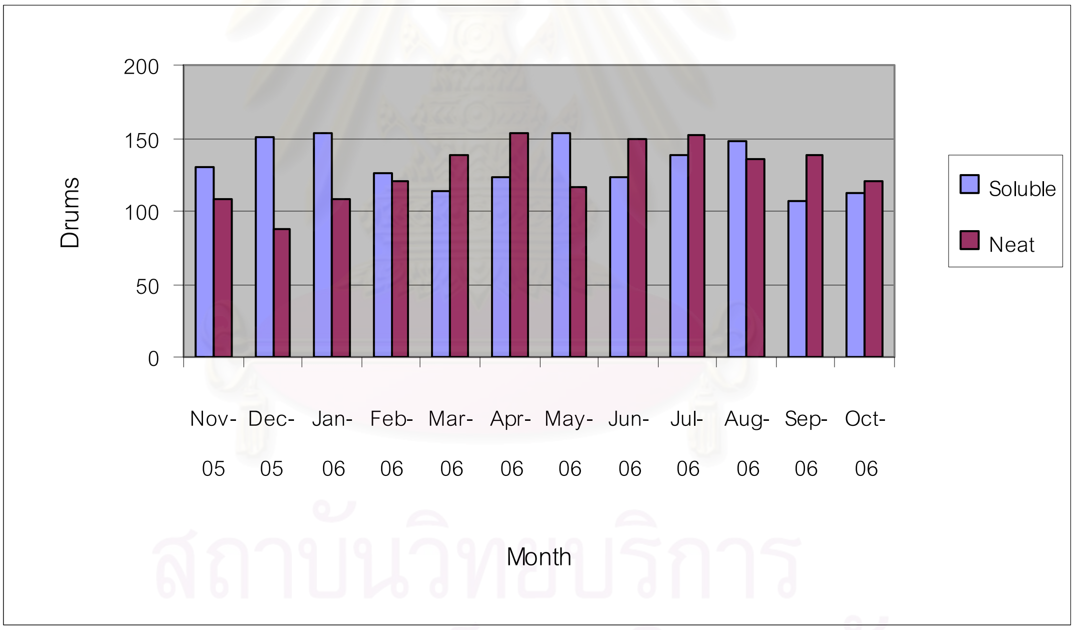

Figure 3.2 Order quantities from November 2005 to October 2006

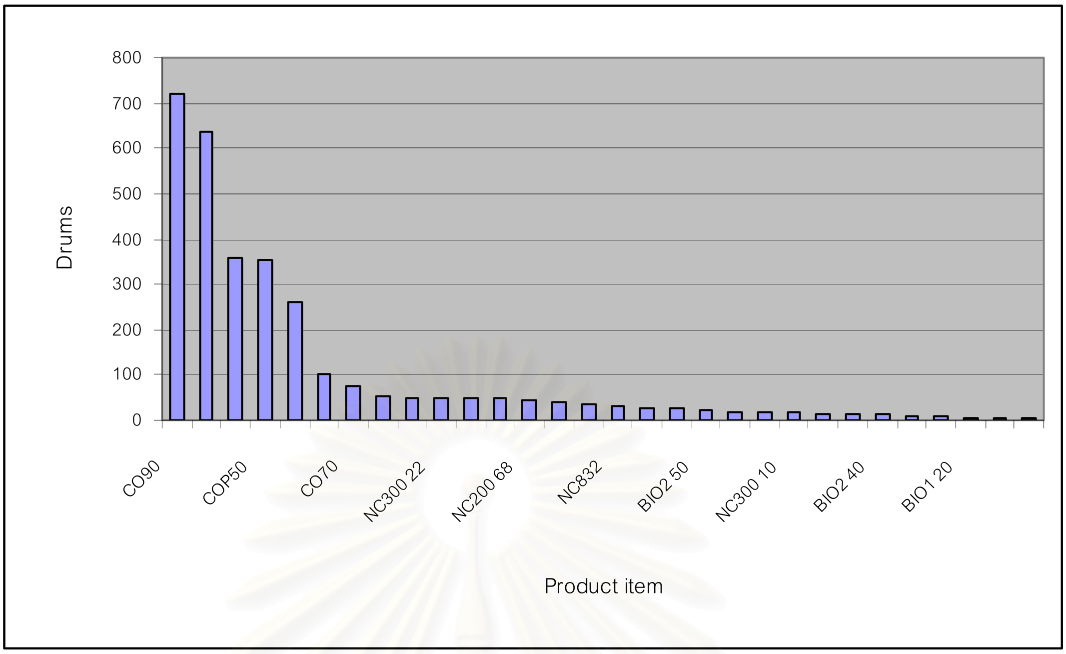

Figure 3.3 the number of drums sold in the past 12 months

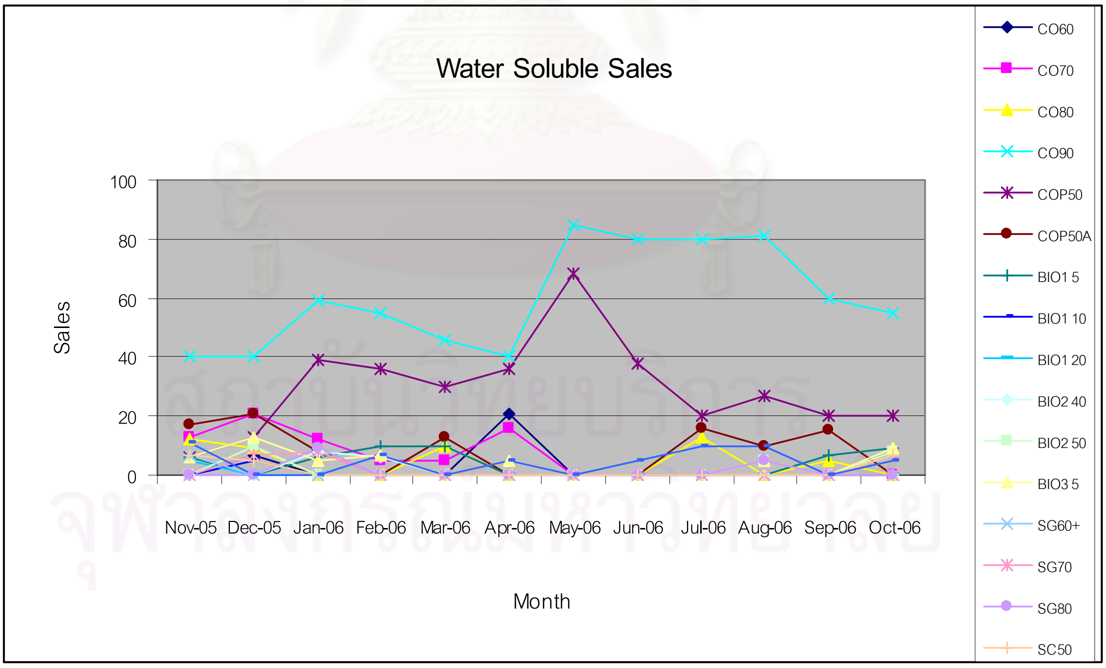

Figure 3.4 Water Soluble Sales (drums)

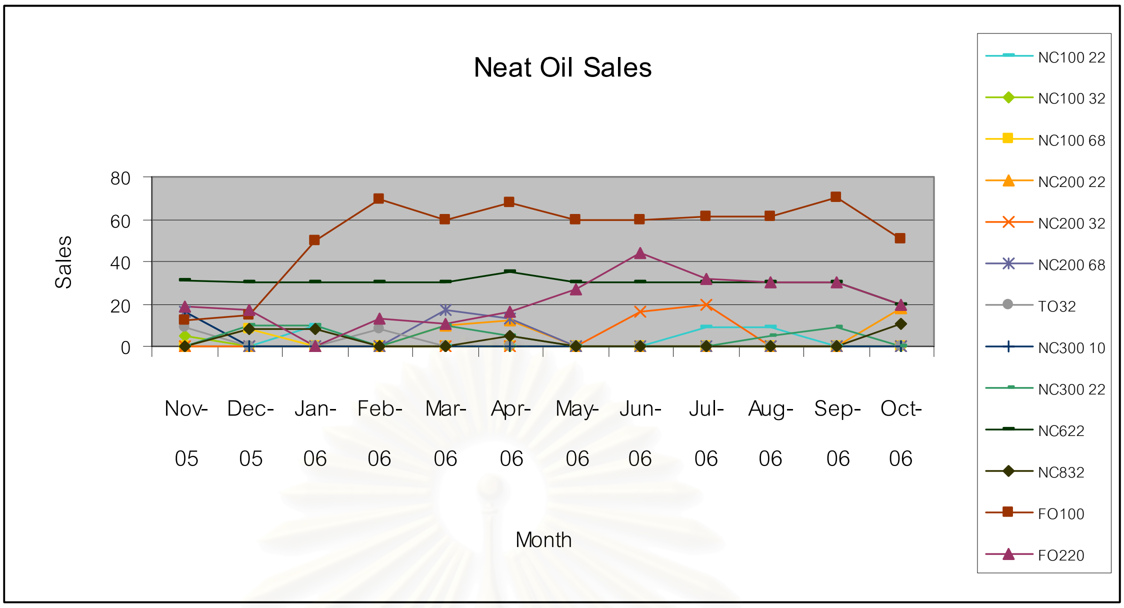

Figure 3.5 Neat Oil Sales (drums)

In Figure 3.2, it would seem that monthly demands were slightly fluctuating and difficult to be forecasted. Moreover, there has been a wide range of product items sold, coupled with low order quantity as shown in Figure 3.3, 3.4 and 3.5. Nevertheless, it could be noted that three-fourth of drums sold during the mentioned period came from 5 product items while the rest came from 24 product items. In the same manner, approx 70.3% of total sales revenue came from 5 product items while approx 29.7% of total sales revenue came from the rest. This set of data slightly follows the 80/20 rule (Pareto analysis). Thus, new production rationalisation might be considered (Babu, 1999; Yeh, 2000). Nevertheless, it appeared that each product item in the same category is nearly customised because it requires different components (e.g. raw materials), mixing times, and manufacturing procedures. For example, CO90 requires blending time of approx 50 min. and a set of four components (including base oil A, additive MP, GY and X) while BIO2 50 requires more than 1 hour and a set of four components (including base oil A and BRG, additive X, and water). Although products ordered by different customers would normally have different specifications, the same product, probably with varying batch sizes and due dates, may be ordered by the same, or other, customers (Yeh, 2000). Further difficulty arises because of the presence of a high level of variability in routing and processing times. This however creates inevitable conflicts of delivery priorities, which are made even more difficult by machine breakdowns, labour absenteeism, and delays in delivery of materials and components, etc. (Persona et al., 2004; Stoop and Wiers, 1996). As mentioned earlier, it could be recognised that the case study factory falls under the versatile manufacturing (VM) environment (Babu, 1999; Bramham et al., 2005; Persona, 2004; Yeh, 2000). Research evidence suggests that this environment has a negative impact on performance because it emerges that VM companies encounter a variety of difficulties in coping with uncertainty associated with the order to delivery cycle and, consequently, they often suffer from delivery unreliability, very long lead time, poor resource allocation, cost increase and customer complaints and dissatisfaction (Persona et al., 2004).

In order to gain an involvement from the staff in this research, MLS's initial kaizen blitz was conducted under the guidance of the consultant brought into the company through a contractual agreement with a consulting firm (ISO project). The initial stage was to select five key team members for the kaizen blitz team (plant manager, production supervisor, warehouse supervisor, procurement officer and sales supervisor). Careful consideration was taken to assure that the team consisted of cross-functional members directly and indirectly involved in the current process (Kumar and Harms, 2004). The team was then educated in lean manufacturing and quality tools & techniques. The kaizen blitz event took two full days (Saturday and Sunday). All participants attended the event full time for 12 hours a day for the first day and eight hours for the second day. In the second day afternoon, all participants were assigned to identify problems occurred in their responsibilities which lead to drum delivery delays. Consequently, a brainstorming session was initiated in the next Saturday. Fishbone chart was used and problems were identified by all participants. Figure 3.6 illustrates fishbone chart for drum delivery delays.

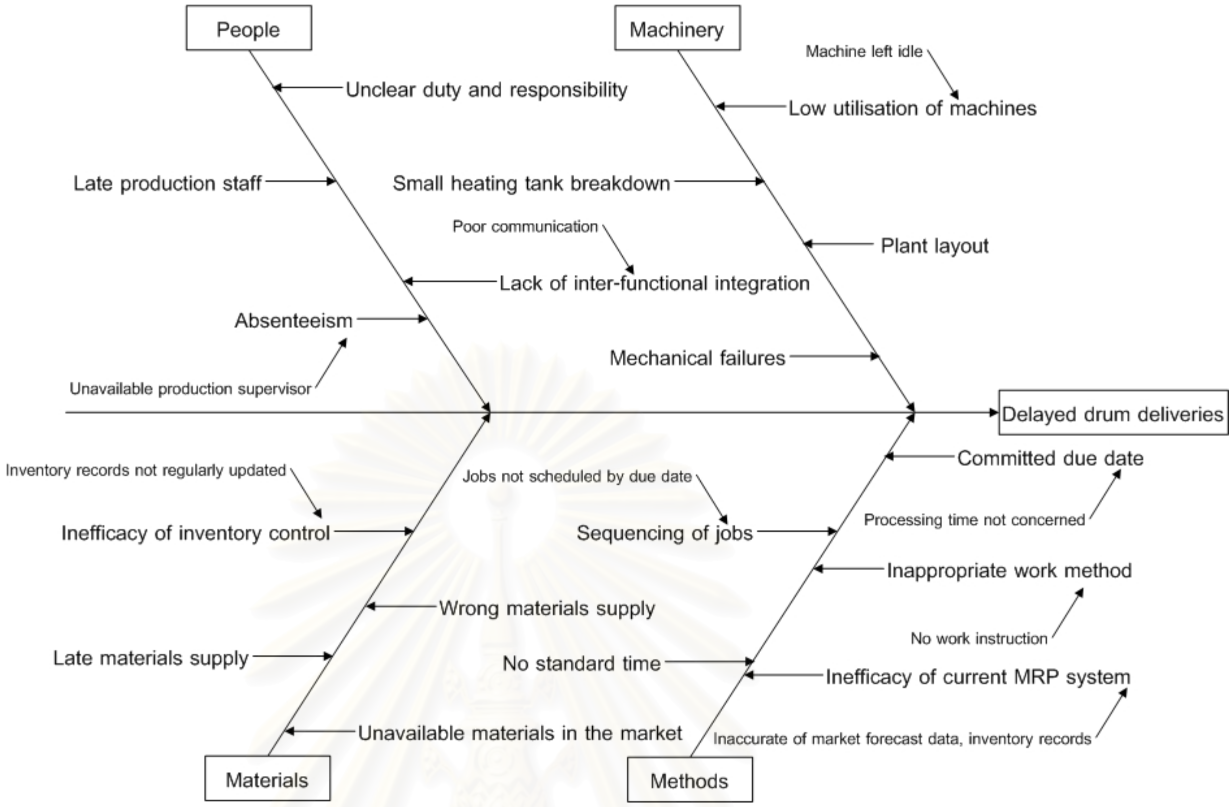

Figure 3.6 Fishbone chart for drum delivery delays

Before any corrective action is taken, it must however be ensured that all the facts are presented. There must first be an understanding of the deviations and what factors came to bear in causing the deviation or poor performance (Kumar and Harms, 2004). Business Process Reengineering (BPR) is an excellent management tool to use during activity analysis (Khan et al., 2007; Fowler, 1998; Motwani et al., 1998; Armistead and Machin, 1997; Armistead et al., 1995; Gunasekaran et al., 2000). BRP is an approach to achieving radical improvements in performance by using resources in ways which maximise value added activities and minimise activities which only add cost either at the level of the individual process or at the level of the whole organisation (Armistead et al., 1995). In other word, it is about making a company more customer-focused and process-based, instead of the traditional procedure-focused and function-based (Gunasekaran et al., 2000). In the following section, BPR concepts will be applied to analyse and identify any significant problems occurred.

3.2 Order to Delivery Cycle

Before changes are made to any current processes, specific tasks and activities should be studied for complete understanding. As BPR is a top-down initiative, it is essential that processes are looked at from end to end, not focusing on any one specific activity (Gunasekaran et al., 2000). A process can be defined as a sequential group of events or activities, which performed together in series (or occasionally in parallel). In this analysis, a process is activities being carried out in the order to delivery cycle which begins at the time the customer places the order and ends when the product is despatched and paid for. The sequence of tasks for this process is described in Figure 3.7. For time purposes, not every minor step or detail was included in listing the tasks involved. In the order to delivery cycle, salespersons are responsible for the initial contact with customers to define product price and delivery date. In doing this, salespersons use a catalogue, called “product list”, in which each family of metalworking lubricants is explored. After the initial offer has been confirmed by the customer, sales office releases an internal commercial order (e.g. neat forming oil, cutting oil soluble, etc.) detailed in specification (viscosity, flash point, etc.) and due date. Once an internal commercial order has been received at the factory, invoice is issued. Configuration management is however fully manual (an experienced person) through a book that contains approx 40 different bills of materials (BOM) referred to past productions, composes like a puzzle, the customer’s order as an aggregation of standard, variant, optional and special groups. In case of non-existent parts, procurement supervisor contacts the laboratory asking for new configuration. The latter usually provides a one level technical BOM that the procurement officer can modify before manually entering into the material requirements planning (MRP) system using a simple database developed in Microsoft Excel environment, in order to make it suitable for manufacturing activities. Once all parts are thoroughly defined, the procurement officer manually schedules the supply and manufacturing tasks. In most cases, it appears that production is scheduled directly from customer orders. Once the blending order has been issued, the manufacturing activities begin. After metalworking lubricants have been packaged, they are subsequently kept in the warehouse waiting for despatch. When the products have been delivered, they will be paid for.

