CRANFIELD UNIVERSITY

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LEAD-TIME REDUCTION AND IMPROVING THE OPERATING EFFICIENCY

SCHOOL OF INDUSTRIAL AND MANUFACTURING SCIENCE

MSc THESIS

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ABSTRACT

For a successful manufacturing company to consistently realise success invariably requires the organisation to find new methods of achieving competitive advantages. Today time is on the cutting edge and represents one of the most determinants of leading companies. This project is a part of an on-going effort to sustain a competitive position and thus maintain company prosperity especially with new competitors entering the European Community (EU). Additionally reduced lead-time at Hephaestus S.A., will lead to reduced operating costs, which will enhance the profitability of this company.

The aim of this project is to develop a generic tool based on the knowledge gained from a literature research into formal methodologies for reducing lead-time. This generic tool was tested by its application to the activities of Hephaestus S.A., and investigated how problems areas can be addressed.

Finally recommendations have been made to Heaphaestus S.A. for reducing its lead-time and improving its operating efficiency.

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CHAPTER 1

INTRODUCTION

A successful manufacturing company can make a significant contribution to the prosperity of the nation (Baines, 1994). For a manufacturing company to consistently realise success invariably requires the organisation to find new methods of achieving competitive advantages. Stalk (1988) states that during the 1980s, manufacturing companies, found that a good source for maintaining their competitive edge was to enhance the quality of their products. This however has now fully evolved and attention is now being directed to speed up the provision of products to the customer. Hence lead-time has become one of the most important factors which distinguish leading companies.

Lead-time reduction can be achieved by a number of methods but a particularly successful approach is to thoroughly overhaul the existing processing methods within the company. Such an evaluation can be made achieved with a number of analytical methods such time-based frameworks. The overall aim of this project is to investigate solutions for lead-time reduction and apply these to a real company, which is Hephaestus S.A., a steam boiler manufacturing plant in Greece.

1.1 RESEARCH

There is a lack of previous work on the subject of lead-time reduction methodologies. Only lately lead-time has received attention from academics and practitioners as an important area for further research. This is mainly due to the fact that it has been recently realised that lead-time can be used as a method of gaining advantage over other competitors.

The principle aim of this study is the following: "The investigation of solutions for reducing the lead-time and apply this to the activities of Hephaestus S.A.". The objectives of this project will proceed as follows:

- Develop a generic tool based on knowledge gained from a literature search.
- Test the implementation of the tool developed to the activities Hephaestus S.A., and exemplify how problem areas can be addressed, with reference to the tool which has been developed.

The first stage was a detailed investigation of the published literature concerning lead-time reduction. This stage was essential in order to establish the extent of current knowledge on lead-time and time-based frameworks. Then this knowledge was analysed to form the foundations of a tool that was developed in the next stages of the project. The following stage included the visits to various industrial areas, and interviews with successful practising managers in order to gain a deeper understanding of this subject. The next stages included the development of a tool based on the knowledge and experience gained. The principle objective of the tool was that it should be suitable for applications in a variety of fields in the industrial area. The subsequent stage was involved with the gathering of data from the manufacturing company in Greece with reference to the tool which had been developed. The final stage was associated with the application of the tool, and some recommendations have been made to the company for tackling the problem of lead-time reduction.

1.2 THESIS STRUCTURE

The structure of this thesis is as follows:

Chapter 2 provides a general description of a steam boiler manufacturing company in Greece. Chapter 3 contains the literature review which sets the terminology used in this thesis, and explores the issues involved with the application of lead-time reduction methodologies. Chapter 4 establishes the extent of current knowledge on time-based frameworks to explore the variety of lead-time reduction methods available. Chapter 5 develops a generic tool based on the knowledge gained from lead-time and time-based frameworks respectively. This generic tool contains four stages and was constructed with the deliberate intention of having a wide field of applications. Additionally in this chapter the principles of the tool are established. Chapter 6 presents the application of the tool that has been developed to the activities of Hephaestus S.A. and attempts to make proposals for achieving the aim of the project. Chapter 7 presents the updating of the tool with reference to the application, which has been carried out. Chapter 8 draws conclusions to the work described in the thesis.

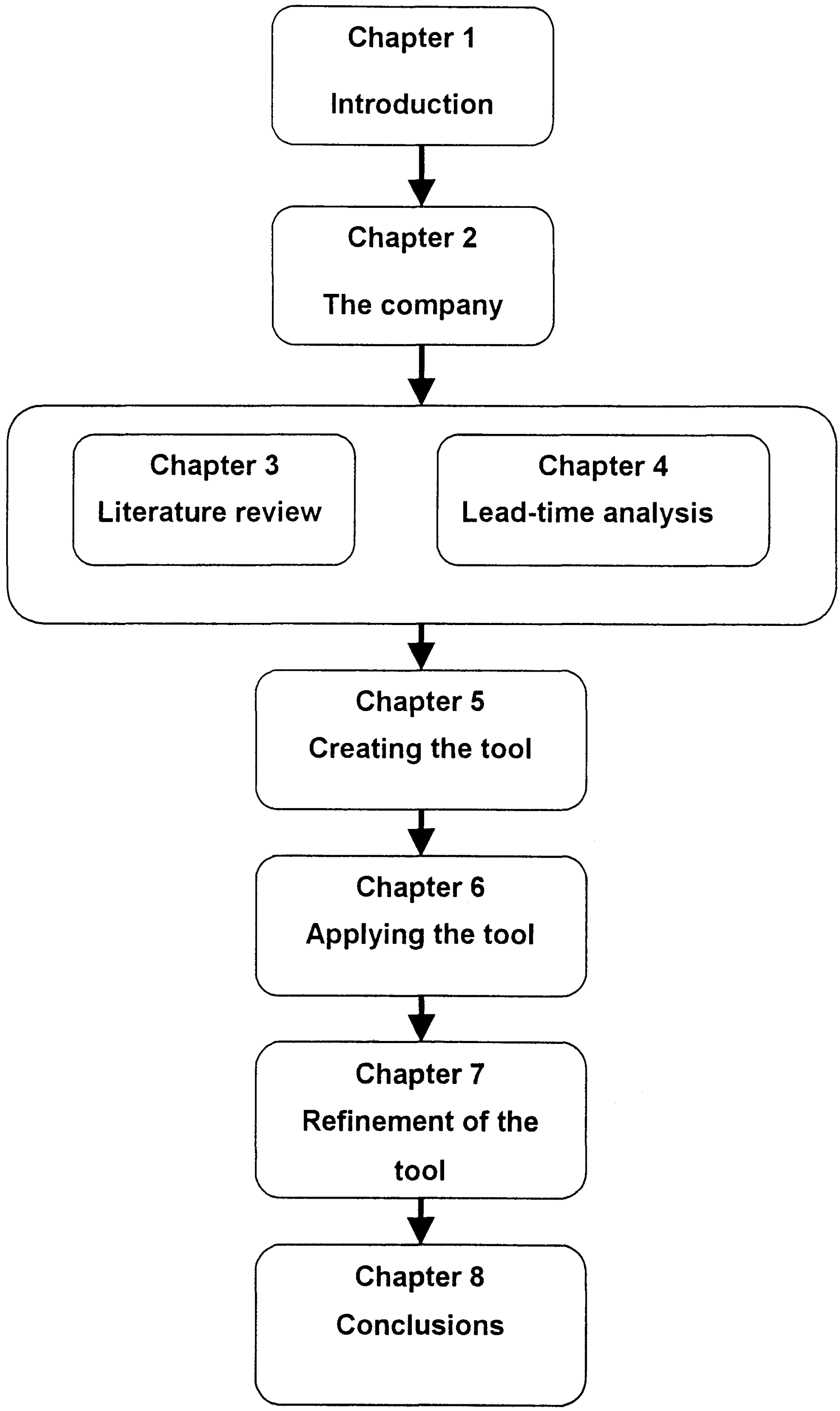


Figure 1.1: Thesis structure

CHAPTER 2

THE COMPANY

The objectives of this chapter is to introduce the company, Hephaestus S.A., and to provide general information concerning the current situation which exists within their manufacturing system. The following information was formed about the following areas:

- Company profile
- Products and services
- Manufacturing environment
- Procurement

2.1 COMPANY PROFILE

Established more than seventy years ago, the company has consistently expanded to its present position as the largest steam boiler manufacturing company in Greece. The company manufactures industrial fire tube steam boilers, steam generators, pressure vessels, heat exchange systems, together with other general heavy fabrication work and is also the sole Greek manufacturing company of Corrugated Flues i.e Types Fox, Morison, Deighton, and the deep corrugated type. Hephaestus S.A. facilities are located in the industrial area of Kalohori, on the outskirts of Thessaloniki, in Greece occupying 9,000 sq. metres with excellent access to the national motorway and rail networks as well as the East Coast Ports. The products manufactured by the company are certified by the American Bureau Veritas, Technische Uberwachung Verein at Bayern Sachsen, Lloyds Register of Shipping, Det Norske Veritas in Norway, Indian Boiler Regulations and the Hellenic Register of Shipping. The competitive edge of the company owes much to the commitment to total quality and after sales service and this maintains the company at the forefront of this type of industry.

2.2 PRODUCTS AND SERVICES

Hephaestus S.A principle activity is the manufacture of steam boilers for industrial purposes. The company also supplies pressure vessels and provides customer after-sale services to the Greek market. This service extends to any make of boiler plant and is conducted by the company's team. Furthermore, Hephaestus S.A. provides its facilities for sub-contracting rolling of heavy steel plates, welding, stress relieving and general fabrications.

Some of the products, which, Hephaestus S.A provides, are the following items:

- Steam boilers
- Hot water boilers
- Steam generators
- Pressure vessels and tanks
- Corrugated furnaces and boiler heads

All these basic products are supplied in a range of sizes to suit customer requirements. The respective percentage of sales for each product is shown Appendix A. This project will focus only on steam boilers and there is a wide range of steam boilers which are manufactured within the plant. Here it must be mentioned that the design life cycle of industrial steam boilers is very long. Only very minor changes have taken place in the design and technology of these boilers during the last 20 years, however the manufacturing methods used have changed more rapidly as new methods became available. The range of the specified product and an outline sketch of a typical industrial boiler product are shown in Appendix B. This project has focused on the steam boiler type K100 for which the average throughput time from the arrival of the raw material for a specified order through shipping is 3.5 months. The total lead-time of this product from the placement of the order of the customer is not known since there are a lot of fluctuations in the on time deliveries of the raw materials.

2.3 MANUFACTURING ENVIRONMENT

Hephaestus S.A. is a make-to-order company and has sufficient capacity to produce 40 steam boilers per annum. Orders placed by customers are usually within the standard range of products available by the company for sale. The company does not have a department (i.e., design office), which caters for the introduction of new products, as its strategy is to focus on the manufacture of already standard products. The principle manufacturing activities are based on sheet metal working and include cutting, rolling, welding operations, and also the installation of control devices and equipment in the assembly area of the shop floor. Here it is of great importance to note that the quality of an industrial steam boiler is not only a matter of excellence. Rather, the quality of the product must be confirmed by the Hellenic Register of Shipping experts for safety reasons. Certificates of quality must accompany the product for its legal acceptance. Quality control is a very thorough and takes the form of many extensive x-ray inspections of the product during all intermediate levels of the production and also high pressure testing before shipping.

2.4 PROCUREMENT

The company suffers from problems of achieving on-time deliveries of the raw material and the individual components necessary for the manufacturing of the products. This is because the company mainly depends for their supplies of raw materials from E.U. since there are no Greek manufacturers of steel plates and tubes. Also the stockists operating in the Greek marketplace are unable in most cases to meet the specific requirements in type and dimensions of the steel plates and tubes required.

2.5 CURRENT COMPETITIVE CHALLENGE

The issue of focusing on lead-time reduction at Hephaestus S.A. can be traced to the fact that today lead-time is such as important factor and can lead to manifold benefits for the company. The ways leading companies manage lead-time in production, in new product development and introduction, in sales and distribution represents the most powerful new sources of competitive advantages. Competing on time appears to be the way of achieving the future domestic and international markets (Tersine, 1995). The reduction of lead-time for Hephaestus S.A. is essential because it will enable the company to sustain a competitive position and business prosperity especially when new competitors from the E.U. Community enter the Greek market place. Hephaestus S.A. with reduced lead-time of its products will achieve to be responsive to urgent customer needs also delivery reliability. Additionally the importance of reduction of lead-time for Hephaestus S.A., comes from the fact that reduced lead-times will provide the means of reduced operating costs which will enhance the profitability of this company.

CHAPTER 3

LITERATURE REVIEW

This chapter performs a literature review, which sets the terminology used in this thesis, and expresses the issues associated with the application of lead-time reduction methodology. Additionally this chapter highlights the importance of lead-time analysis and its associated techniques. The objectives of this chapter are realised by addressing the following items:

1. What is lead-time?

2. Why is lead-time reduction so important?

3. What is lead-time analysis and why is it useful?

4. General overview of lead-time analysis techniques

3.1 A DEFINITION OF LEAD-TIME

Generally lead-time is defined as the total elapsed time between receiving a customer order and fulfilling it (Krajewski and Ritzman, 1996). Inconsistencies were identified in the use of terminology for lead-time throughout the literature research. This is probably because articles and books are referring to various different manufacturing systems, including different departments. However, based on the literature review, lead-time can be primarily expressed in three distinct ways:

1. New product introduction time: this is the amount of time required in order to develop and manufacture a new product.

2. Time for manufacturing existing products: this is the amount of time required to manufacture a standard product.

3. Time for sales and distribution: this is the amount of time, which is required for the product to reach the customer after manufacturing and despatch.

3.2 THE IMPORTANCE OF LEAD-TIME REDUCTION

The importance of lead-time reduction can be traced through the history of production management from the time of Henry Ford, to the more recent Japanese philosophies. Although the importance of lead-time has intuitively realised not until lately it has been explicitly emphasised and explored from academics and practitioners as an important area for further research. Suri (1994) refers to the reduction of lead-time as the means of gaining competitive advantage. Competing with time is also known as "Time-based Competition". Time-based competition means delivering products or services faster than a competing company. Like competition itself, competitive advantage is a constantly moving target. For any company in any industry, it is vitally important not to get stuck with a single simple notion of excellence as its source of advantage. The best competitors, and certainly the most successful ones, know how to keep moving and always stay at the cutting edge (Stalk, 1988). For example Stalk (1988) states "Time is becoming the main battlefield—and weapon—of competition". The methods leading companies manage time in production, in new product development, in sales and distribution represents the most powerful new sources of competitive advantages. Similarly Fry (1993) mentions that for years the traditional approach to manufacturing success has been to provide the customer with a product having the greatest value for the least cost. The emerging time-based approach to manufacturing success is to provide the most value at the least cost in the least amount of time (Fry and Karwan, 1993).

More recently, Stalk (1990) argues that Time-based competitive advantage is the most recent in the succession of the managerial innovations which have had an impact on business outcomes in the last 40 years. The others include experience curve strategies, portfolio strategies, the strategic use of debt, de-averaging of costs, and re-structuring for advantage. Tersine (1995) observed that the importance of time as a competitive advantage in this succession of managerial innovations has been relatively under-scored by the emergence of continuous improvement philosophies in the previous decade. These are primarily Just-In-Time (JIT), Total Quality Management (TQM) and Theory of Constraints (TOC). The succession of managerial innovations was introduced in the period following World War II. Japanese companies used their low labour costs to gain entry to various markets. As wage rates rose and technology became more significant, the Japanese shifted firstly to manufacturing scale based strategies and then to highly focused strategies to achieve competitive advantage; the electronics and automotive industries are a typical example of this strategy. The advent of JIT production brought with it a move to more flexible manufacture, as leading Japanese companies sought to produce by both low cost and a great variety of products to the market. Cutting-edge companies today are capitalising on a critical source of competitive advantage by shortening the planning loop in the product development and manufacturing cycle and trimming the processing time in the factory thus managing time the same way as most companies manage costs, quality, and inventory. Finally Stalk (1988), concludes that as a strategic weapon, time is the equivalent of money, productivity, quality, and even innovation.

The management of time enabled top Japanese companies not only to reduce their costs but also to offer broad product lines, coverage of greater market segments and to upgrade the technological sophistication of their products. These companies are time-based competitors (Stalk, 1988). Similarly Suri (1994) argues that the very act of looking at ways of speeding up the existing procedures results in manifold benefits. Continuing his argument, he states that every aspect of the company that requires improvement it has to do with something about squeezing time out of the process within the company. The deeper the industry will probe the more opportunities can be gained. Strategies based on time can be applied to any business, including banking, insurance, hospitals, food service, and manufacturing. For manufacturing firms, competing with speed primarily means both, the time to bring new products and the time to manufacture an existing product from its raw materials and efforts to reduce these can result in significant competitive advantage. Suri (1994) concludes that if firms finally succeed in implementing Time-based strategies, become formidable competitors in their markets. Additionally these competitors achieve impressive financial results and grow at a rate that is three times the average for that industry (Suri, 1994).

3.3 LEAD-TIME REDUCTION BENEFITS

The benefits of lead-time reduction are manifold and can be expressed as tangible and intangible benefits.

3.3.1 Tangible benefits

Stalk (1990) mentioned that many successful companies find themselves unable to grow and increase their share in the market using traditional approaches such as price cuts. This can be illustrated by an example. The case refers to one customer of custom industrial product who could not increase its share of the purchases using traditional means—price cuts in one form or another—but did so after improving its response time by 75% on every order, including semi-custom fabrication. As customers became confident that they could rely on this company as a sole supplier, its share of their purchases increased from 30 to 45 percent. The results are summarised in the table 3.1:

	BEFORE IMPROVED RESPONSE	AFTER IMPROVED RESPONSE	PROJECTION
Delivery lead-time (weeks)	22	8	6
Volume increase(%)	--	16	41
Domestic share	32	37	45

Table 3.1: As time Compressed, share increases: An Industrial Consumable, (Stalk, 1990)

In the same way Suri (1994), states that increase in share is obvious when the firm's lead-time to bring new products to market is shorter than that of the other competitors. He reinforces that by saying that the firm can beat the competition to market and obtain a substantial market share while the competition catches up with the firm's product (Suri, 1994). The Japanese automobile manufacturers used this strategy very profitably in the 1980s. While Western manufacturers thought that Japanese advantages lay in lower labour costs, or better quality, or government subsidies, their greatest strength lay behind their rapid introductions. Japanese firms in other sectors soon adopted similar practices. For the longest time, the inability of Western firms to understand this strategy, allowed Japanese domination of several additional markets such as consumer electronics (Suri, 1994).

This point can be illustrated very easily from the example of the "war H-Y" in 1981(Stalk, 1988). The turning point of this "war" was the product variety. HONDA responded very quickly to the new challenge of the competitor company YAMAHA. Honda devastated Yamaha's challenge for supremacy in the motorcycle market by introducing 113 new models during 18 months. Honda pioneered structural operational changes that allowed them to execute their process much faster; that means, they used time as one of their competitive advantages. "Time is the secret weapon of business" (Stalk, 1988).

Suri (1994), states that in a different case, that if the firm doesn't succeed in implementing time-based strategy within the interval of time that competitors enter the market, the company will loose substantial market share. Worse yet, while trying to catch up, the firm may haemorrhage so much as to go out of business altogether. The same point is reinforced by Schmenner (1988), where he states the fact for a firm not to implement time-based strategy means that the company is wide open to be attacked by the competitors. Finally he add to this point that implementing a time-based strategy is not a easy task and it can take the organisation several years to transform.

Directly linked and of equal importance benefit with the increase in the share of the company, is the profitability. Suri (1994) considers the advantages of having short time to produce and deliver existing products. This does not refer only to manufacturing—it includes all the steps from receipt of order to shipping. He continues by saying that if the firm may be able to respond fast to the customers, will clearly promote customer satisfaction, and may assist in taking orders away from competitors. If the customer has an urgent need for his product, the company might even charge a price premium and further add to his profitability. The firm may even be able to "skim" the market by charging high prices during the period when there is no competing product. All of this can result in excellent profits for the firm (Suri, 1994). Similarly, Barker (1998), states that the throughput time is indirectly linked with costs consumed. He continues by saying that the only way for business to achieve their fundamental objectives, to maximise their earnings, is to reduce the costs. Since companies are powerless to affect the prices of the products because of market constraints the conclusion that is drawn is that the company should reduce the throughput time in order to make more profit.

Additional important benefit from reduction of the lead-time for existing products is the gaining of productivity. In a study case that was performed by Schmenner (1988) revealed that reducing the throughput time (the length of the time between the arrival of raw materials at the factory and the shipment of the finished product) is the single most important determinant of improved productivity. Reduction does not improve productivity by itself; it stimulates a host of complementary actions and tactics within the factory that, in turn, improve productivity. The study case showed that halving the throughput time is worth an additional two or three percentage points to a plants productivity gain. The investigation of Schmenner (1988) was of great accuracy because it was unanimous and conducted in three factories in USA and Europe considering different factories, products and production processes (Schmenner, 1998). More recently Stalk (1990) in his book "Competing against time", states that for every halving of the cycle times and doubling of the work-in process turns, productivity increases 20 to 70 percent. Likewise, Suri (1994) argues that when firms have been able to cut their product introduction lead times, at the same time, used fewer resources for the development and introduction process. In some cases, firms have cut their introductions lead-times in half and used half the number of people—a fourfold improvement in productivity.

3.3.2 Intangible benefits

Reduction of the lead-time for existing products provides improved integration of the whole enterprise. In order to deliver products faster, it is necessary to streamline the organisation of the company. Searching for ways of squeezing time out of the whole process uncovers sources of poor quality, high work-in-process (WIP), big waste, and thus lowering total operating costs. The result is a lean and mean company which will be very difficult for the competition to beat (Suri, 1994). Suri (1994) states that since most of the resources used in new product introduction are not accounted for as direct costs, but rather as overhead cost, reduction in lead-time results in tremendous reduction in a company's overhead. Consequently this causes excellent profits for a company which successfully reduces its lead-time to bring new products to the market (Suri, 1994). Similarly Barker (1998) assumes an indirect relationship between the throughput time required and overhead costs. Barker (1998) observed that reduced lead-time equates directly to lower fixed costs, lower supervisory cost and lower heating bills. The influence of time is seen as the most damaging creator of negative loss, which increases the costs of both adding value and overhead support.