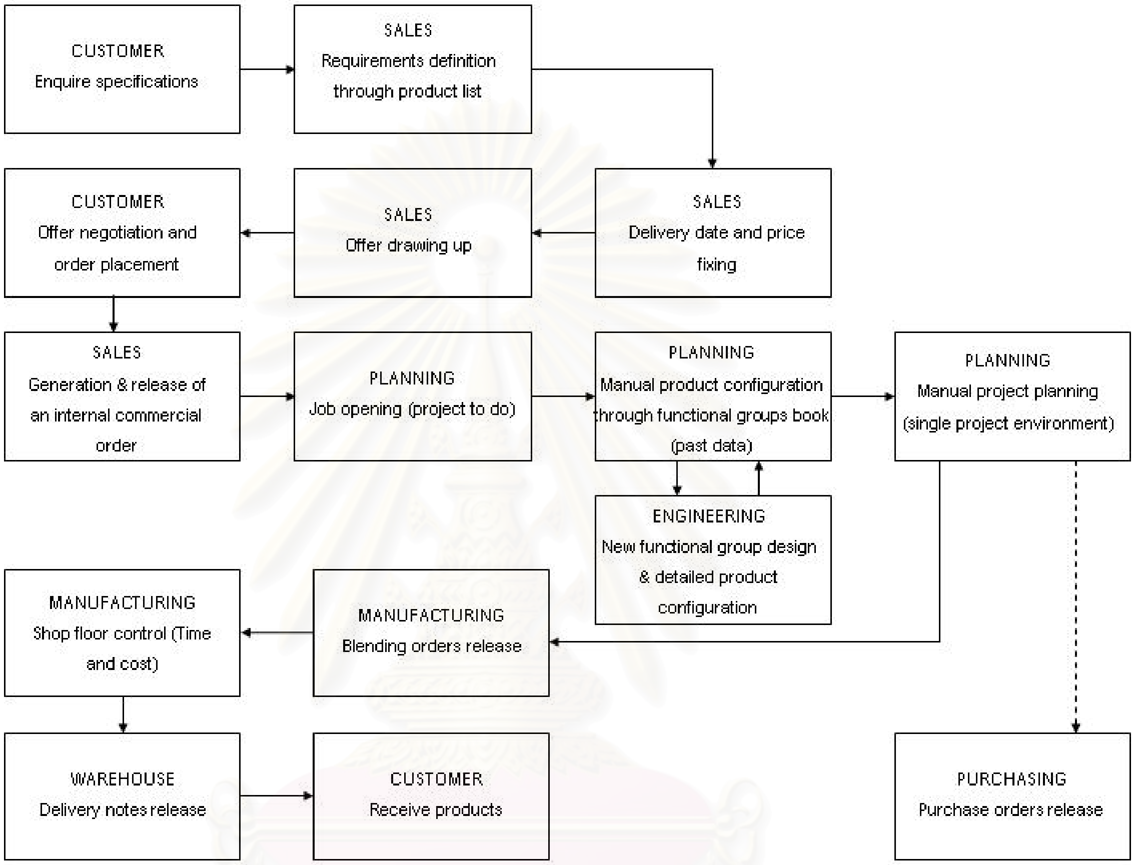

Figure 3.7 Order to delivery cycle in the case study factory

In this research, the analysis will address the way in which current processes are run so as to obtain a feel of how vast improvement can be achieved and then establish an order of priority based upon which processes are costing too much, outputting too low, and from which processes the company will gain most benefit from BPR (Armistead and Machin, 1997; Gunasekaran et al., 2000). By applying process mapping, the non-value-added steps within current procedures will be identified (Armistead et al., 1995; Kumar and Harms, 2004; Zairi and Sinclair, 1995). Process mapping introduced three tools that helped make the specific tasks more visible:

relationship maps, cross-functional process maps and flowcharts (Kumar and Harms, 2004). Through actual documentation of current specific tasks, a better understanding of current processes is gained. The flow chart of the current order to delivery cycle, as shown in Figure 3.7, shows that there are four separate functional areas of MLS currently involved.

Sales

In MTO companies, it is desirable to quote short lead times to customers in order to remain competitive. It is also important to maintain those lead times to promote customer satisfaction and generate further businesses (Babu, 1999). Production configurations are typically set up with the product options from which the customer can choose (often with sales assistance from sales or technical staff), and associated costs and lead times can be generated according to the customer specification (Bramham et al., 2005). In MTO production, most or all the operations necessary to manufacture each specific product are only done after the receipt of a customer order (Amaro, 1999). Therefore, it is essential to quote due dates which can be achieved with the resources available in the shop (Babu, 1999; Yeh, 2000). In the case study factory, a guaranteed delivery date is set at 5 days after an order has been placed which means if customer orders on Monday, products will be despatched no more than Saturday. However, it appears that due dates are currently set by the customer and the salesman with no relation to the required processing time and without contacting other relevant departments. For instance, the committed due date may be set shorter than 5 days if customers request (no matter how much they order). Lack of inter-functional integration between sales, manufacturing, and planning units appeared to cause problems in translating the commercial order into technical requirements and estimating the final costs and due dates (Persona et al., 2004). As shown in Figure 3.7, sales order is created through interaction of the sales personnel with the direct customer. The salesperson finalises the order and issues a hard copy form (an internal commercial order) to the order entry group. More importantly, salespersons have never acknowledged whether resources are sufficient for those required products or due date may be too tight for the required processing time.

Planning

At this stage, there are two groups of staff responsible for planning: order entry and schedule groups. Figure 3.8 and 3.9 show order entry and schedule processes. The order entry group reviews the sales order for accuracy and enter order into computer to issue invoice for the scheduling group. The scheduling group reviews MRP and assigns production work orders (blending orders) where appropriate. Blending order is issued and subsequently distributed to the manufacturing group. However, problems which lead to the lateness in delivery were found in schedule process. Indeed, material requirements planning (MRP) systems help manufacturers determine precisely when and how much material to purchase and process based upon a time-based analysis of sales orders, production orders, current inventory and forecasts (Petroni, 2002). Nevertheless, MRP system in the case study factory appeared to be a bottleneck in the order to delivery cycle. There are two main factors found during the assessment. Firstly, there is no clear specification of individual roles and responsibilities (Petroni, 2002). As a relatively new unit, there is unclear who are involved in MLS. Although procurement officers and warehouse staff are responsible for MRP, decisions are sometimes made by a plant manager. This conflict has caused delays in purchasing, issuing work orders, and jobs scheduling which lead to the lateness in delivery. Secondly, there is inaccuracy of market forecast data, inventory records and manufacturing lead time records (Emiliani, 2000; Persona et al., 2004; Petroni, 2002). Although there is a MRP system using a simple database developed in Microsoft Excel environment, it is not a full MRP system because it deals with either number of item in the bills of materials or number of levels in bills of materials. Inventory records are however updated in the computer once a week (on Friday evening) and not linked to the current MRP system. Despite the fact that there has been no manufacturing lead time record, lead times are estimated by production supervisor. Consequently, MRP becomes less accurate and this leads to material shortage. As high level of uncertainty, with respect to routeings and processing times and uncertainty of customer orders (Babu, 1999), demand forecast is thus slightly inaccurate.

Figure 3.8 Order entry process

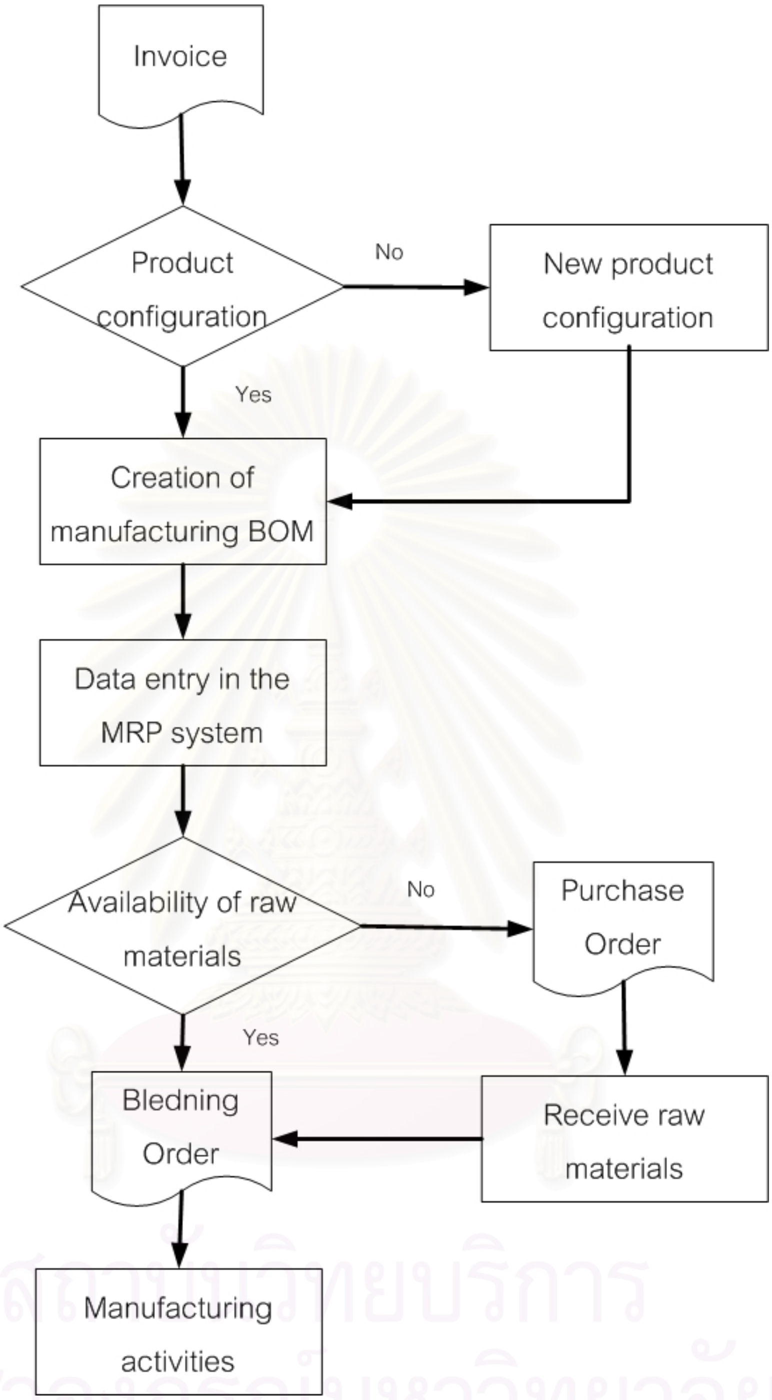

Figure 3.9 Scheduling process

Manufacturing

At this stage, manufacturing group produces make-to-order metalworking lubricants. Upon completion of production, manufacturing group sends the final product and corresponding paperwork over to the warehouse for staging. In producing metalworking lubricants, two kinds of raw materials (base oils and additives) are normally used. Base oils can be classified into three types: mineral, modified mineral and synthetic. These base oils are kept in three oil tanks which each tank contains each type of base oil (see Figure 3.10). On the other hand, additives are all imported from the UK and USA and they are kept in drums (see Figure 3.11). Although lubricating oils can be produced by mixing base oils and additives together in the blending tank, manufacturing procedures may be slightly different depending on what type of lubricant is being manufactured.

Figure 3.10 Base oil tanks

Figure 3.11 Additive drums

In the case study factory, the manufacturing process of metalworking lubricant products generally has five stages. It starts from stock preparation and ends at warehouse waiting for despatch. In the first step, additives and base oils are prepared according to product configuration. For example, NC622 requires 820 litres of base oil X, 100 litres of base oil P, 70 kg of additive 2317, 7 kg of additive 3038, 5 kg of additive 8239, and 3 kg of additive 7110 for 1,000 litres of lubricants (5 drums).

Figure 3.12 Additives is weighed on electronic scale

Figure 3.13 Additives is poured in the blending tank

Next, additive is weighed before pouring into the tank (see Figure 3.12 and 3.13); on the other hand, base oil is filled in the blending tank by opening valve of oil tanks (see Figure 3.14) and consequently base oils will pass liquid control (LC) metre for certain quantity.

Figure 3.14 Valves and pipes of base oil tank

In the second step, additives are mixed with base oils in the blending tank to give product the desired physical properties. As there are two types of lubricant product: water soluble and neat oil, each blending tank is used for each type of product. Figure 3.15 represents two blending tanks in the case study company. Tank on the left hand side is used for neat oils and tank on right hand side is used for soluble oils.

Figure 3.15 Blending tanks

In some types of products, the blending process may be slightly different from the process mentioned previously. For instance, blending process of semi-synthetic oil however requires more than one step, additives are mixed with base oils at first, and then the mixture of base oils and additives will be blended with water again to produce this kind of product. In the same way, neat oil sometimes requires two steps. In case that additive is difficult to dissolve in oil, it is thus first mixed with base oils in a small heating tank and subsequently the mixture of these will be blended with other base oils again in the blending tank. After the blending process, the lubricating oil is subjected to a variety of quality control tests that assess its viscosity, specific gravity, pH, foaming characteristics, corrosion tests, flash points, etc. Figure 3.16 shows capillary viscometers used in the case study company.

Figure 3.16 Capillary Viscometers

As a matter of fact that the properties of lubricants are mostly determined by standardised test methods, these properties help to characterise as well as identify the chemical compositions of lubricants. Nevertheless, the industry often defines specifications for the lubricant, which are based on the application and the results of these tests. These test results can define the suitability of the oil for the end application, and during actual use, the change of properties can be used for judging the suitability of a lubricant for further use and thus help prevent damage of machines and lubricating systems (Mang and Dresel, ed., 2001). Consequently, lubricant that meets quality standards is then packaged and stocked at the warehouse for sale and distribution. Figure 3.17 represents packaging process and figure 3.18 shows metalworking lubricant products are moved to warehouse by a forklift. A summary of salient manufacturing activities can be shown in figure 3.19. Examination of the literature (Porter et al., 1999) shows that there are many different classifications systems for a manufacturing environment. Using such a method enables the case study company to identify strengths or weaknesses within its own system, thereby facilitating change management to increase or maintain competitive advantage. From the literature, it would seem that make-to-order environment falls under jobbing production (job shop).

Figure 3.17 Packaging

Figure 3.18 Warehouse

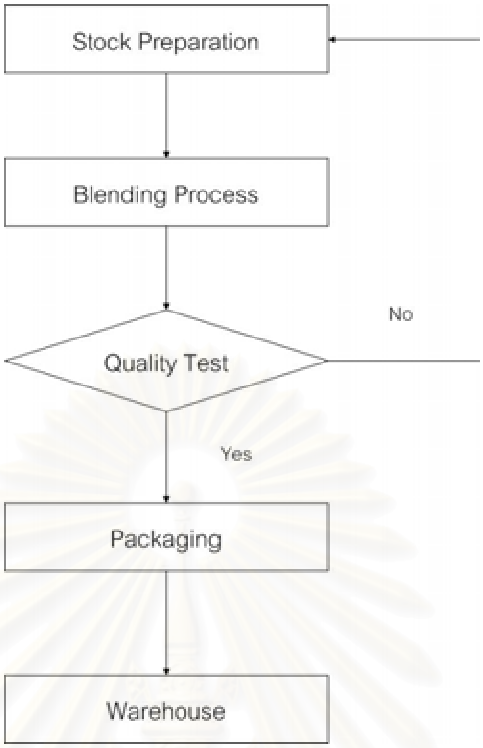

Figure 3.19 Manufacturing process for metalworking lubricant products

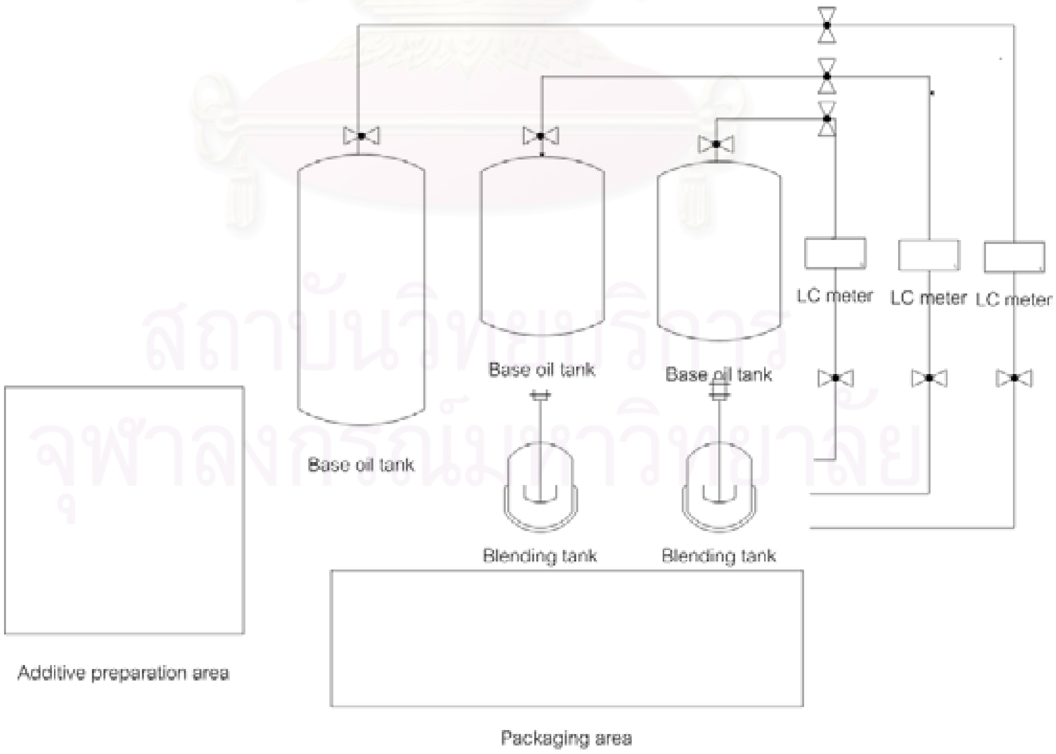

Figure 3.20 Layout of metalworking lubricants section

Jobbing production is characterised by low volume (often one off) production of a wide range of products with demand for any one single product being difficult to forecast. For one-off production, it is not normally expected that a product once produced will be required in that exact form again (or if it is, there will be a long period between orders). Plant capacity is difficult to define being dependent on the product mix at any one time. Routeings through this type of production facility are dictated by the manufacturing needs of the individual products and work centre, layout is based on manufacturing processes. The manufacturing of products in such a job shop is usually represented by production jobs (work orders), each of which consists of a number of operations to be processed at the corresponding work centres in varying sequences (Yeh, 2005). As manufacturing of metalworking lubricant products falls under a job shop environment, it would also seem that layout of MLS is process-oriented. Figure 3.20 represents layout of metalworking lubricants section (MLS).