Schmenner (1998) observed that another less obvious benefit of reduced lead-time reduction is quality improvement. Schmenner (1998) defined throughput time as the weighted average time through the process of all the units of a representative batch or order. Thus, if throughput time is to be shortened, managers cannot afford to let an order languish in a rework station or sit idly waiting for scrapped output to be replaced. All of the order needs to be made correctly the first time if throughput time is to reach its lowest possible value. Feedback on problems must be quick and solutions timely. Problem-solving skills take on new importance and urgency, as does the need to involve everybody in the factory. Finally Schmenner (1998) concludes that throughput time reduction thus complements the push to improve quality. In the same article, Schmenner (1998) presents inventories as the chief culprit in hindering the speedy travel of materials through the manufacturing process. Throughput time reduction stimulates a variety of means for lowering inventories. For instance, the workforce might make a bit of everything demanded every day, building in small volumes in just the quantities sold in the marketplace rather than building large inventories to tide the factory over until the next product is produced. Similarly, Buzzacott (1995) noticed that time and inventory are related by a basic law, referred as "Little's Law". This means that time-in-process equals work-in-process multiplied by the mean-time between successive releases.

Suri (1994) presented an interesting and less frequently appreciated benefit. This is that with a shorter lead-time to market, the firm and its competitors can hit the market at the same time with similar products, yet the company with the short lead-time will incorporate the latest technology. This observation became well understood with an example of comparing two companies, one with two years lead-time to introduce a new product and the other with four years lead-time. If it is considered that both companies wish to introduce a new product at the same time, aiming at a similar market niche, then the company with the shorter lead-time to market is able to start the development after the company with the longer lead-time to market. Consequently the product of the company with shorter lead-time to market will use newer technology because it is well known that most of the design and manufacturing decisions are "cast in concrete" in the first 5 - 20% of the total introductory lead-time.

Stalk (1990) presents that with a reduced lead-time the company are facing less risk to have a financial loss. This is supported by the fact that the company as farther into the future makes forecasts for the demand of the products, the greater probability these forecasts will be wrong at the time of sale. So the company having shorter lead-time minimises the risks of producing products that the customer doesn't want and conclusively eliminating the risk of a possible financial devastation.

3.4 LEAD-TIME ANALYSIS

Lead-time analysis should be the first phase of every lead-time reduction methodology. It is a method which explores those mechanisms which regulate the making of the total lead-time through its component parts. The purpose of this analysis is twofold; the first one is the general description of the process dynamics in order to understand how linkages between different phases of the process affect the build up of the lead-time (Bartezzaghi et al, 1994). The second one is the general description of industrial system dynamics in order to understand how linkages between different departments of a supply chain affect the total lead-time (Stalk, 1988). Forty years ago, Forrester at M.I.T published a pioneering article in the journal Harvard Business Review, July-August in 1958 which established a model of time impact on an performance of an organisation (Stalk, 1988). Forrester with the support of "Industrial Dynamics" tracked the effects of time delays and the rate of decision-making within a simple business system consisting of a factory, a factory warehouse, a distributors inventory and retailer's inventory. The result of this research showed that as long as the factory forecasts of received orders were accurate 19 weeks into the future then the system was stable. When demand increased by 10% the factory responded by increasing production by 40%. When the management realised – too late – that it had overshot the mark, it cut production by 30%. Too late again the management learnt that it had overcorrected. This increase and cutback of the production continued until finally the production stabilised. The survey demonstrated that "time" was the factor which distorted the system so badly (Stalk, 1988). Stalk (1988) highlights the importance and necessity of the analysis of lead-time, by stating that companies are systems of various parts and time is the link which connects all these parts. These ideas are reinforced by Barker (1997), who observed that many organisations failed to achieve lead-time reductions because they did not carry out any analysis of the system or the processes. Time-based analysis and strategy can be effective in both measuring the performance of existing operations and restructuring the organisation. Time-based strategy focus upon improving input conversion and directs attention to constraint removal, and the energy consumed in converting inputs to outputs. The time taken in conversion is considered critical and indicates the capability of the organisation to respond to customer demand and add value efficiently. The stage of the analysis is essential to guide a company into new investments and re-engineering of the process for reducing the lead-time. In the majority of professions and vocations, such as medicine, it would be unthinkable to prescribe a cure in advance of examination or analysis of the patient requiring attention (Barker, 1992:1).

Barker (1992:1) continues his argument that without a framework of analysis of lead-time, it is impossible for a company to achieve the minimisation of lead-time. More recently Barker (1998) observed that without this critical stage of analysis before any action is taken, there is a potential weakness that senior managers or consultants with particular views will direct effort into developments which may add little to improving the overall company competitiveness (Barker, 1998). Similarly Carter et al (1995) states that all the methods that have been written around the methods of reducing the product lead time, are referring that these reduction in lead-times must be achieved through system analysis and attack of the underlying processes.

It has been identified that there are some tools available for the purpose of reducing lead-time. These are MPX (Suri, 1996), WITNESS (Kay, 1998) and BARKER Software (Barker and Barber, 1997). These tools are appropriate for identifying problematic areas with lead-time and can guide action for tackling these problems.

3.4.1 Utility of lead-time analysis

From survey of the literature it has been clarified that lead-time analysis methods are very useful and can guide two actions:

1. Manufacturing System Development

The frameworks provide an overall view of the whole system and guide the management team in a structured manner depending on the problem, and the re-engineering/restructuring of the process (Barker, 1997; Carter, 1995; Barker, 1992:1).

2. Investment Appraisal

Additionally the lead-time analysis provides guidance for investments in new technology and in human resources in order to eliminate bottlenecks on the site (Barker, 1997; Carter, 1995; Barker, 1992:1; Barker, 1992:3).

Barker (1997) observed that the lack of guidance which lead-time analysis provides, caused a few hundred thousands dollars of investment in new technology to be wasted. This was because the investments were made marginally in one of the existing islands of efficiency which affected less than 1 % per cent of the time which the products spent in the factory.

3.5 GENERAL OVERVIEW OF LEAD-TIME ANALYSIS TECHNIQUES

At a general level, lead-time reduction methodologies are characterised by two major factors and these are as follows:

- Customer focus
- Supply chain

3.5.1 Customer focus

Tersine et al (1995) considered that companies should adopt a lead-time reduction strategy which has been focused on the customer. This approach tends to be uniform and is generally supported in articles written by Womack and Jones (1996), Bhattacharya and Jina (1997), Tersine et al (1995), Carter et al (1995) and Stalk (1988). The customer ultimately determines the value and cost of a product and this can vary from one market segment to another. Customer's expectations frequently go beyond the simple ownership of a product. No longer are just price, features and quality the only factors which a customer takes into account. Customers now demand a total service experience rather than simply being satisfied with the basic product itself whose quality is seen as given. Time is now an additional dimension (Stalk, 1990). Likewise Carter (1995) has observed that companies should deal with only those lead-time areas which are most important to the customer. Stalk (1990) argues that the key issue is to understand that the real competitive advantage will come from being fast in those areas where the customers appreciate it. Stalk (1990) continues his argument revealing that customer can also be a nuisance; firstly they want what they want; then they want it when they want it; finally they expect the quality of goods or services purchased to be perfect. Sometimes it seems that the customers are never satisfied. The identification of a need is accompanied by the desire for immediate gratification. The major purpose of a company should be to meet its customer fundamental needs, but this is not always possible (Tersine et al, 1995).

The lean philosophy in the same manner states the following:

> " *Define value precisely from the perspective of the end customer in terms of specific product with specific capabilities offered at a specific price and time."* (Womack and Jones, 1996)

As Taiichi Ohno, one of the creators of the legendary Toyota production system, put it all industrial thinking must begin by differentiating value for the customer from "muda" - the Japanese term for waste (Womack and Jones, 1996).

3.5.2 Supply chain

Carter et al (1995) observed that from the customer's point of view, it does not matter if customers wait for time held up in procurement, manufacturing or distribution. This means that what is best for the whole supply chain is also best for the customer. These reductions in lead-time must take the form both in means and variances. Companies should work with capabilities in order to find out from which area of the company the increased lead-time come from. This becomes obvious by an example in the late 1970, when leading Japanese companies realised that inefficient sales and distribution operations undercut the benefits of their flexible manufacturing systems. This happened in the case of Toyota. The Toyota Motor Manufacturing could manufacture a car in less than 2 days, but the Toyota Motor Sales needed from 16 to 25 days to close the sale, to transmit the order to the factory, get the order scheduled, and deliver the car to the customer. The sales and distribution function was generating 20% to 30% of a car's cost to the customer – more than it cost Toyota to manufacture the car (Stalk, 1988).

3.5.3 The need to develop an approach

Although the factors identified among the articles referring to lead-time reductions, each lead-time reduction methodology approaches the problem of lead-time differently. Each strategy relies on different procedures and mix of techniques (Carter et al, 1995). The different approaches depend on the objectives of each company. The management team should pick up those lead-time reduction methodologies depending on which strategy has adopted. These strategies can be formed by a number of methods, but two methods are most commonly used by practising managers. The first one emphasises the reductions in new product introduction time from product concept to production and this achieved by the application of Concurrent Engineering. This aspect of time is most attractive to those companies which deal with the products at the introductory or growth stages. The second strategy places emphasis on speed in responding to customer demands for existing products. These firms focus on reducing the lead-time from the time when the customer places his order until that order is in the customer's hands (Carter et al, 1995).

3.5.4 Value-added time

Barker (1992) has made intensive research on value-added capability of manufacturing systems in USA and the UK. This research shows that the value-added time is very low and that in some cases this represents only about 5% of total throughput time. The existence of this very big negative loss among manufacturing industries, according to the author, is mainly due to complex production systems and big carrying costs of inventories. Additionally this is a cause of lack of overall strategy to improve value-adding activities and a failure to link everyday actions to long term planning. A failure to plan long term has resulted in management actions and investments becoming diluted and weakened. Manufacturing industry seems to have developed a whole range of unstrategic and non-value-adding practices which do little to support customer demands or throughput. Control investment procedures and performance measurements are these areas where current UK-US thinking needs serious attention.

CHAPTER 4

LEAD-TIME ANALYSIS

The objective of this chapter is to establish the extent of current knowledge on time-based frameworks through a focused review of the literature. By this way is going to be established a foundation of knowledge which will be essential for the next stages of the study.

4.1 ANALYSIS OF EXISTING TIME-BASED FRAMEWORKS

Inconsistencies were identified in the use of terminology of time-based frameworks throughout the literature search. Actually there is no homogenous definition in the literature about what time-based framework represents. This part expose a number of time-based frameworks as their authors defined them.

4.1.1 Barker R.C.

Barker (1997) proposes a theoretical framework, which enables the firm to have an overall and macro view of the total supply chain (manufacturing, procurement). Primarily has been constructed to be applicable within any discrete batch production environment, but further research from the author (Barker, 1997) has revealed that the framework is applicable to any manufacturing industry. The framework aims to provide an analysis of the total manufacturing system (whole components supply chain, assembly operations, machining) and display graphically in a paper form or in a software, the company's value adding capability. This method of analysis, provide the means to the managers to identify where problems with long lead-time exists. Also provides guidance with a logical and structured way to the managers to direct investment appraisal and restructuring of the problematic processes.

The method of analysis is very simple. Along a calendar time continuum actions are divided into positive value-adding activities (machining, assembly etc) and non-value-adding activities (waiting to be processed, moving, stock holding, etc). This method is summarised by the figure 4.1:

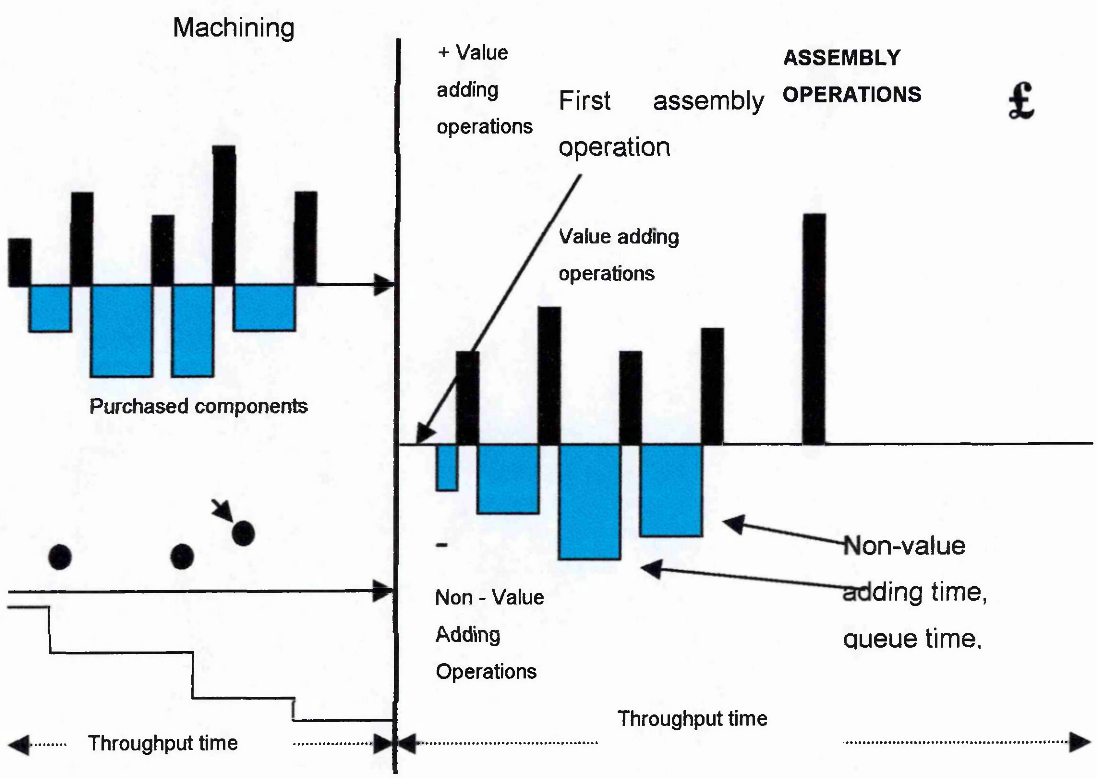


Figure 4.1: Time-based framework, (Barker, 1992:3,1994:1, 1995)

The framework illustrates how time-based strategy can be utilised in restructuring the manufacturing system to align competitive demands and production systems. Attention is directed at removing constraints to ensure that islands of value-adding activity are not separated and offset by long periods of non-value adding time (Barker, 1992:1).

The theoretical framework can be applied for the whole supply chain. Since it has recorded dates and time of the components (both purchased and machining) it is able to achieve better synchronisation in the first assembly operation. Also it can be seen the stock holding of the company for the case of very early deliveries (Barker, 1994:1).

The outputs of the theoretical framework are the following:

1. Total company value-adding profile
2. The relationship between core value-adding time and total factory throughput time.
3. The effect of material of material input costs

More recently Barker (1994:1) supports that this graphical illustration of the whole supply chain reveals large potential for improvement. According to Barker (1994:1), J.I.T techniques, cellular manufacturing and rejection of complicated push type control systems, like MRP and all of its derivatives, can support the reengineering of the process. All these actions are actually steps to simplification. Burbidge reinforced that by stating in his personal communication with Barker (1994:1) the following:

"There are two philosophies of production. One says: Production is very complex; therefore we need more and more complex computer systems - like MRP- to control it. The second says: Production is very complex. The only possible way in which we can increases its efficiency is simplify it"

This time-based framework, except of reduced lead-times, supports competitive criteria such as cost and waste reduction, and improved flexibility. Application of the model has proved significant results. The results are shown in Appendix C.

4.1.2 Bhattacharya

Bhattacharya and Nina (1997) have proposed another framework similar in concept with the previous one. The framework that has been proposed is under the general view of elimination of waste and continuous improvement and it is called Time-Based Process Mapping. The characteristics of the framework are the following:

1. Mapping the manufacturing process as a flow of model on the time dimension.

2. Redesign of the process systematically to eliminate non-value-added components of time.

Bhattacharya and Nina (1997) argue that this framework can be the drive for the business forward. The method of analysis provided by the framework is a graphical illustration of the process along the time continuum and captures three key concepts:

- The inter-relationships between activities
- The breakdown of each activity into value-added and non-value-added components
- The amount of material (raw, W.I.P, and finished goods)

One of the techniques that support the reduction of the lead-time is the creation of parallel processes. This method enables the firm within the same interval of time the execution more than one processes. By this way elimination of time is achieved. Another way that is included in this framework for tackling the problem with lead-time is the elimination of all non-value-added elements within the process. These non-value-added elements represent inspection, moving and other operations that don't contribute to the value according to customer. The last method of the framework that supports the lessening of the lead-time is the minimisation of the batch-size of the product. This method is actually focusing on the elimination of waiting time of products to be processed. All these three methods can be summarised by the figure 4.2. When are combined these three methods of re-engineering of the processes, give maximum and manifold benefits. Some of them are:

- Responsiveness to the customer needs
- Better visibility with a result a better control

Bhattacharya and Nina (1997) have argued that the firm before begin to adopt of such a reengineering in order to achieve reduction in lead-time, it should give a series thought about whether the customers of this company care about speed.

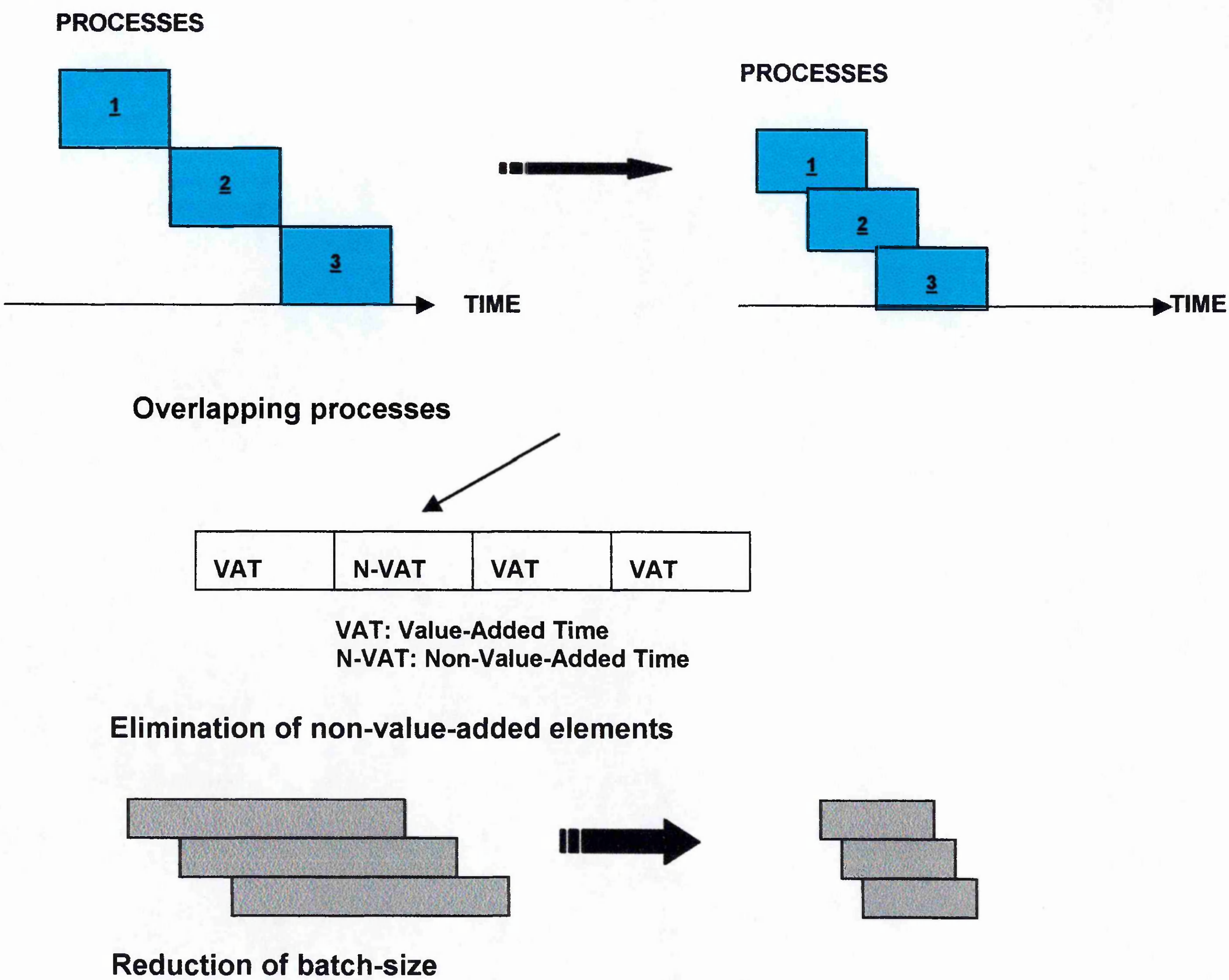


Figure 4.2: Three main method of reducing the lead-time. (Bhattacharya and Nina, 1997)

4.1.3 Womack

Lean thinking, one of the philosophies that have emerged during the last years, is supporting the minimisation of lead-time and has very similar methods with other theoretical frameworks for reducing the lead-time. The basic steps of this philosophy are summarised as follows:

- Define the value precisely with the perspective of the end customer and provide him the product that he wants only when he wants it.
- Identify and eliminate muda (muda is the Japanese term for waste) in all forms (product definition, information system, and physical transformation) for the whole value-adding chain and make the remaining steps creating flow.
- Pursue perfection

The first step is placed within the general idea the companies that are seeking competitive advantage through speed, they should focus on customer's requirements and needs. This idea is common through all the literature based on lead-time analysis techniques and very rational since customer is the one that provides the money to the firm. The associated process strategies that the firm should adopt in order to satisfy these general ideas are to simplify the flow, by eliminating cross flow and back flow throughout the total material conversion chain. One of the techniques proposed for attacking problems with lead-time is the introduction of the concept of "Tact Time". The Tact Time is the number of orders in a given period of time divided by the available amount of the production time. Establishing this concept is critical for the firm to avoid the natural tendency that exists to produce fast, and build up wasteful inventories. This is the best way to push the employees of the industry to do all the work in the available time. The last method proposed by Lean thinking is the

the available time. The last method proposed by Lean thinking is the replacement of complicated "MRP" push type control systems by simplified pull type control systems like "Kanban". This replacement is based on the logic that these systems rely on long-term production forecasts, which are inaccurate in most of the cases, and push companies to produce products that may the customer doesn't want. Some results from the application of one these Japanese techniques are remarkable. For instance "Kaikaku" phase allows managers and shop floor employees to rearrange the layout of a company within a weekend. The application of this method has two main benefits. The first is the reduction in total throughput time and the second is great saving of shop-floor space (Womack and Jones, 1996).