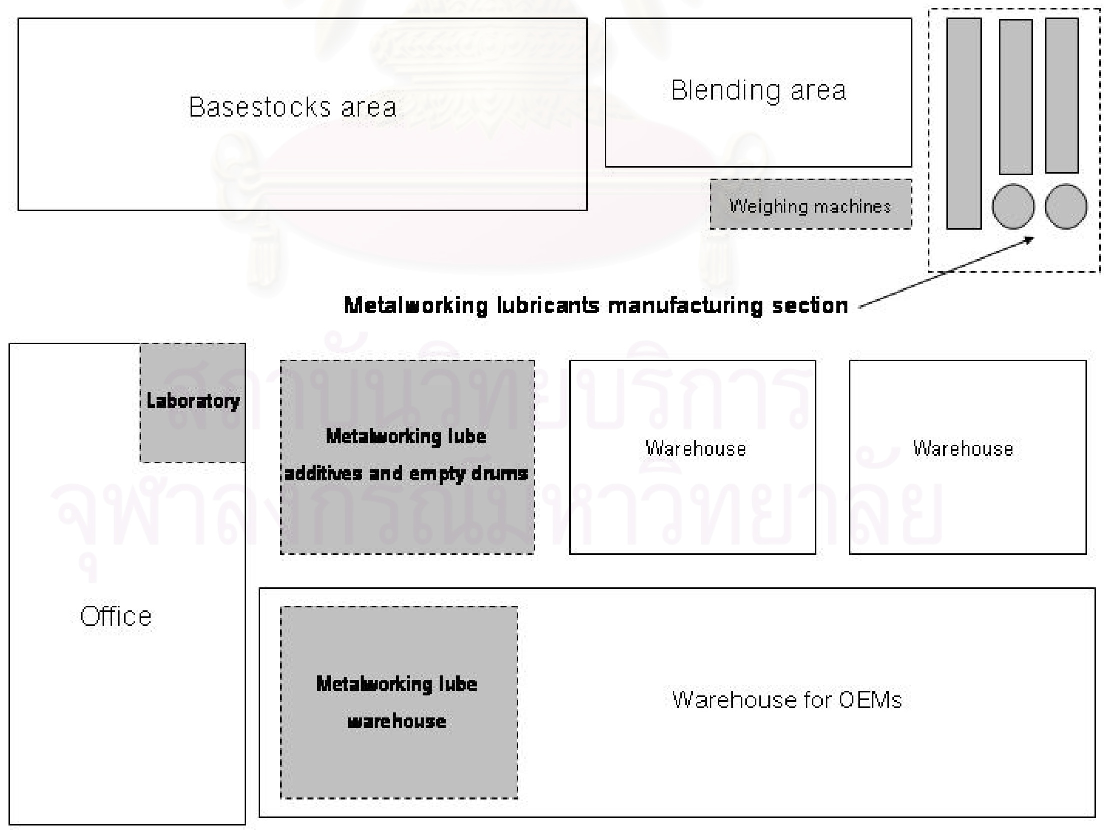

Figure 3.21 Plant layout of the case study factory (not detailed)

In MTO environment, products from a predefined range or product list are requested by the customer. Although material may be purchased and production planned, manufacturing begins only after the receipt of a firm order (Porter et al., 1999). Apparently, MTO manufacturing systems are thus capital intensive (Babu, 1999). Furthermore, enquiries do not arrive in order of importance, thus it would be necessary to re-schedule all jobs each time a high priority job arrives, otherwise the planned capacity level is exceeded and it may cause unacceptable delays to other jobs (Persona et al., 2004). Therefore, it is important to identify problems occurred during manufacturing activities in MLS so as to improve the performance and reduce the number of drums missed delivery date. There is a range of methodologies and techniques aimed at improving the effectiveness and efficiency of operational activity. Each of the methods has a particular background and was created or developed to solve particular forms of improvement problem or problems within particular context. Leanness was introduced as an approach to manufacturing that was aiming at the elimination of waste while stressing the need of continuous improvement (Papdopoulou and Ozbayrak, 2005). Lean manufacturing improves material handling, inventory, quality, scheduling, personnel and customer satisfaction (Taj, 2005). Lean production is a conceptual framework based on a few established principles and techniques (Sanchez and Perez, 2001). Moreover, it was found that lean production practices will often reduce lead times so drastically that it becomes feasible to practice MTO production, and still provide on-time deliveries. The term pull is used to imply that nothing is made until it is needed by the downstream customer, and the application of a make-to-order approach whenever possible (Arnheiter and Maleyeff, 2005). Some of them affect exclusively the production department, while others integrate several company functions. Waste has seven types: waste from overproduction. Waste of waiting time, transportation waste, inventory waste, processing waste, waste of motion, and waste from product defects (Taj, 2005; Rawabdeh, 2005). The seven wastes can be categorised into three main groups: man, machine, and material. The man-group contains the concepts of motion, waiting, and overproduction; the machine-group contains over-processing waste; and the material-group contains transportation, inventory and defect waste (Rawabdeh, 2005). In this article, an assessment tool is applied by using lean concepts and philosophies (Taj, 2005; Sanchez and Perez, 2001; De Toni and Tonchia, 1996; Arnheiter and Maleyeff, 2005; Papadopoulou and Ozbayrak, 2005; Rawabdeh, 2005; Hines et al., 1999) in order to obtain some key information about the status of a manufacturing facility. However, the logic behind lean thinking is that companies jointly identify the value stream for each product from concept to consumption and optimise this value stream regardless of traditional functional or corporate boundaries (Arnheiter and Maleyeff, 2005; Hines et al., 1999). Value stream mapping (VSM) is a type of specific process benchmarking where the initial performance of a particular process is not externally compared but is internally compared with how good that process itself could be (Hines et al., 1999). In other word, it compares the value adding and wasteful activities now with what the process might look like if a realistic percentage of the waste was removed. It thus helps to investigate, evaluate, and measure key areas of manufacturing and the result from the assessment is a deeper understanding of key issues, problem areas, and potential solutions.

3.3 Mapping the value stream

As previously discussed, VSM involves the identification of value adding and wasteful activities based around seven wastes. The VSM tools in combination with the kaizen activity were effectively used within MLS to illustrate and achieve significant process improvements. Kaizen strategies have been initially targeted for the production areas within MLS. In the first attempt to gain work centre profitability through reduction of non-value-added activities, a pre-assessment of the current process was initiated. In this assessment, process activity map was applied to identify non-value-added activities and an example of the result is illustrated in Table 3.1 and 3.2. In the process activity map, time of each activity is the average time of each activity collected between December 2006 and February 2007. The result showed that almost a half of the total time spent in manufacturing activities was found to be delays (waiting). During collecting the data, it was found that the blending time of the same product was uncertain depending on the production supervisor’s decision (experienced person). Furthermore, time spent on each activity was also uncertain depending on how the production personnel work. Apparently, this is because there has been no standard time and work instruction for any activities in MLS.

Table 3.1 Process activity map for cutting oil soluble (CO90) – production supervisor

Step No.	*Time (min)	Distance (m)	O	T	I	D	S	Step Description
1	3	50	X					Collect blending order at the factory office
2	16	36			X			Check equipments (forklift and base)
3	8	44		X				Drive forklift to move additive drums to preparation area
4	20	5	X					Use forklift to move assistant with drums to pour additives
5	5	-				X		Wait until base oil has already been filled
6	2	-				X		Wait until the blending process begins
7	25	15					X	Remove additive drums to recycle drum area (outside)
8	35	-				X		Wait until the blending process is finished
9	5	-				X		Wait until sample has already been collected
10	2	77		X				Walk to laboratory for quality testing
11	40	-				X		Wait for laboratory results
12	2	77		X				Walk to mixing area
13	22	77		X				Move empty drums to the mixing area
14	4	-			X			Check empty drums condition
15	2	10		X				Move empty drums onto the base
16	25	-				X		Wait until empty drums on the base are full with lubricant
17	10	5	X					Put lids onto lube drums
18	10	19					X	Clear out the manufacturing site

Remarks: O = Operation I = Inspect

T = Transport S = Store

D = Delays

*Time = Average Time x (1+15%)

Table 3.2 Process activity map for cutting oil soluble (CO90) – production assistant

Step No.	*Time (min)	Distance (m)	O	T	I	D	S	Step Description
1	3	50	X					Collect blending order at the factory office
2	16	14			X			Check equipments (blending tank, pumps and valves)
3	8	-				X		Wait for additives at preparation area
4	20	20	X					Weigh additives and pour additives into blending tank
5	5	5	X					Start pump and open valves to fill base oil into the tank
6	2	5	X					Push button to start blending process
7	25	63					X	Move additive drums (not used up) to warehouse
8	35	-				X		Wait until the blending process is finished
9	5	5	X					Collect sample
10	2	-				X		Wait for laboratory test
11	40	-				X		Wail for laboratory result
12	2	-				X		Wait until assistant arrive to inform test results
13	22	77		X				Move empty drums to the mixing area
14	4	-				X		Wait until drums have been already checked
15	2	5	X					Start pump and open valve to fill lubricant into drums
16	25	5	X					Fill lubricant into empty drums
17	10	-				X		Wait until lube drums are already covered
18	10	81					X	Drive forklift to move finished goods to warehouse

<u>Remarks</u>: O = Operation I = Inspect

T = Transport S = Store

D = Delays

*Time = Average Time x (1+15%)

As shown in Figure 3.21, raw materials and empty drums are kept slightly far from the work centre. It was also found that warehouse for MLS is slightly far from the work centre. These cause unnecessary transport and should be improved. In addition, work method of the production staff appears to contain many motion wastes. As shown in Figure 3.22, production supervisor uses forklift to move only one drum (finished product) to the warehouse even though he can move more than one at the time (max 4 drums). In Figure 3.23, despite the fact that production assistant can take more than one drum of additive on the pallet at the time (max 3 drums), he takes only one drum.

Figure 3.22 Inappropriate work method

Figure 3.23 Inappropriate work method

As shown in Figure 3.15, there are two machines in MLS. Tank on the left hand side is for neat oil while another is for water soluble oil. When neat oil is being manufactured at the neat oil machine, the water soluble oil machine is however left idle. It could be thus noted that idle machine was found to be waste in the manufacturing activities. Furthermore, an approach to sequencing production jobs on the shop floor was found to be ineffective and leads to the lateness in delivery. Currently, jobs are prioritised in order of blending orders issued by planning group. It appeared that the blending order which is issued first will be handled first at the work centre (FIFO). Production supervisor was not aware of setting priority in any order. In most cases, low priority orders were processed before high priority orders. For instance, an order which the committed due date is on Friday is handled before another one which the committed due date is on Wednesday. As blending time is uncertain, products (especially water soluble oils) often fail quality test. Production personnel then have to start the blending process again and it takes time. Therefore, reworks appear to be another waste in MLS. Since the decision on how much time should be spent on blending process of each product has been made by production supervisor, absenteeism of this person can cease all manufacturing activities in MLS.

Warehouse

Upon completion of production, finished goods are kept at the warehouse area. All products are prioritised in order of due date and then despatched to the customers. However, delivery may be delayed (in case that the order quantity is relatively low and customer is not in the delivery route of that day) because the transport is uneconomical.

At this stage, problems found in the order to delivery cycle can be classified into two groups: controllable and uncontrollable problems. In this article, only controllable problems are however tackled. Significant problems can be thus highlighted as the following.

1. Lack of inter-functional integration

It would seem that lack of communication between departments or business units has caused inaccurate due date quotation, production planning and scheduling, and supply planning. For instance, due dates were committed with no relation to the required processing times (lack of communication between sales office and factory). Inventory records (operated by warehouse) are not regularly updated and linked to the current MRP system (operated by procurement). However, the investigation has clearly indicated that it is highly desirable to have some degree of communication skills, long-term focus and strategic team while intending to implement any new initiative (Achanga, et al., 2006). It is therefore important to have a cross-functional team running the MLS.

2. Unclear duty and responsibility

Lack of clarity in job description can lead to workplace chaos. As previously discussed, there has been a conflict in decision-making between warehouse and procurement. For example, a decision in purchasing raw materials can be made by either procurement officer or warehouse officer (or sometimes a plant manager) even though procurement officers should be in charge of. Therefore, job descriptions are critical during performance appraisals where if the profile has been well defined to employees, they cannot claim being unaware of their duties (Achanga et al., 2005; Petroni, 2002). Furthermore, it outlines the responsibilities and functions that are assigned to a particular position or role.

3. Inefficacy of the conventional shop-floor management system

Inappropriate work methods have caused waste (unnecessary motions) in the shop floor. It would seem that manufacturing lead time can be reduced if unnecessary motions are eliminated. No standard time of each activity makes production planning and scheduling become less accurate because of uncertain manufacturing lead time. Since jobs are prioritised in order of blending order received (FIFO) at the work centre, low priority jobs are thus usually processed before high priority jobs. When the production supervisor is absent, products can not be manufactured because production supervisor is the only person who makes a decision in the blending process.

CHAPTER IV
PROCESS IMPROVEMENT

The problems related to MTO environment have attracted a number of research efforts. Many of these efforts were aimed at improving the agility in dealing with this environment (Babu, 1999). From literature surveys, it is believed that the concepts and philosophies of lean manufacturing are most suited to tackle the problems related to MTO environment (Jina, et al., 1997; Amaro et al., 1999; Babu, 1999; Bramham et al., 2005; Kritchanchai and MacCarthy, 1999; Little et al., 2001). In the previous chapter, problems were identified and analysed. According to BPR and lean concepts, it appears that wastes in the order to delivery were most found in the shop floor. In the first instance, an effort was therefore made to standardise the current products and manufacturing processes (Sanchez and Perez, 2001; De Toni and Tonchia, 1996; Ramesh and Devandasan, 2007; Kaighobadi and Venkatesh, 1994; Arnheiter and Maleyeff, 2005; Papadopoulou and Ozbayrak, 2005; Mathaisel and Comm, 2000; Rawabdeh, 2005). Subsequently, a new shop floor management system is then proposed and implemented so as to improve process efficiency and solve the lateness in delivery. The key features of the approach are presented in subsequent sections to demonstrate how specific process improvements can be effectively achieved.

4.1 Product Structuring

The objective of lean manufacturing in HVLV environments is to eliminate or dampen turbulence in the material flow which, if left unchecked, has a damaging effect on performance (Jina et al., 1997). Product restructuring is most considered as a significant contribution for developing lean management systems for MTO environment (Babu, 1999; Jina et al., 1997; Bramham et al., 2005; Persona et al., 2004; Yeh, 2000). As mentioned earlier, it was found that approx 70.3% of total sales revenue came from 5 product items while approx 29.7% of total sales revenue came from the rest. ABC analysis was thus conducted in order to classify product items into three categories as shown in Table 4.1. As a result, five product items were classified as class A while the rest were class B and C (based on 12-month revenue).

Table 4.1 ABC analysis for metalworking lubricant products

Product Item	Sales	Unit Cost* (Baht)	Revenue (Baht)	%Revenue	%Sales	Category
FO100	637	18750	11943750	22.73%	20.48%	A
CO90	721	12500	9012500	17.15%	23.18%	A
NC622	356	16500	5874000	11.18%	11.45%	A
FO220	259	20625	5341875	10.17%	8.33%	A
COP50	353	13500	4765500	9.07%	11.35%	A
SC60	53	31875	1689375	3.21%	1.70%	B
COP50A	100	16875	1687500	3.21%	3.22%	B
BIO3 5	50	33125	1656250	3.15%	1.61%	B
CO70	77	18000	1386000	2.64%	2.48%	B
BIO1 5	48	17500	840000	1.60%	1.54%	B
NC300 22	49	16875	826875	1.57%	1.58%	B
NC200 68	46	17000	782000	1.49%	1.48%	C
CO80	49	15625	765625	1.46%	1.58%	C
BIO2 50	23	28750	661250	1.26%	0.74%	C
CO60	28	22500	630000	1.20%	0.90%	C
NC200 22	40	15000	600000	1.14%	1.29%	C
NC200 32	36	16250	585000	1.11%	1.16%	C
NC832	32	18125	580000	1.10%	1.03%	C
SC50	19	25500	484500	0.92%	0.61%	C
SG80	14	26500	371000	0.71%	0.45%	C
SG70	15	24250	363750	0.69%	0.48%	C
BIO2 40	14	23000	322000	0.61%	0.45%	C
NC100 22	28	11500	322000	0.61%	0.90%	C

TO32	17	16250	276250	0.53%	0.55%	C
NC300 10	16	15625	250000	0.48%	0.51%	C
SG60+	7	21000	147000	0.28%	0.23%	C
NC100 68	8	14375	115000	0.22%	0.26%	C
BIO1 20	5	21875	109375	0.21%	0.16%	C
BIO1 10	5	19675	98375	0.19%	0.16%	C
NC100 32	5	12500	62500	0.12%	0.16%	C

Remark: unit cost is based on price list on 1 October 2006

From the above table, class A was approx 75% of total drums sold while the rest were class B and C. Since 70.3% of total sales revenue and 75% of total drums sold were products in class A, it would be more appropriate to designate products in class A as the standard product and products in class B and C as the make-to-order product (Kumar and Harms, 2004; Bramham et al., 2005).