4.1.4 Bartezzaghi

Bartezzaghi et al (1993), proposes a time-based framework different from the others frameworks. He argues that although the fact that there has been a wide interest in general frameworks that support the modelling of lead-time, there is still of lack of conceptual models that they can provide the right guidance and justification for reengineering of the process. Continuing his argument he supports that the missing link is an intermediate level of modelling to make explicit the impact of managerial levels on process performance through lead-time reduction. This missing link consists of two elements:

1. Lead-time models, to account for the identification of the basic time components and their composition laws.

2. The structural and managerial factors and the mechanism which actually affect the single components of the total lead-time which are called in this paper "Time Drivers".

These two elements are shown in the figure 4.3.

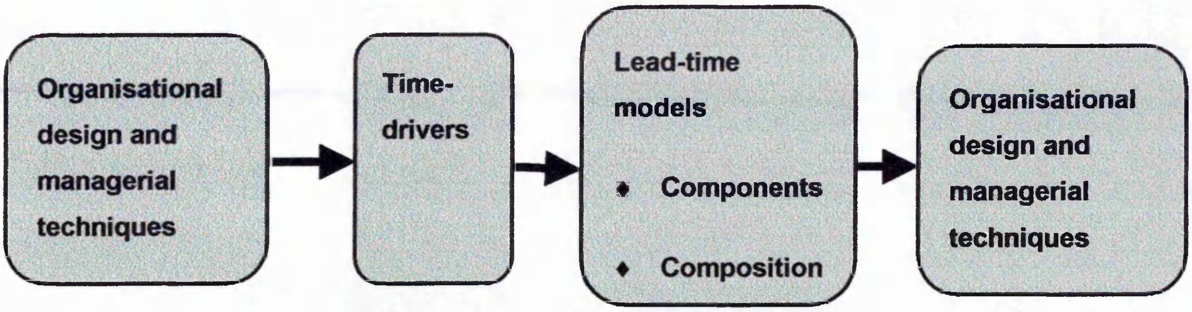


Figure 4.3: The links between organisational design and process performances through Lead-time management. (Bartezzaghi et al. 1993)

Bartezzaghi et al (1993) argues that since these two elements are understood, considerable support for process reengineering can be achieved. And that is because it is necessary for someone to understand in depth the mechanisms that make the lead-time and select the proper techniques to tackle the problem. Two levels of analysis are suggested to face time-related problems. These are the following:

1. An aggregate level in order to be understood the general dynamics of the process and the relationships among the lead-time of different macro phases.
2. A detailed level which entails a thorough analysis of the time components in every activity of the process.

For each of the above levels has been proposed two kinds of lead-time models depending on the characteristics of the business process. The business process taxonomy that is suggested may be classified depending on two characteristics:

process taxonomy that is suggested may be classified depending on two characteristics:

1. The degree of process steadiness, as to repeated start-ups of the process, in terms of technologies, activities, sequences and organisation

2. The degree of the interchange ability of the object-materials or information passing through the process. This refers to the possibility to satisfy customer needs by means of outputs or semi-processed objects not yet assigned.

The lead-time models that have been proposed are the following;

1. Aggregate models: these models are not dependent on the interchange ability and can expressed as two main models:

    - Stage models: they are preferred when process steadiness is high and steady configuration allows the process to be reengineered as a sequence of stages. These models aim to emphasise these relationships by comparing the total lead-time with the simple sum of parts.

    - Logical models: they are preferred when the steadiness is low. These models can capture the effects of non-repetitive processes and analyse logical phases taking place and assessing their lead-times.

2. Detailed models: these models are not dependent on the steadiness and can expressed as two main models:

    - Line models: line model can represent can effectively represent the lead-time of any stockless process. These models emphasise the importance of synchronisation.

    - Buffer model: these models are similar to the line models but they incorporate also buffer time.

This taxonomy is shown in the figure 4.4. This process taxonomy is suggested to enable someone to select the appropriate lead-time models for process reengineering and provides a new approach to modelling lead-time.

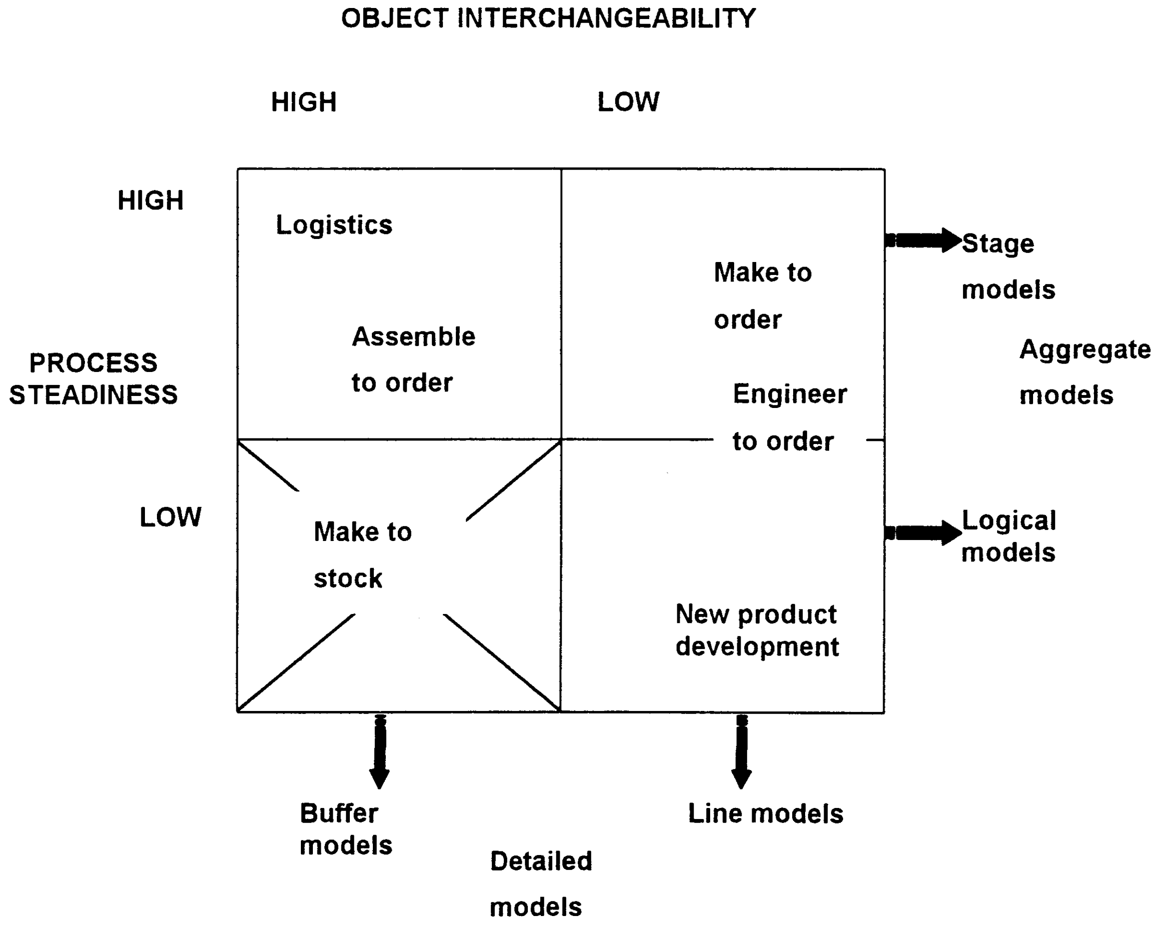


Figure 4.4: Process taxonomy for lead-time modelling / Combining Lead-time models and process features, (Bartezzaghi et al, 1993)

This framework proposed by Bartezzaghi et al (1993) and its suitable lead-time models, both aggregate and detailed can be matched to any kind of business process, depending on the purpose of analysis. It also provides two new lead-time models in terms of components, especially tailored for the purposes of process reengineering and illustrates the composition laws, which account the making of the total lead-time. Finally is capable of identifying the time-drivers, which actually affect the lead-time and its single components.

4.1.5 Suri

Suri (1996) proposes another framework. This framework use Queuing based theory software in order to analyse lead-time and identify existing problems. After the method of analysis this software can justify and guide reengineering of the process where problem exists.

The method of analysis includes a powerful tool-software called "MPX" which is based on queuing theory and supports the methods for reducing the lead-time that are described in the others frameworks but in a more accurate way because takes into account the dynamic interactions of the shop-floor. This tool has as inputs and as outputs summarised by the figure 4.5. Its calculation engine is based on Rapid Modelling Technology, a technology that implements state-of the art Queuing models and supports the rejection of push type systems like MRP in order to eliminate waiting time. The reason behind this proposal of the framework lies upon the fact that all these push type systems work with fixed lead-times for each department. This means that, in order to be on time, a department manager needs to assume a lead-time that will be consistently achieved regardless of whether the department has a lot of work or not. This fact is magnifying lead-times and worsening the situation of long throughput times. The paper proposes replacement of these push type systems by simpler ones pull type systems as "Kanban" methods.

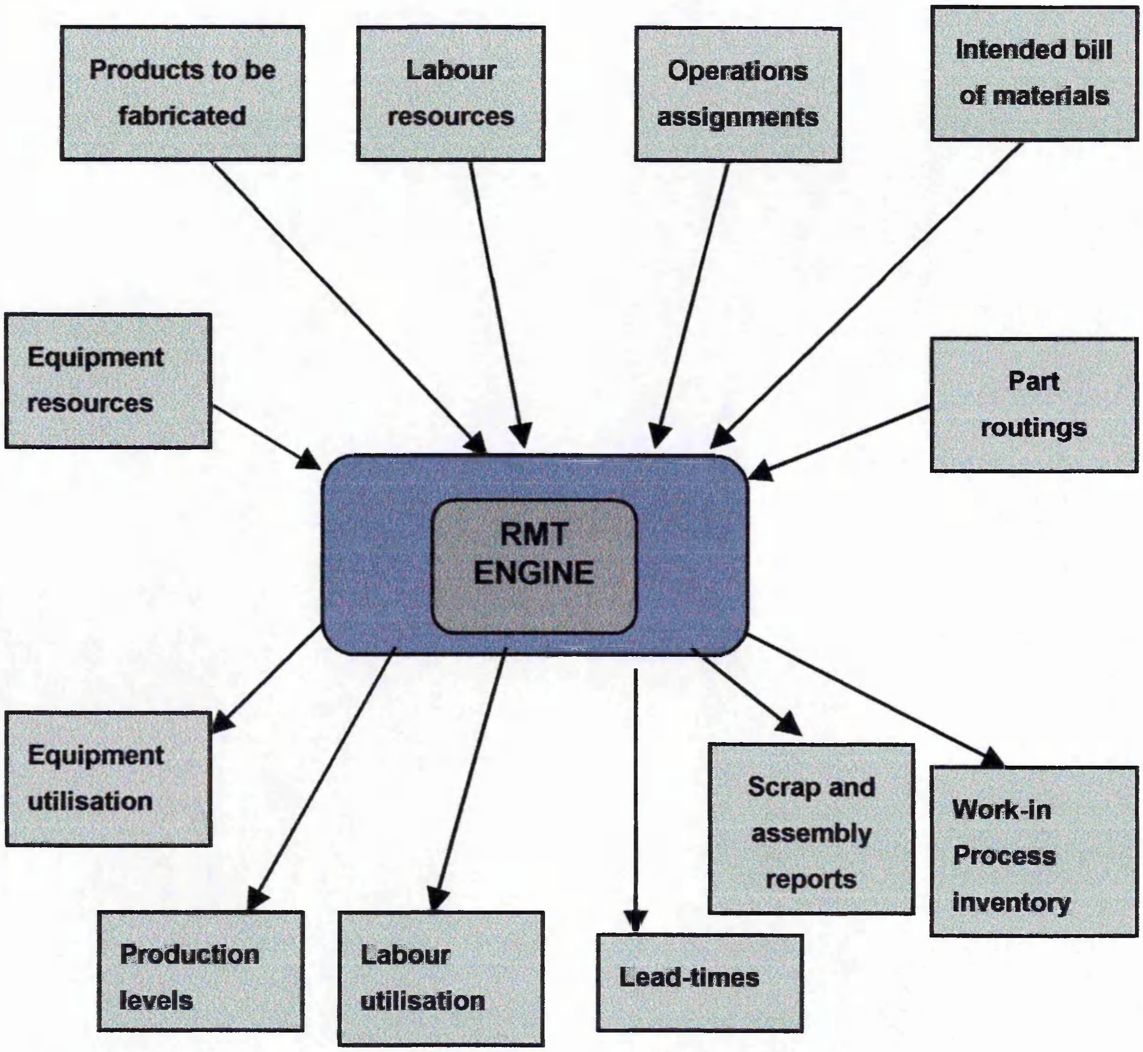


Figure 4.5: Inputs and Outputs of MPX, a state-of-art Queuing Based Analysis Tool. (Suri, 1994)