4.2 Work Study

As there has been no standard time and work instruction for each activity, manufacturing lead time is thus uncertain. Consequently, production planning and scheduling (and MRP) are inaccurate. As shown in Table 3.1 and 3.2, nearly a half of time spent in manufacturing activities were wastes. In this chapter, work study was conducted in order to improve process efficiency by eliminating wastes in manufacturing activities (Mathaisel and Comm, 2000; Rawabdeh, 2005; Hines et al., 1999), to set standard time, and to develop work instruction for each activity. Process activity map was applied to assess wastes in the manufacturing activities (Hines et al., 1999). In the first instance, an attempt was made only to five standard products. However, it was found that working procedures were slightly uncertain. Therefore, rough working procedures were made on a current working procedure basis. Table 4.2 illustrates average manufacturing lead time of each standard product and waste (waiting) found in the manufacturing activities. It could be seen that it takes more than four hours to produce five drums of the standard products and waste (waiting) is nearly 50% of time spent on the manufacturing activities.

Table 4.2 Average manufacturing lead time and waste found in manufacturing activities

Product Item	Average Time (min.)	Delay - Person 1 (min.)	Delay - Person 2 (min.)
CO90	236	112	101
COP50	241	117	106
FO100	263	112	118
FO220	268	112	123
NC622	248	107	103

Time spent on transportation can be reduced by changing the store position. It would seem that approx 14% of time spent on transportation is eliminated when store position has been changed. As shown in Figure 3.21, raw materials are kept slightly far from the work centre. To eliminate waste (transportation), store is then moved to a new position as shown in Figure 4.1 below.

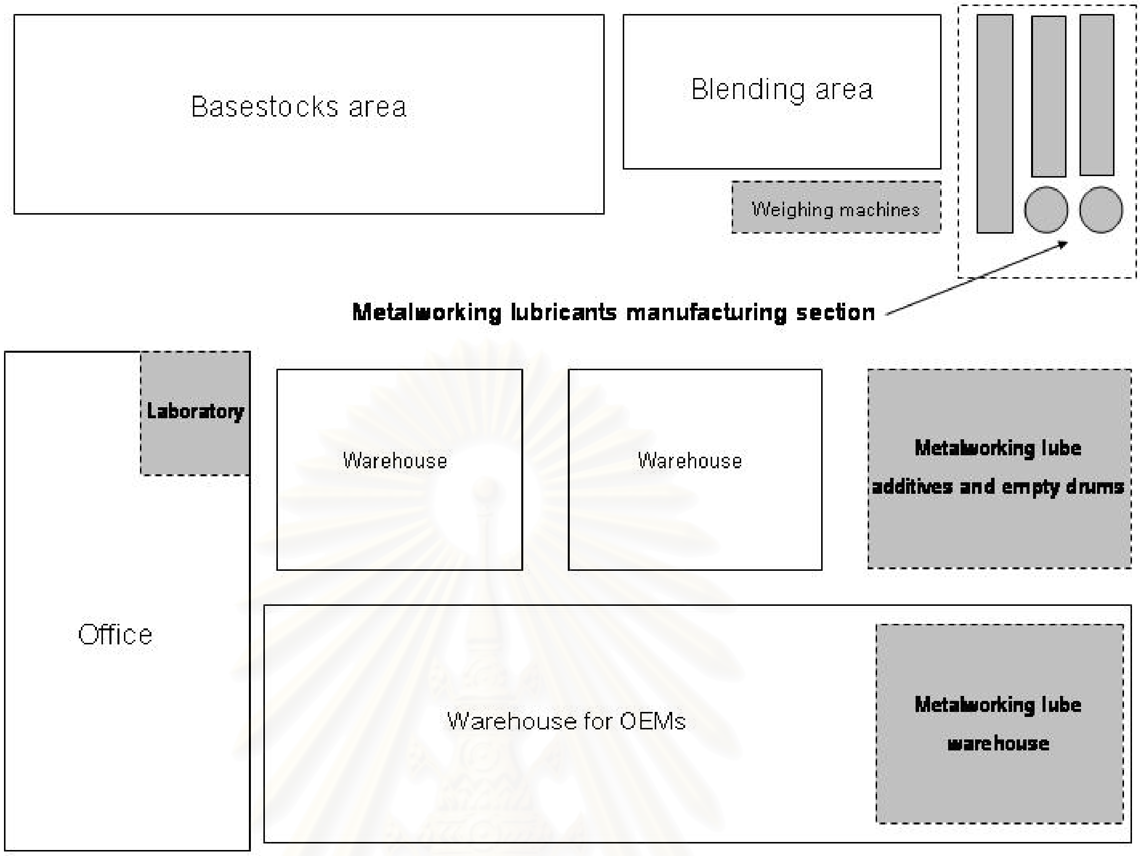

Figure 4.1 New MLS Layout

In the same way, the MLS warehouse is moved to a new position (in front of the work centre) from the current position (opposite the office) as shown in Figure 3.21. Table 4.3 shows average manufacturing lead time after store position was changed.

Table 4.3 Average manufacturing lead time after store position changed

Product Item	Average Time (min.)	%Reduction
CO90	207	12.29
COP50	212	12.03
FO100	227	13.69
FO220	232	13.43
NC622	202	18.55

Waste (waiting) in the manufacturing activities can be reduced by changing working procedures. The new working procedures of the standard products were thus developed and average manufacturing lead time was reduced by approx 35.4% as shown in Table 4.4 below.

Table 4.4 Average manufacturing lead time after new working procedures developed

Product Item	Average Time (min.)	%Reduction
CO90	139	32.85
COP50	144	47.22
FO100	175	29.71
FO220	175	32.57
NC622	150	34.67

In order to make new work instruction which is user-friendly, standard products were designated into three types: cutting soluble, neat oil (heat), and neat oil (using oil-dissolved additive). After method study was conducted, it was found that there were inappropriate work methods in the manufacturing activities. An attempt which aimed at eliminating waste (motion) was made to change the current work methods. Another waste found in the manufacturing activities was reworks. In order to reduce waste (reworks), an experiment was thus conducted to find out the appropriate blending time of each standard product. However, the detailed laboratory results were kept confidentially and can not be revealed in this article. Consequently, new work instruction was developed and average manufacturing time was reduced. Indeed, a discrepancy between standard and make-to-order products is the blending time. Make-to-order products can be classified into two types: soluble and neat oils. In the same way as standard products, an experiment was set to find out the appropriate blending time of each make-to-order product. Table 4.5 represents manufacturing lead time of each metalworking lubricant after work study was conducted.

Table 4.5 Manufacturing lead time for metalworking lubricant products

Product Type	Average Time (min.)
Cutting Oil Soluble	134
Neat Oil	154
Neat Oil (Oil-Dissolved Additive)	124
MTO Soluble Oil	184
MTO Neat Oil	134

In MLS, there are two machines (one for water soluble oil and another for neat oil). Thus, both water soluble oil and neat oil can be produced at the same time. Due to machine constraints, there are six possible events that can be occurred in MLS.

Table 4.6 Possible events of metalworking lubricants production

Event	Soluble Oil Machine	Neat Oil Machine	Average Time (min.)
1	Cutting Oil	Neat Oil	141
2	Cutting Oil	Neat Oil (Oil-Dissolved Additive)	132
3	Cutting Oil	MTO Neat Oil	132
4	MTO Soluble Oil	Neat Oil	162
5	MTO Soluble Oil	Neat Oil (Oil-Dissolved Additive)	162
6	MTO Soluble Oil	MTO Neat Oil	162

From Table 4.6, work study was conducted again in each particular case so as to find out average manufacturing time. Indeed, one of the bottlenecks found was the quality test. However, the test of neat oil and soluble oil are treated separately. For instance, neat oil requires viscosity test (using capillary viscometers) but soluble oil requires foaming characteristics test (using foaming test apparatus). When soluble oil and neat oil are produced at the same time, waste (waiting) can be reduced. As there are eight working hours each day, it could be therefore noted that the maximum capacity of each type is fifteen drums per day (fifteen drums for soluble oil and fifteen drums for neat oil).

4.3 Quotation Process

A quote is a document that describes the commitment by a business to the customer in term of product specification, price and delivery. A quote results from a quotation process that must convert a description of customer needs into organisational capabilities (Bramham et al., 2005). Resources need to be provided within the front-end of the business to facilitate the quotation process (Bramham et al., 2005; Kritchanchai and MacCarthy, 1999). Moreover, customer requirement definition and commercial configuration of customer order need a double side communication. On the commercial side, salesperson collects information from the customer and sends to planning officer for making the feasibility analysis such as rough-cut capacity and material availability, price and delivery date estimation, etc. On the technical side, planning officer generates BOMs, routings, and all information required for detailed supply and production planning after an order has been confirmed. Figure 4.2 illustrates the salient phases of the proposed integrated model of quotation process for VM companies. This model has been developed in the light of shortcomings, problems, approaches and solutions found in the literature and highlighted by the analysis of the case study factory (Babu, 1999; Bramham et al., 2005; Persona et al., 2004; Little et al., 2001; Yeh, 2000). In particular, the activities that should be taken into consideration by salespersons for the definition of an integrated solution supporting the quotation process in VM environment (which correspond to the first problem previously described) are highlighted by different thickness boxes.

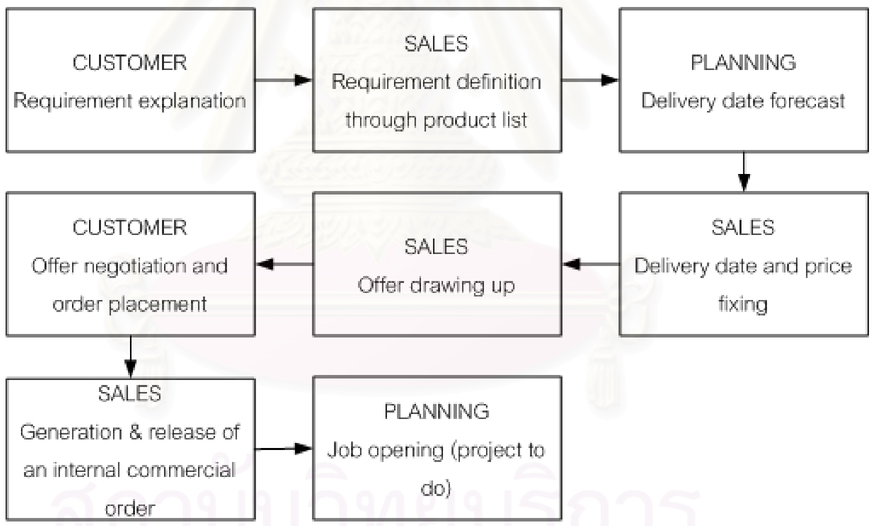

Figure 4.2 The proposed integrated model of quotation process in VM context

Key process stages form the basis of the conceptual model of the quotation process. Firstly, customer needs are discussed through product list (standard products and MTO products). Next, customer requirement definition will be sent to planning officers for making a rough-cut feasibility analysis, price and delivery date estimation, discussion modifications with internal experts, and decision whether customer request is accepted or rejected. In the negotiation stage, salesperson may present alternative standard product specification instead of MTO request. Once an order has been placed, salesperson generates an internal commercial order and sends it to planning officers for supply and production planning activities.

4.4 Material Requirements Planning

Material requirements planning (MRP) is a management system for production and inventory. Figure 4.3 illustrates the flows of information within a MRP system and indicates three primary inputs to the MRP system: master production schedule, bill of materials file, and inventory master file. It could be seen that a major output from the MRP system is the planned order release report. As the third problem had been identified, an attempt was made to improve the current MRP system. In the first instance, MRP inputs (master production schedule, inventory master files, and bill of materials file) were addressed and developed. Subsequently, the new MRP system was then developed and proposed.

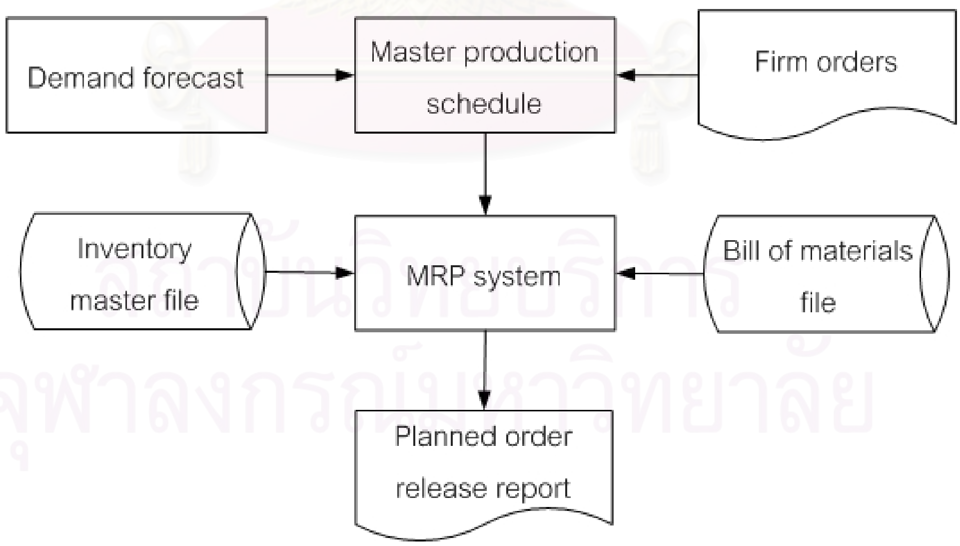

Figure 4.3 Schematic of MRP system

<u>Aggregate Planning and Master Production Schedule (MPS)</u>

The master production schedule is based on actual customer orders and predicted demand (Ashayeri and Selen, 2005; Little et al., 2001; Persona et al., 2004). This schedule indicates exactly when each ordered item will be produced to meet the firm and predicted demand. In other word, it is a time-phased production plan. The fundamental premise was that two pure production strategies exist, namely level and chase (Buxey, 2005). A level plan maintains a constant daily (aggregate) production rate, and draws upon stockpiles of finished goods whenever monthly output dip below their matching sales marks. Alternatively, a chase type plan adjusts the labour inputs in order to track the expected monthly demands. Common tactics for varying capacity are overtime or undertime, hiring or firing to change equipment manning levels or the number of operational shifts, and subcontracting some works out. As related to the characteristics of metalworking lubricant products and manufacturing processes, pure push strategy is ignored due to the following reasons.

- It is hard to obtain a reliable forecast for an unreliable demand, which has to be buffered with large safety stocks.
- Manufacturing lead time of each product is slightly short and average monthly demand does not in excess of the maximum capacity (after improved, approx 41.13% of the maximum capacity).
- As the matter of fact that the potential market consists of just a small group of customers, there is a relatively high chance of non-saleability (if all products produced-to-stock).
- Large numbers of product types increase the risk of having aged stocks, eventually leading to obsolete products (e.g. most products tend to sediment, if kept more than six months).

The chase rationale is based on similar logic to lean production (Porter et al., 1999; Sanchez and Perez, 2001; De Toni and Tonchia, 1996; Papadopoulou and Ozbayrak, 2005). The pure chase strategy is critical when products are valuable, or hard to store, and for goods that are perishable, or carry an appreciable risk of obsolescence (Buxey, 2005). Also, high product variety rules out accurate sales predictions over long time horizons, making stockpiling hazardous (a relatively high chance of non-saleability). A pure chase strategy is apparently applied to any product which is not classified as a standard product. On the other hand, all standard products require another strategy over the chase alternative. A modified chase strategy calls for some stockpiling, but firms alleviate the risks of holding unwanted goods by making informed tactical decisions (Buxey, 2005). For instance, export orders, indent orders, and the large orders associated with contract manufacture are all placed well before their required delivery dates. Such jobs are slotted into the MPS sooner than is strictly necessary to smooth out peaks and troughs (Ashayeri and Selen, 2005). As a result, the activity based on forecasts is the procurement of raw materials and empty drums whereas the activity based on orders is the manufacture of all standard lubricant products.

Bill of Materials (BOM)

Traditionally, companies use two separate data structures, bill of material (BOM) and routeing, to organise production data required for production planning and control (Yeh, 2000). A BOM is used to specify raw materials and components that make up a product. For a product or component to be manufactured, a routeing is used to specify the sequence of operations required at corresponding work centres. In MTO production, multi-level products and multi-item customer orders are two special operating characteristics that need to be addressed (Babu, 1999; Yeh, 2000). A set of production jobs, coupled with varying routeings and material requirements are needed to make a multi-level product. Production jobs created for making multiple line items on a customer order are required to be effectively linked, so that the customer order can be better managed in the production process (Meybodi, 1995; Yeh, 2000). Nevertheless, a great deal of time required to improve MRP system was spent restructuring BOMs and verifying their accuracy (Ashayeri and Selen, 2005; Bramham et al., 2005; Yeh, 2000). In the first instance, BOM file was thus developed in order to determine exactly what items, and in what quantities, are required to complete an order for a given item. The result of exploding a BOM for a give product is a time-phased requirement for specific quantities of each item necessary to make the finished product. Figure 4.4 illustrates an example of product structure tree developed for NC622.