This framework can justify the need of excess capacity. It is stated that a company that wants to compete on time should plan for idle capacity. This idle capacity must be seen from the managers as a strategic investment, which will pay-off in the long term. Managers should stop try to plan for utilisation of the machines of the company nearly to 100%. This idle capacity can be expressed as buying more machines of the same type or employment of multifunctional workers, in order to eliminate bottlenecks wherever appears. The tool can also support decisions like minimisation of batch type and identify the exact lot size that the company should use in order to eliminate waiting times in the shop floor. By this way the firm is going to achieve minimisation of the lead-time.

4.1.6 Burbidge

Burbidge (1993) has made a research on the subject of lead-time for companies that manufacture "One Of Kind" products. These products are those of which only one of the kind is produced. This framework mentions that decisions as Cellular approach, delegation of decision making in the shop floor and automation are important factors but very small by their own. The article mentions that lead-time can be discomposed in two basic elements:

- Design and Production Planning (DPP) Time
- Material Throughput Time (MMT)

The proposal for reducing the MMT, is the simplification of the flow of the material by introducing Group Technology (GT) and continuous line flow (CLF). This means that factories have to change the traditional process oriented approach of the layout to a layout that is arranged according to some product families. The framework proposes methods for reducing lead-time for existing products like the introduction of shift working, close scheduling, reductions in set-up times. It is argued that introducing accountability to the workers for the lead-time can reinforce these methods. The firm of this kind, in order to reduce the DPP time has to overlap design time activities and activities for the production of this product. This can be achieved by forming a central design and production office, supported by subsidiary offices for detailed planning in assembly division. Other methods that are proposed for reducing of DPP time include the use of CAD system, which saves space and time, and the standardisation of the products which means to manufacture the new product as far as possible from standard components. Also the method of Critical Path Analysis can support the reduction of lead-time since it is a method for determining the lead-time in terms of customer. By defining the critical path the company can put all the non-value-adding activities in a parallel manner with as a result the reduction of the total lead-time.

4.1.7 Spanner

Many authors that have referred to business strategies have recognised that the firms utilise various degrees of differentiation and scope in order to position their products in various market segments. Spanner et al (1993) in their article exposed that to create and sustain a competitive position in the market, companies need to synergise their business strategy with its different functional strategies and skills. Generic business strategies can be viewed in two dimensions. First is scope and the second one is differentiation. This is illustrated in figure 4.6:

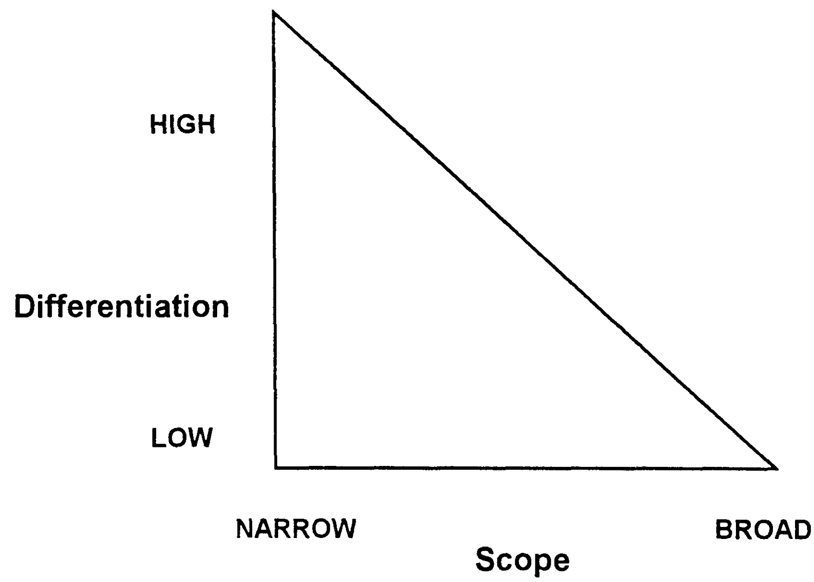


Figure 4.6: Interplay of generic market characteristics, (Spanner et al.1993)

Spanner et al (1993) argue that the traditional approach of combination of the two strategies, price leadership and differentiation cannot provide firms a long-term growth. Spanner et al (1993) propose that firms in order to sustain long-term competition and continued growth in the market have to mix functional strategies and generic strategies. The framework proposes that firms should incorporate "time" in the previous two-dimensional view scope differentiation. By this way it is created a 3-dimensional diagram shown in the figure 4.7.

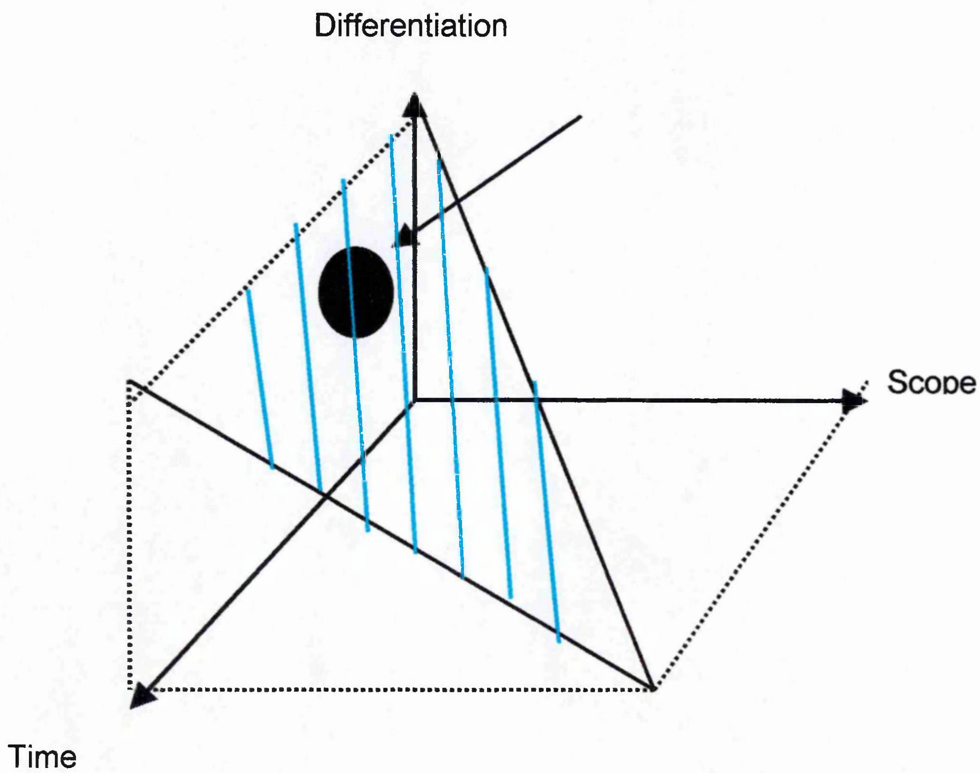


Figure 4.7: Tree dimensional view of strategy (Spanner et al., 1993)

The ideal position for the company is to reach the black point in the 3-dimensional diagram in figure where low cost is achieved despite a high variety of products serving narrow market segments. The proposed framework discomposes time in flexibility, cost, quality, and customer service in conjunction with generic strategies and provides four additional 3-dimensional figures. The conclusion is that flexibility, quality, and customer service can be provided even with broad variety.

4.1.8 Booth

Booth (1995) argues that up to now the manufacturing companies have had to choose between three generic strategies of pursuing a cost leadership strategy involving mass production, adopting a differentiation strategy to obtain higher revenues across a segment or focusing on a single niche well removed from the main segment. Continuing his argument he states that this can be avoided by adopting the concept of Agile Manufacturing. Agile manufacturing is a concept that enables manufacturing companies to produce in volume but to deliver into a wide variety. The companies seek to combine the advantages that time compression techniques provide with techniques that reduce the costs of variety. This intention of these companies is to be able to offer almost instant delivery of small quantities of goods with an individual specification. In order for the companies to become Agile they have consider three things:

- The customer expectations of lead-time versus the manufacturing lead-time.
- The variety of products to be offered to customers.
- The stage in the production process when the variety of goods becomes differentiated.

Booth (1995) proposes that one of the steps that the manufacturing company must be achieve to become Agile, is the use of cellular manufacturing to reduce lead-times and maximise flexibility. Also J.I.T practices have to be adopted in order to eliminate the inventory that usually is held by manufacturing companies for just in case. Also reduction in set-up times must be achieved in order to enable the reduction of the batch sizes. The reduction of the batch size is going to eliminate a big part of the queuing time. Lastly integration of all the departments must be achieved by the use of information systems that are becoming cheaper every year (Booth, 1995).

4.1.9 Barker-Fry

Throughout the history monetary control has been the universal standard unit of measure which reported company profitability and performance in the marketplace (Barker, 1995; Barker, 1993). Barker (1995) demonstrates by the support of the method of analysis that it has already predetermined, that financial performance measures are inappropriate to support lead-time reductions. The weakness of these obsolete performance measures is placed behind the fact that cost accountants are unable to record the impact of reducing the throughput time, stock or reject rates because both activity and non-value-adding activity cause cost in the organisation. The financial performance measurements cannot guide investments and the restructuring of the processes. Fry and Karwan (1993) and Barker (1993) state that the only reason that many manufacturers fail to significantly shorten lead-times and improve time-based performance is their total reliance on inappropriate performance measurements. Fry and Karwan (1993) give the explanation that financial performance measurements can not support time-based strategies, due to the fact that in the past, labour and materials have represented 70-80% of the total costs. Today labour represents a 10% of the total cost of the product and overhead the largest percent of total manufacturing cost. These financial performance measurements are still leading the operation managers to dysfunctional behaviours. However some of these weaknesses have been eliminated by adopting Activity Based Costing (ABC), but this was only seen as a partial solution, attacking one part of the problem (Barker, 1995). Finally Barker (1995) concludes that for a firm that wants to reduce the lead-time, measures of performance must be replaced by other measures that are more accurate. These measures can be inventory turns, percentage of on time deliveries, throughput time.

CHAPTER 5

CREATING THE TOOL

The objective of this chapter is to present the construction of a tool based on the knowledge gained from lead-time and time-based frameworks respectively. The purpose of this tool was to develop a general lead-time reduction approach, which will enhance the competitive situation of a company and was designed to have a broad range of applications.