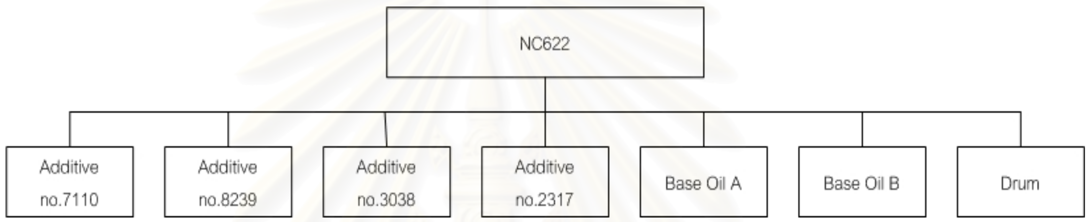

Figure 4.4 Product structure tree for NC622

As shown in Figure 4.4, product structure tree has only one level. As mentioned earlier, all level 1 components have been purchased from outside with different lead times. To be very user-friendly, the BOM of each product was thus developed in Microsoft Excel environment. Table 4.7 represents an example of BOM for NC622 (a one-level product).

Table 4.7 Bill of materials (BOM) for NC622

Product Item	Order (l)		
NC622	1000		
Components	**Quantity (l)**	**Quantity (kg)**	**Quantity (drum)**
Base Oil B	821		
Base Oil P	97		
Additive no.2317		80	
Additive no.3038		8	
Additive no.8239		5	
Additive no.7110		3	
Drum			5

<u>Inventory Master File</u>

In addition to the bill of materials, the inventory master file contains detailed information regarding the number or quantity of each item on hand, on order, and committed to use in various time periods. Two pieces of information are required from the inventory master file: quantity on hand and lead time (for purchase). More importantly, this inventory master file must be linked to MRP system and regularly updated. Once the three sources of information are available (i.e. master production schedule, bill of materials, and inventory master file), the MRP system can produce a requirements plan (Pibernik, 2006; Yeh, 2000). New inventory master file was then developed as shown in Table 4.8.

Table 4.8 Example of inventory master file

Base Oil		
Name	On-hand Quantity (l)	Lead Time (day)
Base Oil A (60)		3
Base Oil B (150)		3
Base Oil C (500)		3
Base Oil P		5

As previously discussed, the management of inventory (raw materials) becomes an important aspect in the case study factory. Consequently, it is necessary to anticipate material shortage situations and actively manage the allocation and re-allocation of available raw materials on the basis of customer requirements and priorities as well as contractual relationships (Pibernik, 2006). New MRP system was thus developed as shown in the following figure. In Figure 4.5, MRP system for standard products was proposed. The procurement is based on demand forecasts from the previous periods at the beginning of the current month. Procurement officer inputs forecasted demands in the BOM file and then check the availability of resources in inventory master file. Subsequently, purchase order (P/O) is thus issued.

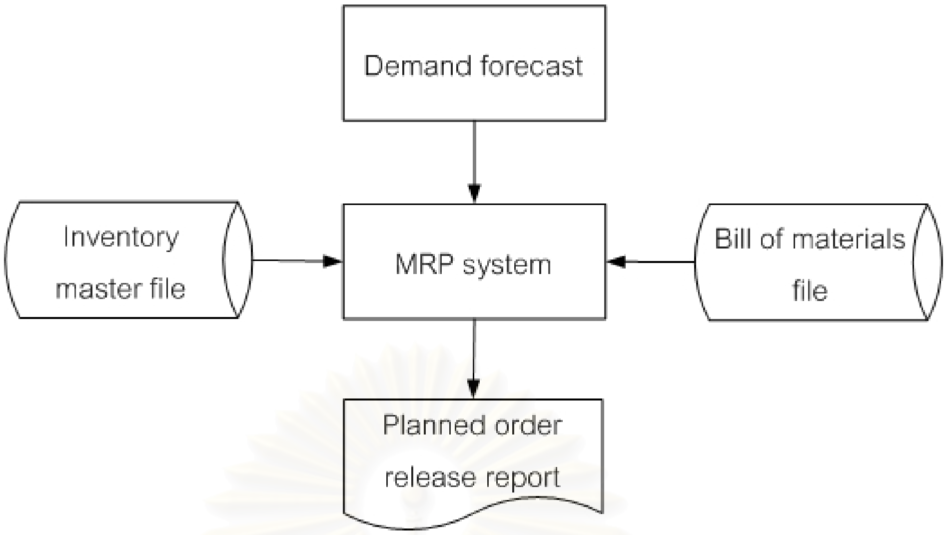

Figure 4.5 MRP system for standard products

On the other hand, MRP system for MTO products was proposed in Figure 4.6. The procurement is based on firm orders. Customer requirements are input in BOM file and procurement officer then check the availability of resources in the inventory master file. Subsequently, purchase order (P/O) is thus released. Nevertheless, the procurement of additives and base oils sometimes depends on the market price. MRP system however must be implemented as a total system, and implementation of any part of it without the rest will not be successful (Petroni, 2002). Thus, MRP system must be linked to all activities in the order to delivery cycle.

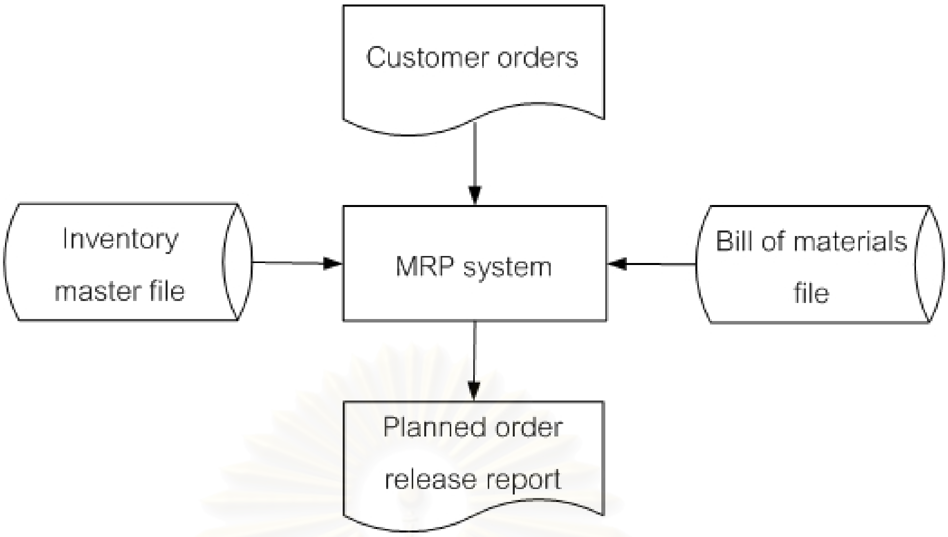

Figure 4.6 MRP system for MTO products

4.5 Shop floor management system

In a job shop of process-oriented layout, a work centre is designed to perform a particular operation activity, and is capable of processing products (jobs) with a wide variety of specifications (Yeh, 2005). In the kaizen blitz activity, participants claimed that one of the reasons of job lateness is a consequence of inefficacy of a conventional production scheduling approach. Production scheduling, which is a part of the planning and control of individual production units, lies at the very heart of the performance of manufacturing organisations (Stoop and Wiers, 1996). Additionally, it is time constrained and highly dynamic (Rogers, 1989). On the other side the scheduling function interacts with the other functions of a company. It is affected by the middle-range planning, which examines the stock levels, the demand forecasting and the requirements plan, in order to achieve the optimisation of the production in combination with the allocation of resources (Metaxiotis et al., 2002). As previously discussed, the work in a job shop is made-to-order and thus has critical customers' due dates associated with it. In the case study factory, scheduling is still a typically human domain and a priority rule used is first in, first out (FIFO). Nevertheless, humans are not very well equipped to control or optimise large and complex systems, and the relations between actions and effects are very difficult to assess (Stoop and Wiers, 1996). Moreover, scheduling approaches are generally constrained by finite capacity resources; precedence relations (i.e. routeings); and start dates and due dates of jobs (Kumar and Narendran, 1997; Gargouri et al., 2002; Appelqvist and Lehtonen, 2005). On the shop floor, many day-to-day disturbances which cause the performance deviations can be divided into three categories (Stoop and Wiers).

Capacity

Capacity disturbances can be divided into disturbances caused by machine capacity and operator capacity (Ulusoy and Ozdamar, 1996). In the kaizen blitz activity, plant manager pointed out that machine breakdowns have caused the job lateness. Maintenance plans were thus developed and implemented to avoid any breakdowns. Furthermore, it was found that the absence of production supervisor has led to the job lateness because on one can operate without the guidance of production supervisor. Nonetheless, this problem has been tackled by developing the work instruction as mentioned earlier. Therefore, any production staff can operate under the guidance of the work instruction.

Order

One of the order-related aspects that delay the progress of individual orders is the unavailability of raw materials (Stoop and Wiers, 1996). Since sales of the standard products are approx three-fourth of the total sales, the procurement of raw materials should be thus made in advance. On the other hand, the demands of the MTO products are very fluctuating. It would be therefore more appropriate to purchase any raw materials only when an order is placed. As previously discussed, the new MRP system was developed to address this problem. In the kaizen blitz activity, it was found that uncertain blending times have caused reworks and led to job lateness. Nonetheless, this problem was addressed by conducting work study as mentioned earlier. Another problem found during the kaizen blitz activity is that due dates are often committed without any concerns regarding processing times and resources. Nevertheless, this problem was handled by developing a new quotation process.

Measurement of data

All participants agreed that a disturbance related to the measurement of data is that of processing times estimated by plant manager. Schedulers who confront with significant processing time uncertainty often discover that a schedule which is optimal with respect to a deterministic or stochastic actual processing times. This type of a disturbance can often be found in MTO companies because of the lack of historical data about processing time of newly developed products (Stoop and Wiers, 1996). The determination of capacity efficiencies is another example of problematic measurement of data. A cause for this specific problem is that the definition of capacity is often unclear (Stoop and Wiers, 1996; Gargouri et al., 2002). As has been discussed, these problems were tackled by conducting the work study. Consequently, work instruction was developed and standard times of each process were set.

As mentioned earlier, many disturbances occur on the shop floor. Therefore, schedules have to be adjusted frequently. However, some techniques do not offer the possibility to adjust the schedule manually (Stoop and Wiers, 1996). It was suggested that interactive systems utilise human judgement in addition to using the capabilities of a computer during the decision making process (Rogers, 1989; Kondakci and Gupta, 1990; Davis and Kanet, 1997). Human beings, although limited by their ability to process information, can recognise patterns, identify problem areas, resolve ambiguity and uncertainty, and can adapt themselves to changing conditions (Kondakci and Gupta, 1990). Nonetheless, the success of interactive scheduling depends on the information supplied to the scheduler (Ulusoy and Ozdamar, 1996). Make-to-order companies have a few standard products. They tender a quotation, including the price and delivery lead time, for a particular job in response to a customer's enquiry. As a result, jobs must be prioritised by due dates (Babu, 1999). However, availability of resources must be checked before scheduling any jobs (Gargouri et al., 2002; Kumar and Narendran, 1997). A despatching rule is a rule that prioritises all the jobs that are waiting for processing on a machine (Metaxiotis et al., 2002). The prioritisation scheme may take into account the jobs' and the machines' attributes, as well as the current time. Whenever a machine has been freed, a despatching rule inspects the waiting jobs and selects the job with the highest priority (Stoop and Wiers, 1996; Westbrook, 1994; Yeh, 2005). Nevertheless, shop floor management system must be linked to other activities in the order to delivery cycle as illustrated in Figure 4.7 below.

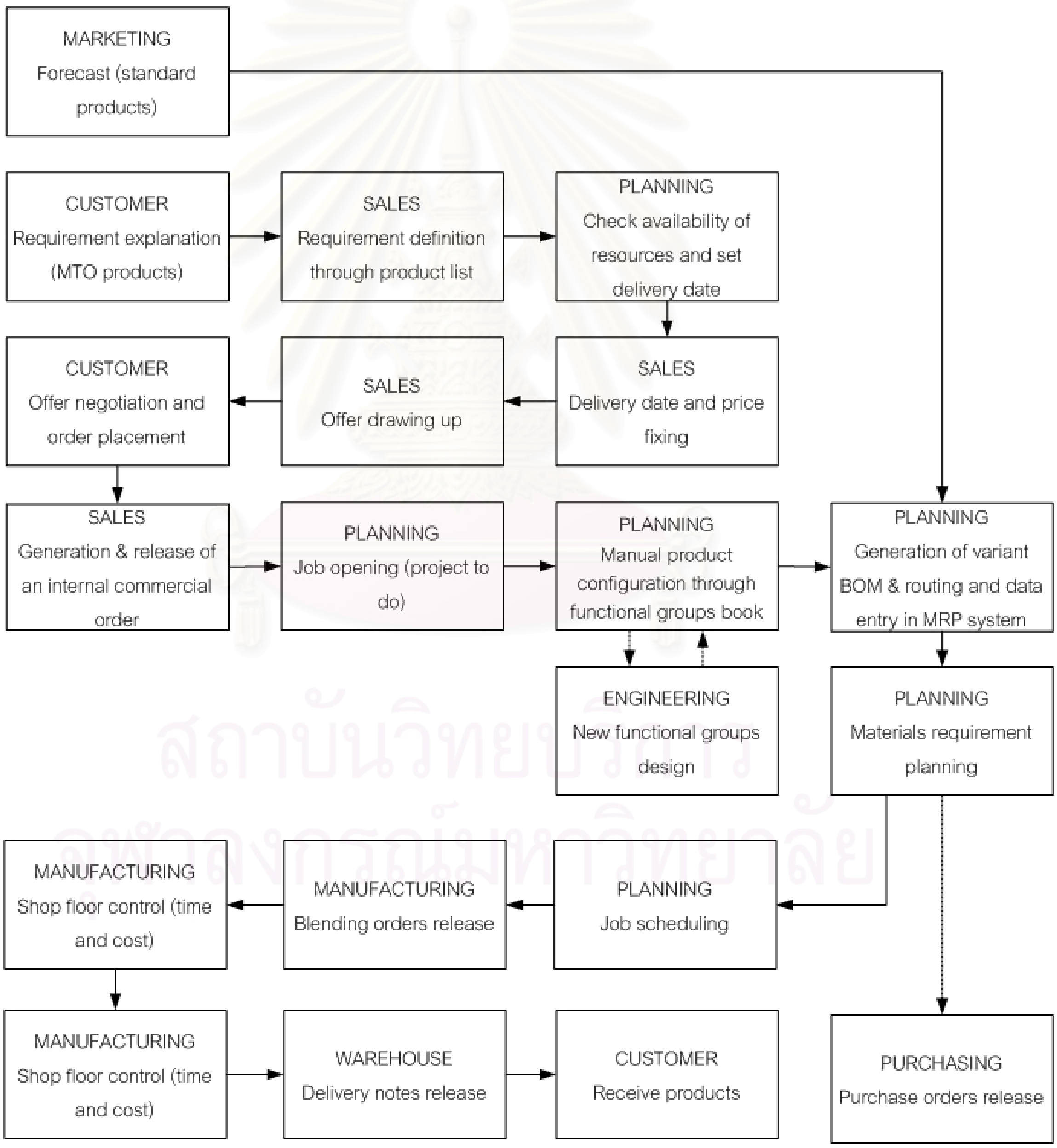

Figure 4.7 The proposed integrated model of order to delivery cycle

This cycle has been developed in the light of shortcomings, problems, approaches and solutions found in the literature and highlighted by the analysis of the case study factory. To sum up, an integrated solution supporting the order to delivery cycle in MTO environment can be described as the following phases (Ashayeri and Selen, 2005; Babu, 1999; Bramham et al., 2005; Buxey, 2005; Houghton and Portougal, 2001; Kritchanchai and MacCarthy, 1999; Little et al., 2001; Meybodi, 1995; Yeh, 2000).

1st Phase – before order confirmation

Salesperson is responsible for the initial contact with customers to check requirement definition through product list. Customer's enquiry is then passed to planning officer for setting delivery date. The setting of a realistic delivery date (due date) requires considering actual capacity and workload (Yeh, 2000). Once an initial offer has been confirmed by the customer, sales office releases an internal commercial order detailed in specification and due date.

2nd Phase – supply and production activity planning

Once an internal commercial order has been received, planning officer checks BOM and then enters into MRP system. In case of non-existent parts, planning officer contacts the laboratory asking for new configuration. Subsequently, purchase order is thus issued. For standard products, procurement of raw materials is made ahead before order placement (Petroni, 2002). Once work order is released, jobs are scheduled using priority despatching rule (if a job is completed at a workstation, the job with the shortest due date in the queue will be processed next). Nevertheless, overtime may be considered, if rush orders arrive (depend on negotiation with customers).

3rd Phase – supply and production activity control

Once a work order (blending order) has been released, manufacturing activities start. All metalworking lubricant products are kept in warehouse waiting for despatching. The performances of the operations can be conceptually divided into two categories: cost performances, including the production costs and the productivity, and non-cost performances, regarding the time, flexibility and quality (De Toni and Tonchia, 2001; Sweeney and Szwejczewski, 1996). Nevertheless, the company still uses Kaplan & Norton's balanced scorecard to measure overall performance. Since this research aims at tackling a problem of drum delivery delays, percent of late deliveries and percent of jobs that meet schedule are used as main performance measure.

4.6 Multi-functional team

The organisational structure of the case study company is presented in Figure 4.8. It would seem that metalworking lubricants section is a small part of the case study factory under the production division. As previously discussed, one of the major problems found in the case study company is that there has been no clear duty and responsibility of the staff in this section.

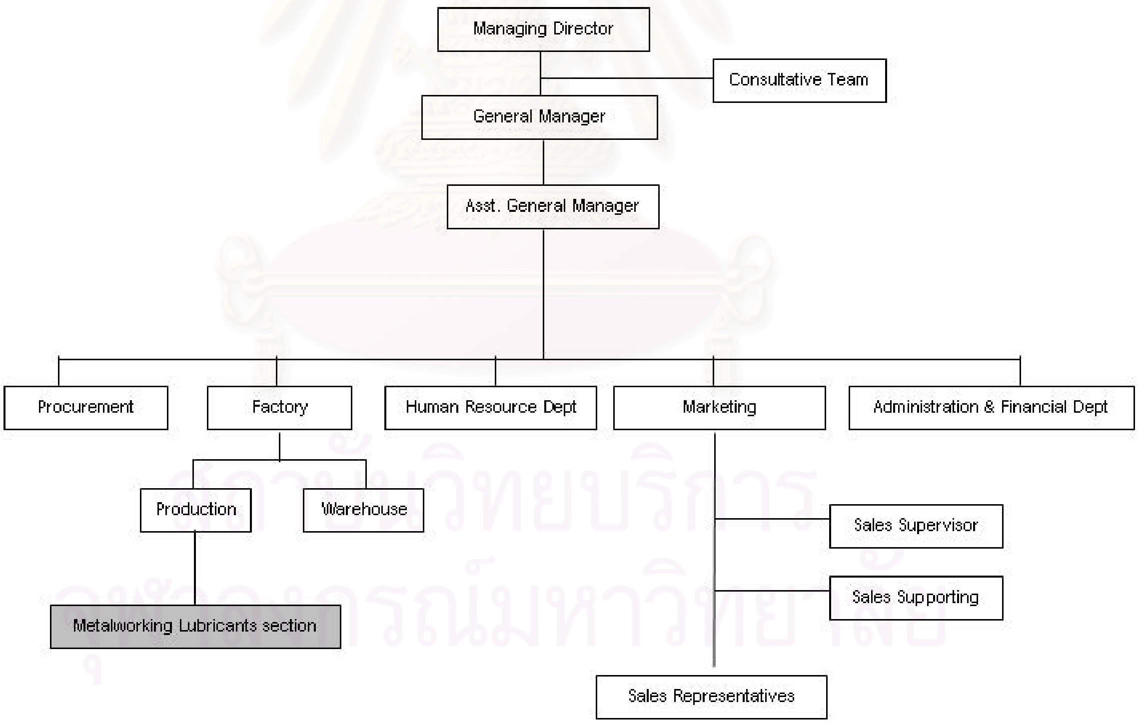

Figure 4.8 Organisation chart of the case study company

As a matter of fact that worker involvement is essential and critical, it is vital to set up a cross-functional team as well as define job duties and responsibilities for the personnel involved in MLS first (Achanga et al., 2006; Armistead and Machin, 1997; De Toni and Tonchia, 1996; Emiliani, 2000; Kumar and Harns, 2004; Petroni, 2002). A kaizen team is thus changed to MLS team. Consequently, a cross-functional team was developed to run all operations in MLS (Armistead and Machin, 1997; De Toni and Tonchia, 1996). Job duties and responsibilities were thus clearly defined to all personnel in this team. Apparently, there are three departments (marketing, factory and procurement) which are in charge of the order to delivery cycle of metalworking lubricant products. Nevertheless, there is currently no planning department in the case study company and it is not clear who is responsible for production planning in MLS. To tackle this problem, duties and responsibilities of the relevant staff were set. Job descriptions were therefore created (see in appendix). A summary of job descriptions can be illustrated as follows.

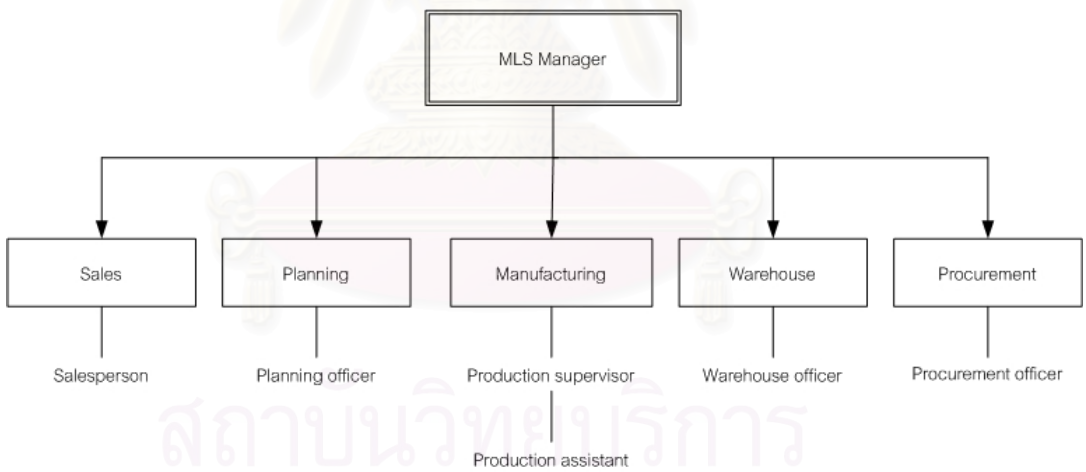

Figure 4.9 MLS chart

<u>MLS manager</u>

MLS manager is responsible for planning, organising, directing and controlling all manufacturing operations as well as handling and controlling the performance of the following sections: production, delivery, quality control, and maintenance in order to achieve the company's targets.

Production Supervisor

Production supervisor is in charge of coordinating with team on date and blending vessels to be used. This person is also responsible for planning all daily production activities and supervise subordinate to ensure completion of assigned task as well as verification of all results.

Production Assistant

Production assistant is responsible for producing finished products through blending process in an accurate manner, according to production schedule, safety handling of chemical substances in production area, and packaging formulated products in drums.

Warehouse Officer

Warehouse officer is responsible for planning the optimum inventory levels of finished goods and raw materials and coordinating with procurement on raw material requirements and logistics. This position is also in charge of preparing and delivering all finished goods as well as ensuring that preservation and handling are safe and comply with regulation and standards.

Procurement Officer

This person is in charge of all procurement activities and co-operating with all other departments. For instance, preparing and compiling Purchase Orders, establishing and maintaining potential vender record, and handling all clarifications during technical & commercial evaluation stage.

Salesperson

There are two types of salespersons: sales supervisor and sales supporting officer. Sales supervisor is responsible for all sales activities and monthly sales target. For example, developing and maintaining good relations with both new and existing customers as well as promoting products. This position is also in charge of responding to customer questions and complaints, and providing customer service as required by individual accounts. Furthermore, this person may take part in roadshow, trade events, both locally and internationally. On the other hand, sales supporting officer is however in charge of understanding and providing technical solutions to demanding customers as well as dealing with technical questions and quality complaints. This position has to co-operate with sales supervisors.

4.7 Case results

Many efforts were made to improve the efficiency of the processes. Firstly, metalworking lubricant products were designated into standard and MTO products (Babu, 1999; Bramham et al., 2005; Grunberg, 2003). As a result, there are five standard products and twenty four MTO products. This can help the company to effectively management its inventories (Ashayeri and Selen, 2005). After problems were identified and analysed, a bottleneck of order to delivery cycle was found in manufacturing processes (Armistead et al., 1995; Fowler, 1998; Grunberg, 2003; Gunasekaran et al., 2000; Khan et al., 2007; Kumar and Harns, 2004; Motwani, 2003). Secondly, work study was thus conducted to reduce the cycle times and develop standard work instruction. Result shows that average cycle times of standard product were reduced by an average of 37.80% as illustrated in Table 4.9. Wastes (motion, waiting, reworks and transport) were eliminated from the manufacturing activities (Hines et al., 1999; Jina et al., 1997; Rawabdeh, 2005, Remesh and Devadasan, 2007).

Table 4.9 Average cycle times after work study

Product item	Before	After	%Diff.
CO90	236	139	41.10
COP50	241	144	40.25
FO100	263	175	33.46
FO220	268	175	34.70
NC622	248	150	39.52

As cycle time was decreased, the case study company can increase its production capacity up to 30 drums per day (15 drums of neat oil and 15 drums of soluble oil). Subsequently, the proposed integrated model of order to delivery cycle was implemented at the case study factory in March 2007. Before implementation, production performances were measured for four weeks (week1-4), giving a reference level of performances. During a four-week test period (week4-8), the application was used for three shifts a day, excluding weekends. The application was taken into operational full time use in the second week of March 2007 (week8-14). Figure 4.10 and 4.11 represent demands during the period of the study. After a new system has been implemented, it would seem that soluble oil and neat oil demands did not exceed the maximum capacity. Average soluble oil demand was approx 47.43% of the maximum capacity and average neat oil demand was approx 45.05% of the maximum capacity.

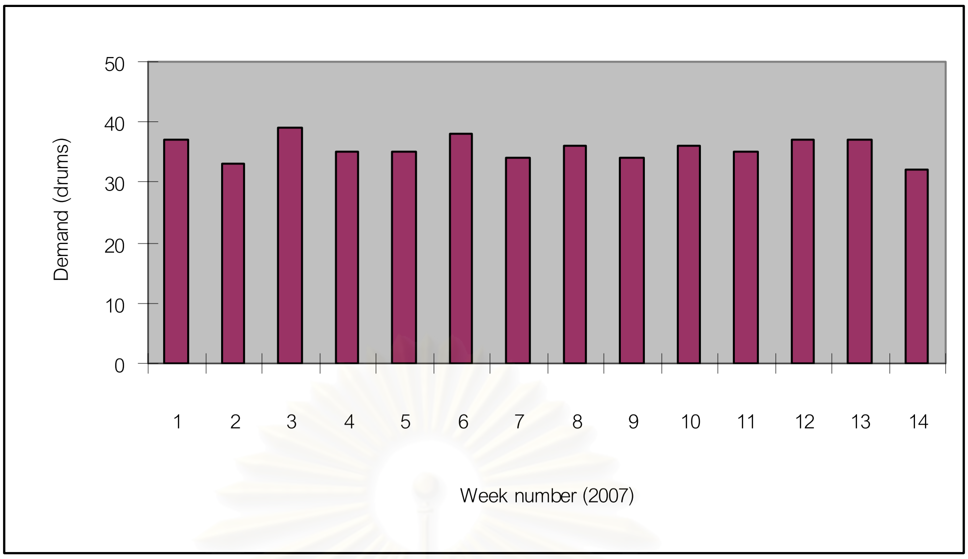

Figure 4.10 Soluble oil demands during the period of the study

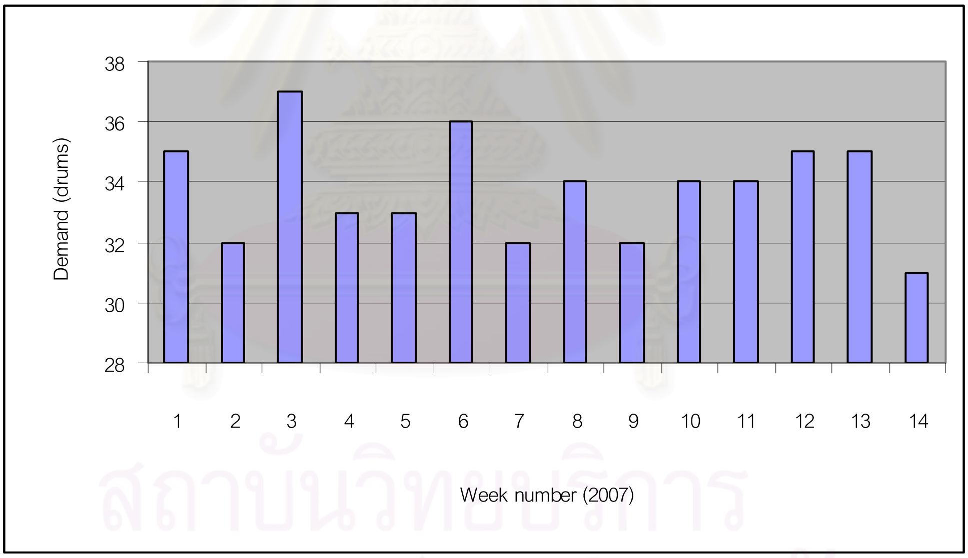

Figure 4.11 Neat oil demands during the period of the study

Results show that percent of late deliveries have decreased from a reference level of 49.29 to 2.83 (see Figure 4.12). In the period of the study, machine breakdowns, late materials supply, wrong materials supply, unavailable materials in the market and illness of operators were not found; otherwise these problems would bias the results. The percent of late deliveries during the study for weeks were compared using two-sample t-test (one-tail, assuming unequal variances). The improvement from reference period (week1-4) to operational use (week8-14) is highly significant ($p < 0.001$). The improvement from reference period (week4-8) to test period is also statistically significant ($p < 0.05$) while the improvement from test period to operational use is not statistically significant.

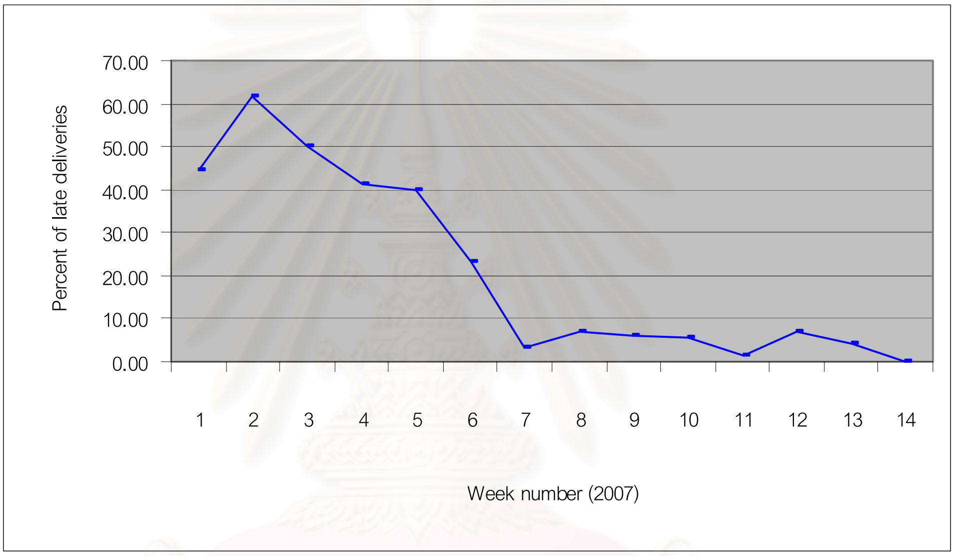

Figure 4.12 Percent of late deliveries

The percent of jobs that meet schedule have increased from a reference level of 39.22 to 95.37. The percent of jobs that meet schedule during the study for weeks were also compared using two-sample t-test (one-tail, assuming unequal variances). The improvement from reference period (week1-4) to operational use (week8-14) is highly significant ($p < 0.001$). The improvement from test period (week4-8) to operational use is very significant ($p < 0.01$) while the improvement from reference period to test period is not statistically significant.

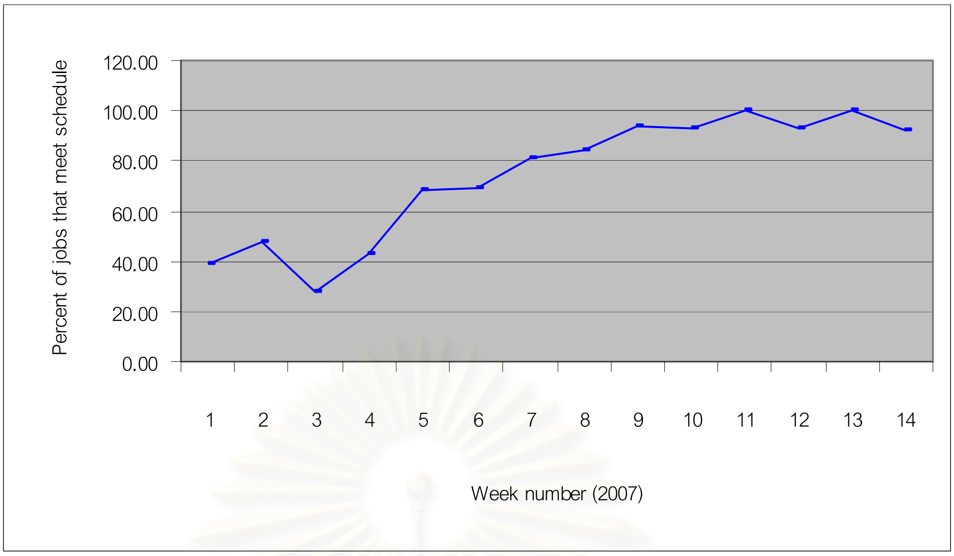

Figure 4.13 Percent of jobs that meet schedule

According to the above results, it can be therefore recognised that the proposed integrated model of order to delivery cycle can effectively solve a problem of drum delivery delays. Furthermore, it can be seen that number of overtime has decreased from a reference level of 20.25 to 1 (see Figure 4.14).

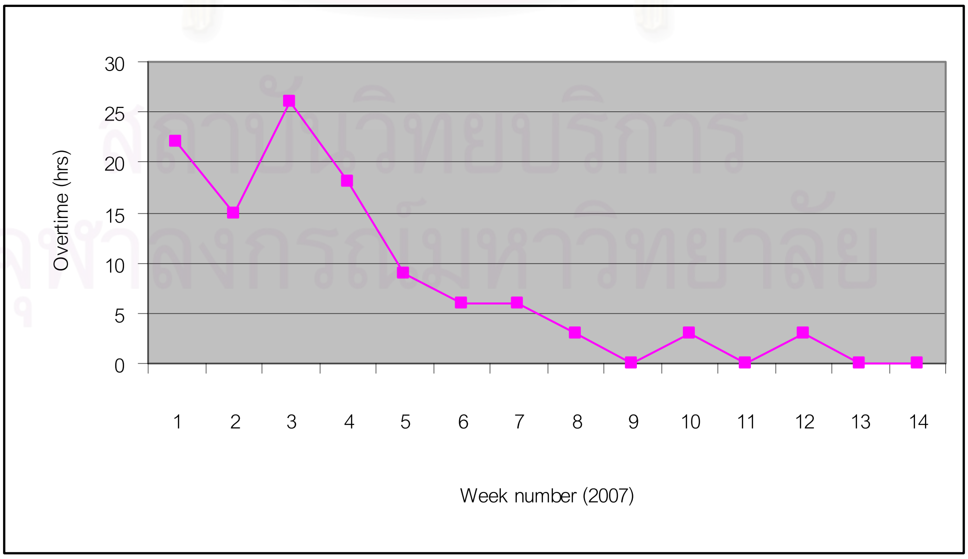

Figure 4.14 Number of overtime

The number of overtime during the study for weeks was compared using two-sample t-test (one-tail, assuming unequal variances). The improvement from reference period (week1-4) to operational use (week8-14) is very significant ($p < 0.01$). The improvement from reference period (week4-8) to test period is also very significant ($p < 0.01$), and likewise the improvement from test period to operational use is very significant ($p < 0.01$). Inventory turnover rate was increased from a reference level of 7.68 to 10.58 (see Figure 4.15). By using two sample t-test (one-tail, assuming unequal variances) for data comparison, it can be seen that the improvement from reference period (week1-4) to operational use (week8-14) is highly significant ($p < 0.001$). The improvement from test period (week4-8) to operational use is very significant ($p < 0.01$), and likewise the improvement from reference period to test period is very significant ($p < 0.01$).