5.1 COMBINING STEPS

The method used to establish the foundation of the tool which has been developed, was firstly the creation of a matrix which had as an objective to sort out all the available time-based frameworks into various statements. These statements are as follows:

1. **Motives**:

   - Why was it important for the manufacturing company to reduce the lead-time?

2. **Process:**

   - How lead-time is analysed?
   - How the decision is made?
   - Stages of lead-time reduction methodology

3. **Content:**

   - Content is concerned with the outcome of the process, which was followed in the previous stage of the matrix.

4. **Context**:

   - Context is concerned with the understanding of the situation within the company. For this specific case the search was directed to the different ways, companies were competing through time.

Among the time based-frameworks the common steps identified for each of these various statements. In the next stage these common steps were combined in order to establish the foundation of the tool developed.

The methodology that was followed in order to reach these commonalties is summarised in figure 5.1 and additionally some representative samples are shown in Appendix D.

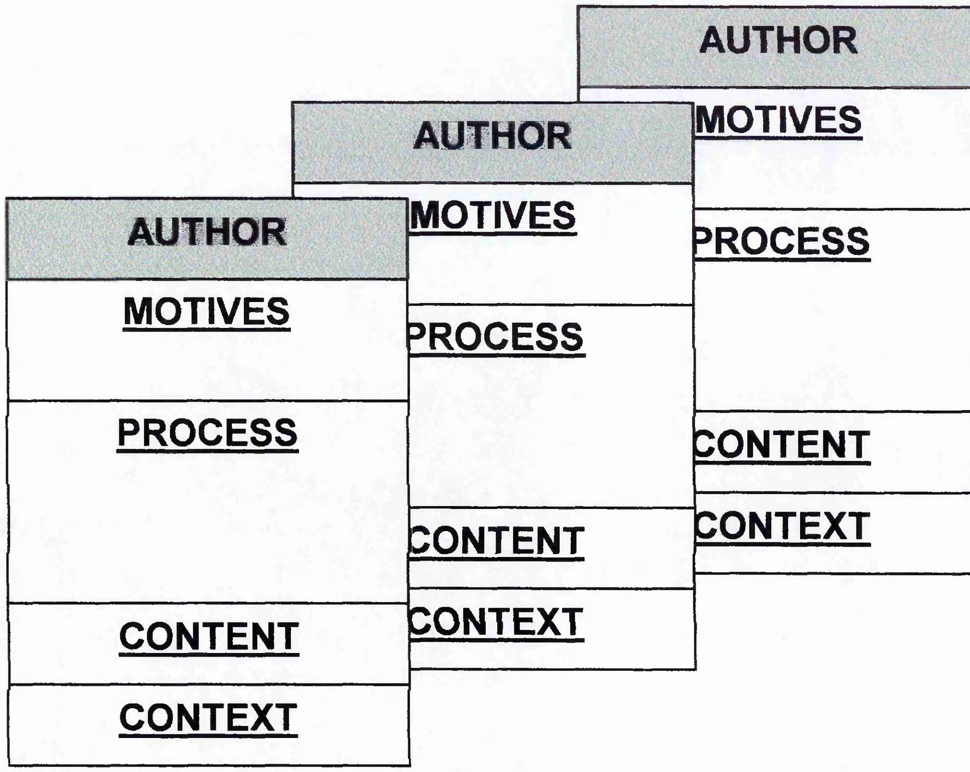


FIGURE 5.1: Combining steps from matrices

5.2 OVERVIEW OF THE TOOL

The purpose of this part is to summarise the procedure of the tool, which was created. The tool consists of 4 stages and these are as follows:

Stage 1: Identify the Business Objectives.

The purpose of this stage is to identify the current business objectives of the company. The output of this stage can be mainly expressed as two manufacturing objectives generated by taking a business level view.

Stage 2: System Analysis Tool.

This stage is involved with the selection and the application of one or more system analysis tools in order to identify problems with the lead-time in the important areas of the company.

Stage 3: Theoretical Framework.

This stage represents the theoretical framework. This theoretical framework *consists of some underlying principles, which were identified in the survey of* literature.

Stage 4: Implementation.

This stage involves the selection and the implementation of techniques, which reduce the lead-time of the whole system. Figure 5.2 illustrates these stages of the tool.

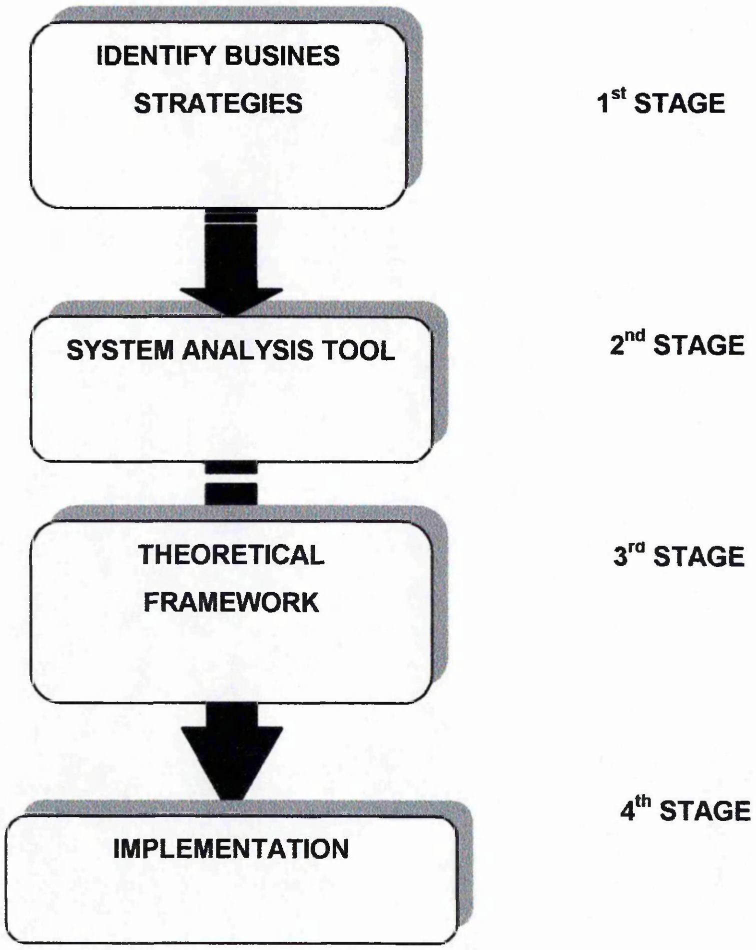


Figure 5.2: Schematic Overview of the Tool

5.2 DESCRIPTION OF THE TOOL

The purpose of this part is to describe the stages of the tool in greater detail and to provide the outputs of each stage.

Stage 1: Identify Business Objectives

This stage identifies the current business objectives of a company and has derived from the fundamental principle that has been established from the literature, that the focus of the company should be placed on the customer needs. The output of this stage is mainly expressed as two manufacturing strategies, generated by taking a business level view. These two most commonly formed strategies are described as follows:

1. Fast to market strategy

This strategy emphasises reductions in new product introduction time - from product concept to production. This is about the total process for managing development from pre-concept stage through the launch and establishment as an active product (Carter et al, 1995). The focus of the strategy is to improve linkages and communication between all the activities, which are responsible for a new product. Developing a new product is primarily concerned not with the processing and movement of materials but with the processing and communication of ideas (Buzacott, 1995). These companies that have adopted this kind of strategy, usually has employees in multifunctional teams from all the departments involved in the introduction of a new product such as design, engineering, and procurement (Stalk, 1988). This manner of working has also eliminated the revise and the approval methods which are usually performed in a sequential way in traditional factories (Suri, 1994). This strategy enables the company to introduce more new products faster than its competitors, and thereby dominate the market (Carter et al, 1995).

2. Fast to product strategy

In contrast, fast to product strategy emphasises speed in terms of responding to customer demands for existing products. Those companies who have adopted this strategy, they focus on reducing the lead-time from the time that the customer places the order until that order is in the customer's hands (Carter et al, 1995). The challenge for these companies is to convert rapidly and efficiently the raw materials into saleable products (Weng, 1998). This strategy can mainly identify problems of lead-time within the material conversion chain.

The output of this stage will be the identification of the current strategy, which will actually represent the main areas of the whole system, which are important for the company. This output is going to be used for the following stage of the tool.

Stage 2: Method of Analysis

This stage is the most important for the case of reduction of lead-time. At this point it must be clarified that without this stage it is impossible to direct and guide decisions with accuracy about reducing the lead-time in a manufacturing system. It is as important as the examination of a patient by a doctor before prescribing a suitable cure (Barker, 1998).

This stage has 2 sub-stages, which will now be described.

Sub-stage 1: Selection of the system analysis tool

This first sub-stage is concerned with the selection of the appropriate system analysis tool. This selection is dependent on the Output of stage 1, because depending on the strategy of the company, the selection will be based on the areas of the whole company those are of great importance i.e. for a example for a company that emphasises the introduction of new products in the market one of the areas that would be important would be the design department. This selection can involve more than one system analysis tool. This is because each analysis tool may be able to identify problems with specific areas of the whole system. Based on the knowledge gained from the literature review, some modelling tools have been identified which enable identification of problem areas to lead-time to be made. The tools identified include some paper based graphic techniques and some software techniques such as MPX (Suri, 1996) and WITNESS (Kay, 1998). A summary of these tools is given in the table 5.1. (Suri, 1996; Barker, 1992:1; Barker, 1994:1; Barker and Barber, 1997).

MODELLING TECHNIQUES WHICH SUPPORT

IMPLEMENTATION LEAD-TIME REDUCTIONS STRATEGIES

CATEGORIES OF MODELLING TECHNIQUES	DEFINITION	GENERIC MODELLED TECHNIQUES	Representative Modelling Tools Software
SCHEMATIC	Graphical illustration	Time Process Mapping	PAPER GRAPHING TECHNIQUE (Barker, 1992:1)
			SOFTWARE (Barker and Barber, 1997)
SIMULATION	A model of the behaviour as a whole by defining in detail how various components interact with each other	Discrete Event Simulation	WITNESS (Kay, 1998)
MATHEMATICAL	Explicit Analytical Formulae	Queuing Theory	MPX (Suri, 1996)

Table 5.1: Modelling techniques that support lead-time reductions, (based on Baines, 1994)

Sub-stage 2: Application of the selected system analysis tool

The second sub-stage is involved with the application of the selected system analysis tools. After the application of the tools, the output of this stage is firstly the identification of areas where problems with lead-time exist and secondly the order of importance depending on the magnitude of the problem. The whole output of this second stage is going to be used for the stage 4, which is going to provide guidelines for the sequence of the selection of techniques for lead-time reduction.

Stage 3: Theoretical Framework

The third stage represents the theoretical framework. This framework consists of some principles that have been identified among techniques, which support lead-time reduction within a system. This classification was carried out according to the reasons that have caused the problem with increased lead-time. These principles are as follows:

1. Simplification

This principle is based on the simple premise that increased lead-time is a result of a process. This process can be focused on an individual activity or it can refer to a series of linked processes. Reduction of the lead-time is required if these processes are to be changed. Simplification of the system reduces the lead-time by acting on those steps that no longer contribute to the added value. These steps are often the ones which are either carried inefficiently or no longer necessary. For those steps, which are inefficient, improvements can be obtained through either re-thinking or combination. Re-thinking involves asking how the same function can be provided more efficiently. Combining means taking two or more steps which have similar purposes, and combining these steps into one. Simplification of the system aims for a process, which requires fewer steps for its completion. The result is often a simpler process. For firms that want to reduce the lead-time, simpler processes are more attractive because these take less time and are easier to control. Some associated techniques are the re-arrangement of the factory layout (Based on Carter et al, 1995; Barker, 1997; Bhattacharya, 1997).