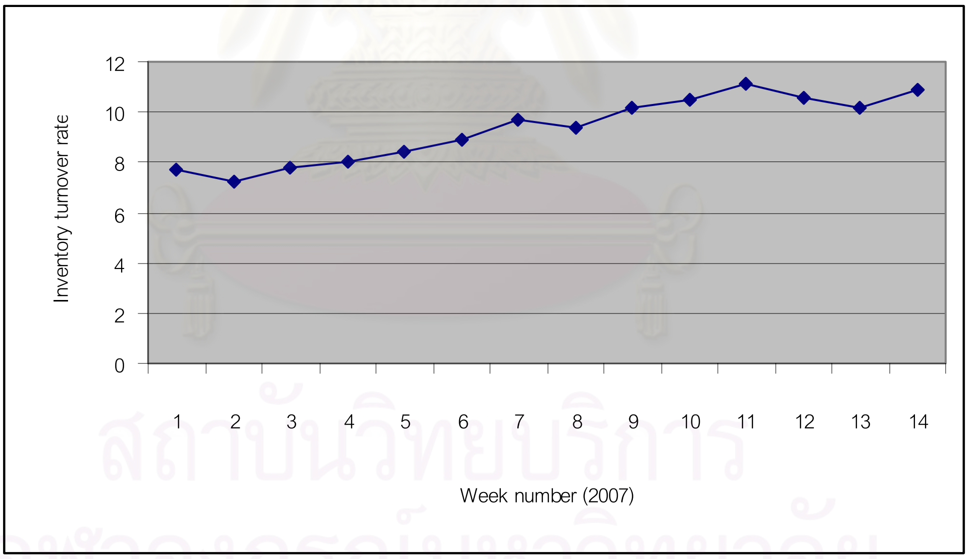

Figure 4.15 Inventory turnover rate

The percent of reworks have increased from a reference level of 30.62 to 1. The percent of reworks during the study for weeks were also compared using two-sample t-test (one-tail, assuming unequal variances). The improvement from reference period (week1-4) to operational use (week8-14) is highly significant ($p < 0.001$). The improvement from reference period (week4-8) to test period is also highly significant ($p < 0.01$) while the improvement from test period to operational use is not statistically significant.

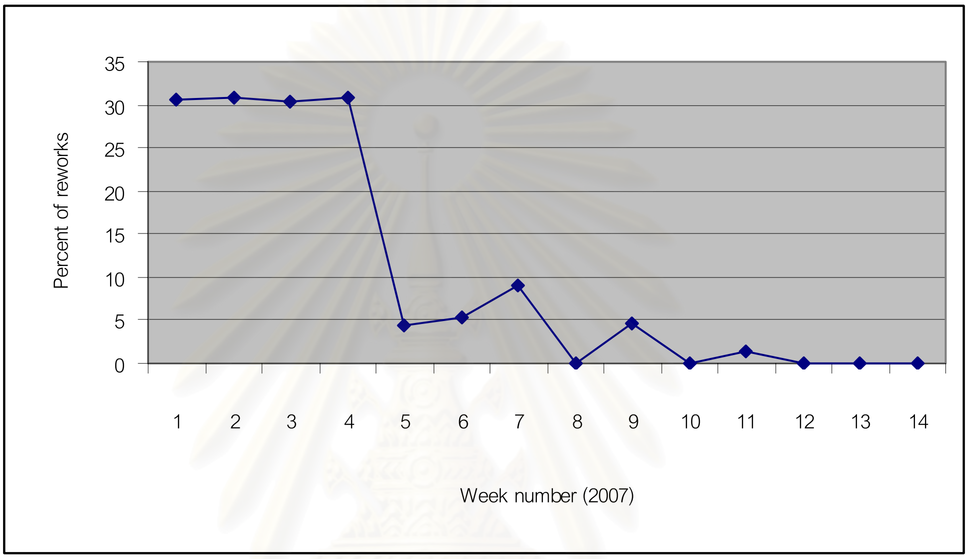

Figure 4.16 Percent of reworks

The number of labour-hours has decreased from a reference level of 28.25 to 9. The number of labour-hours during the study for weeks was also compared using two-sample t-test (one-tail, assuming unequal variances). The improvement from reference period (week1-4) to operational use (week8-14) is very significant ($p < 0.01$). The improvement from reference period (week4-8) to test period is also very significant ($p < 0.01$), and likewise the improvement from test period to operational use is very significant ($p < 0.01$).

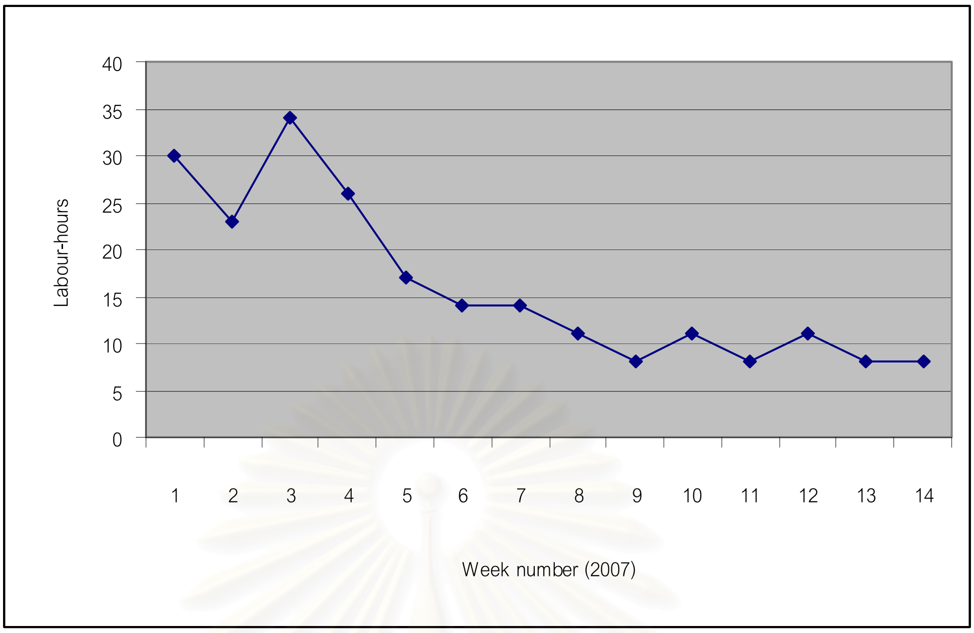

Figure 4.17 Labour hours

As all products are made-to-order, it is difficult to improve machine utilisation. However, machine utilisation for water soluble oil has increased from a reference level of 44% to 68% while machine utilisation for neat oil has increased from a reference level of 46.5% to 67%. This resulted from improvements in work methods. Moreover, utilisation can be improved if the company sets up a minimum production for each machine.

Nonetheless, difficulties occurred during the implementation that deviate the results were a consequence of many factors. The main aspect stopping a new system from being run effectively is the hierarchical structure, and the fact that people are not empowered enough to make and carry out their own decisions. Although a cross-functional team has been formed, MLS personnel still can not make their own decisions. Since many decisions are generally made on a subjective basis, it will not be as easy as introducing a policy or rule to adhere to. One possible way of overcoming this is for the departmental co-ordinator to initially take on a coach-cum-manager role to begin with (Gunasekaran et al., 2000). It means that although eventually he will take a less dictatorial role, just after the implementation, it is recommended that he acts as a guide for decisions such as purchasing. After a while, the newly empowered employees will have more of an idea, and be able to make better decisions on their own. As has been stated previously, scheduling is a manual task in the case study company because some elements of scheduling are very hard to automate (e.g. negotiating with suppliers about delivery dates). Making the system more transparent to the scheduler can be achieved by using simple decision rules, and by offering support that enables the human scheduler to monitor, adjust and implement schedules. However, human cognitive abilities fit well only with few task elements. As a result, mistakes can occur when many jobs have to be scheduled by procurement officer at one time. Electronic Gantt charts are widely recommended to improve performance of scheduling tasks where much information would have to be integrated mentally (Stoop and Wiers, 1996). Furthermore, external factors (e.g. pick-up truck breakdowns, wrong product supplies, accident, etc.) also deviate the results. Therefore, it can be seen that deviations are a consequence of human factors and uncontrollable factors. Nevertheless, human factors are controllable and can be managed. In order to ultimately be successful, a company must educate their workforce and create a fulfilling work environment for each of their employees (Kumar and Harms, 2004). Worker involvement is essential and critical in today’s business. Gaining the worker’s trust and commitment is extremely important.

CHAPTER V
CONCLUSION

Conclusion

In an MTO production environment, it is customers that are fundamentally important. Production activities are relevant only when they are co-ordinated to meet customers' demands. The characteristics of MTO environment (i.e. high product variety, low volumes, customisation, long lead time, uncertainty, etc.) make the order to delivery cycle and production planning and control, two really complex value adding processes. Lean & BPR model discussed in this paper provides a comprehensive solution to a complex shop floor management problem, in MTO environment where company has to be able to respond to dynamically changing market conditions. The dramatic performance improvements available by following lean & BPR principles are well established in MTO environment. The benefits that leanness offers to those systems in terms of flexibility, costs, lead times, efficiency, business volume and profitability are very attractive and capable of ensuring better competitive edge in meeting greater and serious challenges that lie ahead in the future. BPR is less directly focused and thus more of a general improvement methodology. Its particular approach is to consider radical change as a means of improving operations. This radical change allows new, revolutionary ideas to evolve; these may make a dramatic change in performance, compared to the evolutionary and incremental improvements that are often delivered by the more focused methods. Lean & BPR is a conceptual model based on a few established principles and techniques. Some of them affect exclusively the production department while others integrate several company functions. Figure 5.1 represents the basic structure of lean & BPR model according to the most common lean production and BPR principles found in the literature. Four elements of the model are derived from common basic lean and BPR practices which contribute to improve the company's performance.

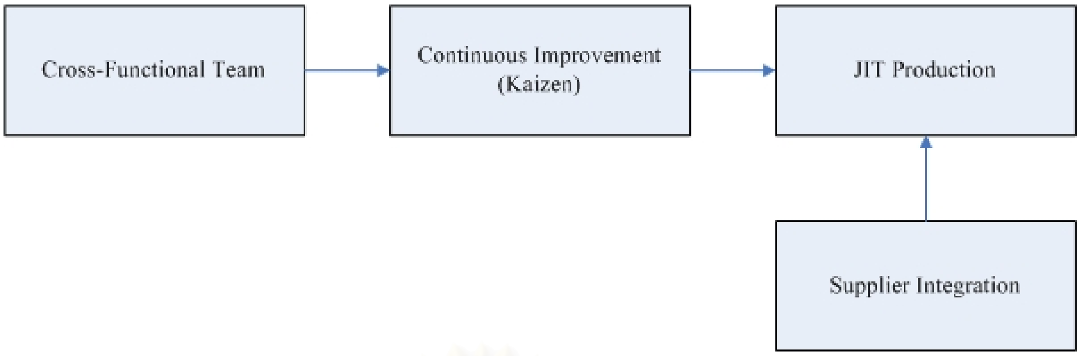

Figure 5.1 Lean & BPR model

There are a number of models or steps proposed in the literature for implementing any models. However, no standard integrated methodology for model implementation exists yet. As the number of organisations launching improvements efforts is growing rapidly, there is thus a need for more practical guidance for practitioners through the process of innovation and change. When implementing lean & BPR model, a company should consider a four-phase comprehensive improvement plan. The inputs of this model were generated from the review of literature. The four phases of the model include identifying, analysing, implementing,, and evaluating.

In the first phase of the model, business process that needs to be improved was identified. Then, objective of the project and indicators were defined. A cross-functional team (kaizen team) was formed through kaizen blitz activity. However, key staff members from the primary organisational units involved in the process should be included in the team. Training includes soft skills and employee trainings to use the old and new tools of quality. In order to gain awareness from employees (both in office and in a shop), it is extremely important to train and educate them in kaizen activities. The training of employees and staff started from concepts such as 5S, business process reengineering, lean production, value stream mapping which are simple to explain and equally well demonstrable. The beauty and simplicity about kaizen training is that SMEs with tight budgets can incrementally introduce the umbrella concepts of kaizen, which will eventually take them to be a world-class company that will always be looking to improve. Once the company has instilled a kaizen culture, further concepts under the kaizen umbrella can be implemented.

In the second phase, the project team evaluated and documented current processes, uncovered bottlenecks, and established baselines and benchmarks for gauging future improvements. During this phase, the efforts of the project team are focused on identifying breakthrough opportunities and designing new work steps or processes that will create quantum gains and competitive advantage. Process activity map is an excellent tool to use during activity analysis. Use of process activity map enables gaining consensus among everyone involved through his or her ownership and participation. Process activity map also helps identify the non-value-added steps within current procedures and helps guide the worker towards eliminating them.

The third phase, referred to as implementing involves actual improvement to the reinvented process or organisation. A phased approach was used to introduce the system into the company. For example, the major change over for the company was moving from traditional procurement practices to lean procurement practices. With a traditional procurement system, the focus was on supply and demand. This resulted in the maintenance of a large paperwork, and slow pace at which changes were made. By implementing lean procurement, the company was focusing on the key elements of JIT production. The areas of JIT production the company focused on value added (customers only want to pay for what makes the product better). Team's responsibility is to reduce their production to include only those areas that are essential to the product. Work study was also conducted to eliminate non-value-added activities in the shop floor. By changing work methods and procedures, cycle time can be significantly decreased. One of the lean management features is an attempt to reduce task time variation by organising data. Traditionally, companies use two separate data structures, bill of material (BOM) and routeing, to organise production data required for production planning and control. A BOM is used to specify raw materials and components that make up a product. For a product or component to be manufactured, a routeing is used to specify the sequence of operations required at corresponding work centres. In the first instance, BOM file was thus developed in order to determine exactly what items, and in what quantities, are required to complete an order for a given item. The result of exploding a BOM for a give product is a time-phased requirement for specific quantities of each item necessary to make the finished product. In addition to the BOM, the inventory master file contains detailed information regarding the number or quantity of each item on hand, on order, and committed to use in various time periods. Two pieces of information are required from the inventory master file: quantity on hand and lead time (for purchase). However, it is important that inventory master file must be linked to MRP system and regularly updated. Research indicates that under a cross-functional team results in superior performance. In terms of inter-organisational processes, it is suggested the benefits of partnering with external suppliers. The company worked very closely with related vendors during the model implementation process, even allowing vendors to provide inputs on how to improve their system. When any problems were discovered, managers would meet to discuss the same and contact vendors for fixes. Several key vendors played an active role in the overall implementation.

The final phase of the model involves evaluating the success of the improvement efforts against the performance objectives established in the first phase. After this phase, it is important to loop back to the first phase to keep the improvement process continuous. The success of model implementation has been reported back to everyone within the company. This not only motivates the workforce, but it also becomes a catalyst in creating a culture of continuous improvement (a culture where improvement activities will become a normal everyday activity). As MLS has its own staff, machines, area and management systems, it can be a strategic business unit which is independent of other departments to increase company's profitability.

Lean & BPR model demonstrates that productivity can be continuously improved, with no limit, by identifying and eliminating waste using Kaizen and related tools. Nevertheless, it is important to remark that lean & BPR model is not a panacea to solve short-term competitive problems, but its effects can also be seen in the long-term.

To ultimately be successful, a company must educate their workforce and create a fulfilling work environment for each of their employees. Apart from lean production, lean behaviours however extend the definition of productivity to include human behaviours (i.e. negative thoughts, low trust, inconsistency, politics, and ego). The amount of waste presented in human behaviours it probably grater than the waste that exists in production. Finding and eliminating behavioural waste can have a profound impact on overall business productivity and sustain high rates of productivity improvement. An integrated model of lean & BPR provides a structured approach to change in business settings, and is based upon a simple idea that most organisations can relate to the elimination of waste in production and behaviours. This solution sets clear direction, identifies specific activities to perform, aligns people, and establishes the foundation for motivating people. Behavioural waste and confusion are reduced so that people can focus on doing work that adds value in the eyes of the customer, which ultimately benefits employees, suppliers, and organisation.

In addition, it could be noted that lean & BPR approach can improve shop floor management decisions. It not only reduces the number of shop floor problems to be solved by production personnel, but more importantly enhances the organisation's capabilities to respond faster and be more focused to market changes. As the success of model implementation, MLS could be a pilot project for further development for the engineering business unit.

Suggestion

Significant benefits such as decreased percent late deliveries, increased percent of jobs that meet schedule and reduced cycle time can accrue from the successful implementation of lean & BPR model. However, it is suggested that the long-term implementation' success rate of any approach is low, especially among small and medium-sized enterprises (SMEs) that have yet to exploit the full potential of the model in their organizations. Installing a new system such as an integrated model of order to delivery cycle is a major change and therefore a critical stage that has to be properly managed. The full implementation of a new system may lead to achieving all of the previous tasks or at least some of them. However, the relevant literature reveals many problems still occurring with model implementation (Achanga et al., 2006). Some of these problems are that personnel do not comprehend the main goals for lean implementation, personnel involved in the implementation process do not have a clear understanding of the approach to implementation and personnel have not had previous experience in the implementation of complex information systems.

It is therefore recommended that senior management of the case study company must be mindful of the challenges that they are subscribing to because it requires dedicated unlearning of embedded mindsets and habits. Key success factors in implementation include (Achanga et al. 2006; Emiliani, 2000):

1. Long-term and unwavering personal commitment by all senior managers
2. Gaining a deep understanding of both lean production and lean behaviours
3. Understanding current business process and the behaviours that limit productivity through stakeholder feedback and root cause analysis
4. Defining the desired future business processes and behaviours
5. Engaging in daily practice of the unified system
6. Educating key stakeholders on plans, process, and progress
7. Documenting and sharing experiences
8. Resisting temptations to engage in corrupted forms of lean production and lean behaviours

In addition, there is also the need to balance superior efforts with reward. This however should be documented so that no unfairness implications can be issued or implied. Employees in any job, not just in the shop floor, should be applauded for excelling within the guidelines of prescribed controls and measurements. For instance, prizes should be awarded for cost savings ideas at quarterly “all-employees” meetings. Additional responsibility coupled with enhanced position and title can lead to increase worker satisfaction and productivity (Kumar and Harms, 2004).

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Appendices

Appendix A: Input files for MRP system

Table A.1 Inventory master file (additives and other components)

Additives for Neat Oil		
Name	Quantity on hand (kg)	Lead Time (day)
Additive no.2317		3
Additive no.2515		3
Additive no.2540		3
Additive no.2811		3
Additive no.3038		3
Additive no.7110		3
Additive no.8100		5
Additive no.8239		3
Additive no.9410		5
Other Components for Neat Oil		
Name	Quantity on hand (kg)	Lead Time (day)
Chem V-189		5
Chem V-178		5
Additives of Soluble Oil		
Name	Quantity on hand (kg)	Lead Time (day)
Additive APX		3
Additive GY		3
Additive 2000X		3
Additive BRG		3
Additive 016		3
Additive VPL		3
Additive GFC900		3
Additive SGL		3

Table A.2 Inventory master file (base oil and drum)

Base Oil		
Name	Quantity on hand (l)	Lead Time (day)
Base Oil A (60)		3
Base Oil B (150)		3
Base Oil C (500)		3
Base Oil P		5
Drum		
Name	Quantity on hand (unit)	Lead Time (day)
200L Drum		3

Table A.3 Example of BOM file (NC622)

Product Item	Order (l)		
NC622	1000		
Components	Quantity (l)	Quantity (kg)	Quantity (drum)
Base Oil B	821		
Base Oil P	97		
Additive no.2317		80	
Additive no.3038		8	
Additive no.8239		5	
Additive no.7110		3	
Drum			5

Table A.4 Example of BOM file (NC100)

Product Item	Order (l)		
NC100	600		
Components	Quantity (l)	Quantity (kg)	Quantity (drum)
Base Oil A	589		
Additive no.2811		12	
Drum			3

Appendix B: Statistical analysis

Table B.1 An analysis of case result – percent of late deliveries

Period	Mean value	n	t-test significance results	p result	Level
Reference	49.29	4	Reference and Test	0.010982	Significant
Test	18.21	4	Reference and Operational use	0.000191	Highly
Operational use	2.83	6	Test and Operational use	0.093039	No

Table B.2 An analysis of case result – percent of jobs that meet schedule

Period	Mean value	n	t-test significance results	p result	Level
Reference	39.22	4	Reference and Test	0.000408	Highly
Test	75.66	4	Reference and Operational use	0.000113	Highly
Operational use	95.37	6	Test and Operational use	0.005422	Very

Table B.3 An analysis of case result – number of overtime

Period	Mean value	n	t-test significance results	p result	Level
Reference	20.25	4	Reference and Test	0.003044	Very
Test	6.00	4	Reference and Operational use	0.002213	Very
Operational use	1.00	6	Test and Operational use	0.007551	Very

Table B.4 An analysis of case result – inventory turnover rate

Period	Mean value	n	t-test significance results	p result	Level
Reference	7.68	4	Reference and Test	0.003915	Very
Test	9.10	4	Reference and Operational use	0.000002	Highly
Operational use	10.58	6	Test and Operational use	0.002918	Very

Table B.5 An analysis of case result – percent of reworks

Period	Mean value	n		t-test significance results p result	Level
Reference	30.62	4	Reference and Test	0.000411	Highly
Test	4.73	4	Reference and Operational use	0.000000	Highly
Operational use	1.00	6	Test and Operational use	0.068889	No

Table B.6 An analysis of case result – number of labour-hours

Period	Mean value	n		t-test significance results p result	Level
Reference	28.25	4	Reference and Test	0.003044	Very
Test	14	4	Reference and Operational use	0.002213	Very
Operational use	9.00	6	Test and Operational use	0.007551	Very

Appendix C: Work instruction

Table C.1 Work instruction for standard product – cutting oil soluble

For production person1

Step No.	Average Time (min)	Step Description
1	2	Collect blending order at the factory office
2	7	Check equipments
3	4	Drive forklift to move additive drums to preparation area
4	12	Use forklift to move production person2 (with drums) to pour additives
5	3	Open valves to fill base oil into the tank
6	2	Move filling apparatus to blending tank
7	8	Remove additive drums to recycle drum area (outside)
8	5	Move empty drums to the mixing area
9	5	Check empty drums condition
10	20	Wait until blending process finishes
11	2	Wait until sample has already been collected
12	2	Walk to laboratory for quality testing
13	42	Wait for laboratory results and walk to mixing area
14	15	Put lids onto lube drums
15	5	Clear out the manufacturing site

For production person2

Step No.	Average Time (min)	Step Description
1	2	Collect blending order at the factory office
2	7	Check equipments
3	4	Wait for additives at preparation area
4	12	Weigh additives and pour additives into blending tank
5	3	Start pump and open valves to fill base oil into the tank
6	2	Push button to start blending process
7	8	Move additive drums (not used up) to warehouse
8	5	Move empty drums to the mixing area

9	5	Move empty drums onto the base
10	20	Wait until blending process finishes
11	2	Collect sample
12	2	Wait for laboratory test
13	42	Wait for laboratory results
14	15	Fill lubricant into empty drums
15	5	Drive forklift to move finished goods to warehouse

Table C.2 Work instruction for standard product – neat oil

For production person1

Step No.	Average Time (min)	Step Description
1	2	Collect blending order at the factory office
2	7	Check equipments
3	4	Drive forklift to move additive drums to preparation area
4	15	Pre-mix base oil and additive in small heating tank
4	7	Use forklift to move production person2 (with drums) to pour additives and mixture
5	3	Open valves to fill base oil into the tank
6	2	Move filling apparatus to blending tank
7	8	Remove additive drums to recycle drum area (outside)
8	5	Move empty drums to the mixing area
9	5	Check empty drums condition
10	40	Wait until the blending process finishes
11	2	Wait until sample has already been collected
12	2	Walk to laboratory for quality testing
13	32	Wait for laboratory results and walk to mixing area
14	15	Put lids onto lube drums
15	5	Clear out the manufacturing site

For production person2

Step No.	Average Time (min)	Step Description
1	2	Collect blending order at the factory office
2	7	Check equipments
3	4	Wait for additives at preparation area
4	15	Weigh additives
4	7	Pour additives and mixture into blending tank
5	3	Start pump and open valves to fill base oil into the tank
6	2	Push button to start blending process
7	8	Move additive drums (not used up) to warehouse
8	5	Move empty drums to the mixing area
9	5	Move empty drums onto the base
10	40	Wait until the blending process finishes
11	2	Collect sample
12	2	Wait for laboratory test
13	32	Wait for laboratory results
14	15	Fill lubricant into empty drums
15	5	Drive forklift to move finished goods to warehouse

Table C.3 Work instruction for standard product – neat oil (oil-dissolved additive)

For production person1

Step No.	Average Time (min)	Step Description
1	2	Collect blending order at the factory office
2	7	Check equipments
3	4	Drive forklift to move additive drums to preparation area
4	12	Use forklift to move production person2 (with drums) to pour additives
5	3	Open valves to fill base oil into the tank
6	2	Move filling apparatus to blending tank
7	8	Remove additive drums to recycle drum area (outside)
8	5	Move empty drums to the mixing area
9	5	Check empty drums condition

10	20	Wait until the blending process finishes
11	2	Wait until sample has already been collected
12	2	Walk to laboratory for quality testing
13	32	Wait for laboratory results and walk to mixing area
14	15	Put lids onto lube drums
15	5	Clear out the manufacturing site

For production person2

Step No.	Average Time (min)	Step Description
1	2	Collect blending order at the factory office
2	7	Check equipments
3	4	Wait for additives at preparation area
4	12	Weigh additives and pour additives into blending tank
5	3	Start pump and open valves to fill base oil into the tank
6	2	Push button to start blending process
7	8	Move additive drums (not used up) to warehouse
8	5	Move empty drums to the mixing area
9	5	Move empty drums onto the base
10	20	Wait until the blending process finishes
11	2	Collect sample
12	2	Wait for laboratory test
13	32	Wait for laboratory results
14	15	Fill lubricant into empty drums
15	5	Drive forklift to move finished goods to warehouse

Table C.4 Work instruction for MTO product – soluble oil

For production person1

Step No.	Average Time (min)	Step Description
1	2	Collect blending order at the factory office
2	7	Check equipments
3	4	Drive forklift to move additive drums to preparation area
4	12	Use forklift to move production person2 (with drums) to pour additives
5	3	Open valves to fill base oil into the tank
6	2	Move filling apparatus to blending tank
7	8	Remove additive drums to recycle drum area (outside)
8	5	Move empty drums to the mixing area
9	5	Check empty drums condition
10	70	Wait until the blending process finishes
11	2	Wait until sample has already been collected
12	2	Walk to laboratory for quality testing
13	42	Wait for laboratory results and walk to mixing area
14	15	Put lids onto lube drums
15	5	Clear out the manufacturing site

For production person2

Step No.	Average Time (min)	Step Description
1	2	Collect blending order at the factory office
2	7	Check equipments
3	4	Wait for additives at preparation area
4	12	Weigh additives and pour additives into blending tank
5	3	Start pump and open valves to fill base oil into the tank
6	2	Push button to start blending process
7	8	Move additive drums (not used up) to warehouse
8	5	Move empty drums to the mixing area
9	5	Move empty drums onto the base
10	70	Wait until the blending process finishes

11	2	Collect sample
12	2	Wait for laboratory test
13	42	Wait for laboratory results
14	15	Fill lubricant into empty drums
15	5	Drive forklift to move finished goods to warehouse

Table C.5 Work instruction for MTO product – neat oil

For production person1

Step No.	Average Time (min)	Step Description
1	2	Collect blending order at the factory office
2	7	Check equipments
3	4	Drive forklift to move additive drums to preparation area
4	12	Use forklift to move production person2 (with drums) to pour additives
5	3	Open valves to fill base oil into the tank
6	2	Move filling apparatus to blending tank
7	8	Remove additive drums to recycle drum area (outside)
8	5	Move empty drums to the mixing area
9	5	Check empty drums condition
10	30	Wait until the blending process finishes
11	2	Wait until sample has already been collected
12	2	Walk to laboratory for quality testing
13	32	Wait for laboratory results and walk to mixing area
14	15	Put lids onto lube drums
15	5	Clear out the manufacturing site

For production person2

Step No.	Average Time (min)	Step Description
1	2	Collect blending order at the factory office
2	7	Check equipments
3	4	Wait for additives at preparation area
4	12	Weigh additives and pour additives into blending tank

5	3	Start pump and open valves to fill base oil into the tank
6	2	Push button to start blending process
7	8	Move additive drums (not used up) to warehouse
8	5	Move empty drums to the mixing area
9	5	Move empty drums onto the base
10	30	Wait until the blending process finishes
11	2	Collect sample
12	2	Wait for laboratory test
13	32	Wait for laboratory results
14	15	Fill lubricant into empty drums
15	5	Drive forklift to move finished goods to warehouse

Appendix D: Job description

Job Title: MLS Manager

Job Summary:

MLS manager is responsible for planning, organising, directing and controlling all manufacturing operations as well as handling and controlling the performance of the following sections: production, delivery, quality control, and maintenance in order to achieve the company's targets.

Responsible to: Assistant General Manager

Duties:

- Plan monthly, weekly and daily production in line with MLS's overall plan.
- Lead production team to meet production targets.
- Leading daily production meetings.
- Planning of manpower, shifts, spare parts, consumables, and tools needed in the production department in accordance with the production plan.
- Reporting downtimes, performance rates and quality rates.
- Reporting key performance indicators (Balanced Scorecard)
- Participating in setting the maintenance and spare parts planning of production lines.
- Reports near loss and loss investigation for production Department.

Job Title: Procurement Officer

Job Summary:

This position is in charge of all procurement activities and co-operating with all other departments. For instance, preparing and compiling Purchase Orders, establishing and maintaining potential vender record, and handling all clarifications during technical & commercial evaluation stage. Procurement officer is also responsible for job scheduling.

Responsible to: MLS Manager

Duties:

- Analyses all requisitions to determine actual needs in terms of specifications, quantities and lead times.
- Analyses all quotations/bids from suppliers against the established needs.
- Negotiates with suppliers to obtain the best quality optimum cost.
- Continuous search and development of new suppliers and contractors through a validation process.
- Reviews and validates all Purchase Orders and Contracts.
- Schedules all jobs in MLS and issues blending orders

Job Title: Warehouse Officer

Job Summary:

Warehouse officer is responsible for planning the optimum inventory levels of finished goods and raw materials and coordinating with procurement on raw material requirements and logistics. This position is also in charge of preparing and delivering all finished goods as well as ensuring that preservation and handling are safe and comply with regulation and standards.

Responsible to: MLS Manager

Duties:

- Responsible for Warehouse Operation internal & external and related works as to stock control and material movement
- Optimise Space Management for stocking Goods at Factory and external Sites
- Maintain the service of delivery to the company standard
- Respond to the customers and principals feedback
- Provide information to subordinates and superior regarding the customers
- Improve the service of goods returned for the principals and the customers
- Control and ensure that subordinates adhere to the requirements placed upon them in regard to the delivery and good returned

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Job Title: Production Supervisor

Job Summary:

Production supervisor is in charge of coordinating with team on date and blending vessels to be used. This person is also responsible for planning all daily production activities and supervise subordinate to ensure completion of assigned task as well as verification of all results.

Responsible to: MLS Manager

Duties:

- Control all production lines and report the output of working to MLS Manager
- To troubleshoot production related issues during shift

Job Title: Production Assistant

Job Summary:

Production assistant is responsible for producing finished products through blending process in an accurate manner, according to production schedule, safety handling of chemical substances in production area, and packaging formulated products in drums.

Responsible to: Production Supervisor and MLS Manager

Duties:

- Manufactures metalworking lubricant products under guidance of production supervisor

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Job Title: Salesperson

Job Summary:

There are two types of salespersons: sales supervisor and sales supporting officer. Sales supervisor is responsible for all sales activities and monthly sales target. For example, developing and maintaining good relations with both new and existing customers as well as promoting products. This position is also in charge of responding to customer questions and complaints, and providing customer service as required by individual accounts. Furthermore, this person may take part in roadshow, trade events, both locally and internationally. On the other hand, sales supporting officer is however in charge of understanding and providing technical solutions to demanding customers as well as dealing with technical questions and quality complaints. This position has to co-operate with sales supervisors.

Responsible to: MLS Manager

Duties:

- Performs sales duties under the supervision of MLS Manager according to defined company and marketing division policies and objectives
- Analyzes the objectives and needs of customers and reports to MLS Manager
- Be able to provide business consultancy, marketing, training and sales support services to customers
- Generates sales growth with the agreed territory, providing successful territory maintenance and support to each specified store
- Handles product complaints and uses good judgments in recommending replacement of products
- Works closely with customers to develop strategic plans to stimulate business growth
- Provides sales thru and competitive pricing reports to monitor movement of product and market to sales management on monthly basis
- Attends conventions, sales meetings and exhibits to keep abreast of new marketing programs and new developments in the industry and to learn the capabilities of new products
- Maintains records of calls and sales activities

BIOGRAPHY

Mr. Kanin Kaewin was born on April 15, 1983 in Bangkok, Thailand and has lived there until now. His father is a civil engineer and has worked for a state enterprise no less than 20 years. His mother used to work in a commercial bank before changing her banking career into an entrepreneur. Mr. Kaewin attended Triam Udomsuksa School in 1998 as a science-mathematics student. In 2001, he passed the entrance examination to study in the Faculty of Engineering, Chulalongkorn University where he gained a B.Eng. in Chemical Engineering. In the fourth year of his undergraduate study, his senior project was funded by Thailand Research Fund (TRF) under Industrial and Research Projects for Undergraduate Students (IRPUS) programme and was granted the Representative Chemical Engineering Senior Project Award (2005) from the Faculty of Engineering. Furthermore, his research project "Effects of Liquid Feed Rate on the Efficiency of Air-Lift Reactor" was awarded the 1st Prize in the Professional Vote and 4th Prize in the Industrial Vote from Thailand Research Fund (TRF) in the 2005 exhibition. Since May 2, 2005, he has been recruited by a lubricating oil manufacturing company and has worked as assistant plant manager. With a recommendation from Professor Sirichan Thongprasert, Mr. Kaewin decided to pursue a master degree in Engineering Management at Regional Centre for Manufacturing Systems Engineering.