2. Integration

This principle is based on the premise that lead-times are increased because processes are performed in a sequential manner. In such environments lead-times grow for several reasons. Firstly the sequential nature of the processes themselves lengthens lead-times. When dealing with a new product design project manufacturing can only get the design after it has been approved, by previous departments in the process. In most cases, these upstream departments may include product design, marketing, and finance. Secondly areas where orders or designs become lost or misplaced often separate the "strong walls" between functional areas. Finding these orders increases lead-times. Thirdly revision is a sequential process which takes longer to complete and more costly to implement. Manufacturing problems are often not discovered when the design is at the conceptualisation stage in product engineering. These problems are only uncovered after the design has been completed and passed onto manufacturing. Once the errors have been detected these must pass through the entire sequential process again. Integration tries to tear down these "strong walls" and bring the various interested parties together so that they share the necessary information and insights. Integration tries to enhance co-ordination by bringing the various departmental activities together e.g., design, manufacturing, marketing etc. Alternatively integration tries to bridge the inter-company gaps by bringing together customers and suppliers. Some associated techniques are JIT II, the use of information systems and the creation of multifunctional teams from all the departments of the company (Based on Carter et al, 1995; Pragman, 1996).

3. Standardisation

Standardisation is based on the premise that lead-time is increasing because each task of the process and each part of the product are treated by the company as being unique. This principle focuses on what is the minimum activity necessary to get the task done. This can be achieved by re-using steps or parts, which are common or standard. Re-using parts and using common process can reduce the levels of activity that are devoted to these areas. With standard processes, people are not faced with the dual task of designing a new product and learning new processes. Instead, they work with a process that is already known to them. They can focus their attention on designing the product within the context of this standard process. Additionally people learn to respond to each order in the same way. One technique associated with this principle is Group Technology (Based on Carter et al, 1995).

4. Variance control

This principle focuses primarily on the predictability of the process. It attempts to control lead-times by eliminating those activities or tasks with the highest level of variance. When variances are high and the process is unpredictable, a common response is to lengthen the lead-times. These added segments of lead-time serve to buffer or protect the overall system from any problems created by the increased variability. With variance control, those tasks, with the highest level of variance are eliminated or controlled by attacking those factors responsible. Some associated techniques with this principle, are Total Quality Management and J.I.T techniques (Based on Carter et al, 1995).

5. Attention to bottlenecks

This principle is based on the premise that lead-times are increasing because of the presence of resource constraints in manpower, machines, tooling and material. This principle achieves lead-time reduction by avoiding those delays, which are created whenever orders must compete for access to constrained resources such as manpower, machines, tooling or material. It does so in two ways. Firstly by planning in a manner to ensure excess resources at bottleneck sites and secondly by trying to have more skilful workers present. Such workers are better able to respond to and accommodate variations in product mix or workloads. At no time every resource must be scheduled for maximum utilisation. One technique associated with this principle is training in multi-sklling (Suri, 1994; Buzacot, 1995; Based on Carter et al, 1995; DTI, 1987).

6. Automation

This last principle is based on the assumption that problems with lead-time are technology related which means that these new technologies are inherently better and take less time. Lead-time is long due to of old machines and lack of automation. This principle relies on the substitution of older and less efficient procedures, technologies, and techniques by new and more efficient ones. Some techniques available are Flexible Manufacturing Systems (FMS) and CAD/CAE (Based on Carter et al, 1995).

Stage 4: Implementation

The last stage of the tool is involved with two sub-stages and these are as follows:

Sub-stage 1: Selection of techniques.

This sub-stage has as its objective the selection of a set of techniques that are going to result in lead-time reduction of the system. This selection must be based strongly on the two following points:

- **Output of stage 2,** which has identified the problem areas that exist with lead-time and these, must be placed in order of importance depending on the magnitude of each problem.
- **Output of stage 3,** which has classified the techniques available for the reduction of the lead-time depending on the causes of increased lead-time.

The selection of these techniques is based on the combination of these outputs from the previous stages.

Sub-stage 2: Implementation of techniques.

This sub-stage is concerned with the implementation of the selected techniques for tackling the problem with lead-time. The implementation must be accompanied by the replacement of financial performance measurements. This replacement derives from the need for evaluation of the results gained in lead-time reduction by the implementation of the selected techniques.

CHAPTER 6

APPLICATION OF THE TOOL

The objective of this chapter is to investigate the application of the tool which has been developed for the case of Hephaestus S.A. Some techniques have been recommended to solve the problems with lead-time.

6.1 DATA COLLECTION

Qualitative information for the case study has been collected through interviews with the various staff on site. This enabled a better understanding to be achieved of the problems the company was facing with lead-time. The data was collected from two visits to Hephaestus S.A., and also from some limited documentary data available from the company. This limitation derives from the fact that in normal day-to-day functioning of the company a number of data are not required. Hence, in this project these unrecorded data could not be obtained from the company.

6.2 APPLICATION OF THE TOOL

Stage 1: Identify Business Objectives

The first stage of the tool was involved with the identification of the current strategy at Hephaestus S.A. The company emphasises the manufacturing of industrial steam boilers, within a pre-determined range of type and dimensions. As noted previously this company does not have any department for the introduction of new products. The most important area identified for this company was the material conversion chain. This study is focused on a specific type of steam boiler referred as the K100.

Stage 2: Method of Analysis

This stage of the tool involves the selection of the methods of analysis and their application. The method proposed by Barker (1992:1) Barker (1994:1), Barker (1994:2) and Barker (1996) was selected for the case of Hephaestus S.A. This is a general model of analysis and is being used to identify areas in the material conversion chain where problems exist with lead-time. This method was selected based on the output of stage 1 which directs attention on one of the important departments at Hephaestus S.A..

Additionally this method of analysis was selected because of the fact that it is a very simple in concept and also provides a graphical illustration of all the processes against the time continuum by dividing them into positive value-adding activities and non-value-adding activities. Value-adding activities are defined as those activities which add value to the product like cutting, mixing and drilling and non-value-adding activities which do not add value to the product like moving and inspecting. By this method a scaled map is created which depicts where these activities are placed against time. The minimum data that should be imposed on this model is the recording of the total time elapsed from the first production operation through to shipping of the completed product, and the ratio of time spent adding value. By conducting this rough cut analysis it is possible to identify constraints and poor system synchronisation and make improvements towards a reduced throughput time (Barker, 1992:1). The output of this method of analysis will provide guidelines for the selection of the appropriate techniques in the stage 4 of this approach.

The data required for the application of this method of analysis can be gathered by tracking a single product through the shop floor and the recording of all the times taken for each value-added activity and for each non-value-added activity. By this way a graphical illustration is provided in a paper form, of all the activities on the shop floor of Hephaestus. S. A. and also the means of identifying the causes of increased lead-time.

This model was applied for the case of Hephaestus S.A. The tracking of a particular product from the time of arrival of the raw material through to shipping was impossible since its average throughput time in the material conversion chain is 3.5 months. The recording of the value adding operations was therefore carried out for different steam boilers the K 125, K 85,and K100 which have the same production operations and more or less take the same time. This was necessary in order to overcome this difficulty of the tracking of the steam boiler K 100. The time of these value-added activities and the order in which these are carried out for the K 100 steam boiler is shown in Appendix E. Appendix E shows also the 4 inspections activities which take place at predetermined stages in the whole of the process of the material conversion chain.

The recording of the time value-added activities represented only 3.34 % of the total throughput time. This figure was estimated by finding the ratio of the time value-added activities to the total throughput time on the shop floor which is 3.5 months. This low figure of the negative loss indicated a large waste within the whole material conversion chain. This indication required further investigation in order to establish the causes for this negative loss. This figure includes all the internal activities of the company, from the first production operation through the shipping of the final product. The important indication here is that there is a large negative loss caused by non-value-added activities within the total material conversion chain. This examination did not enable the timing of the non-value-added activities to be recorded and to be ranked in order of importance. The output of this stage is not therefore sufficiently accurate for application to stage 4 of the tool. The method that was followed in order to investigate the negative loss was to place all the value-added activities against time. Between these value-added activities, gaps have been placed indicating the existence of the non-value-added activities and this mapping is shown in Appendix F. With this map of all the activities within the total material conversion chain, questions were raised concerning the cause of these gaps. A further investigation based on qualitative information in the shop floor revealed that this negative loss consisted mainly of moving time, inspections and stoppages due shortages of consumables and manpower.

More specifically the current layout on the shop floor was examined and this showed that the raw materials pass through a complex route and there is unnecessary flow of the material. The current material flow has been mapped and this is shown in the Appendix G.

Additionally many stoppages were caused by shortages of consumables such as electrodes for the electric welding operations and bolts. These shortages were due to the fact that the company does not have a satisfactory method of ensuring that these consumables are regularly reordered. When consumables run out on the shop floor the workers inform the management team who then place an order to the suppliers of consumables.

Another part of the negative loss, which was identified, was due to a relatively low range of skills among the workers on the shop floor. This was mainly due to the fact that the management team had for the last three years, followed a policy of replacing highly skilled workers by less skilled workers from foreign countries in order to reduce operating costs. The current shop floor skill level breakdown is shown in Appendix H.

Also four inspection operations are conducted through the material conversion chain at predetermined stages of the processes. These inspections include x-ray diffraction analysis and this is necessary to ensure the quality of the welding sections in the steam boilers before the final and compulsory inspection that is performed from Hellenic Register of Shipping. During these operations the shop floor is evacuated for safety reasons for at least 2 hours. These inspections are not performed by Hephaestus S.A. but are carried out by an out-sourcing company. This method of x-ray inspection makes it very difficult to schedule these inspections in a satisfactory manner with the internal activities of the company.

Further investigation was also conducted into the procurement of the raw materials, which revealed that the problem with the total lead-time had been caused to a large extent by the overdue deliveries of the raw materials such as tubes and steel plates. This problem arises from the fact that there are no internal manufacturers of steel plates and tubes in Greece at the present time. The availability of these materials from the suppliers operating in Greece is also very limited. This is because the material required for the manufacture of steam boilers is of a very specific type and dimensions. e.g. 17Mn 4 steel plate. This is even a difficult material to procure in the European market. The problem that the company faces is long delays in the delivery of these raw materials, because it is effectively supplying these raw materials from manufacturers in European countries and also due to long transportation problems. The company can actually achieve on-time deliveries are to pay extra delivery charges. The percentage of the overdue deliveries for these raw materials is shown in Appendix I.

Stage 3: Theoretical framework

This stage includes the theoretical framework, which is only for reference purposes and is not included in any application. The output of this stage is helpful for providing guidelines for the selection a set of techniques.

Stage 4: Implementation

This stage involves the selection of appropriate techniques, which can reduce the lead-time for Hephaestus S.A.. This stage is depending on the output of stage 2 which has pointed out the areas with problems of lead-time. In a different case having all the data needed the selection would have been based also on the magnitude of the problem and therefore would have been more accurate. This selection was guided additionally by the theoretical framework presented in the stage 3, which had classified available techniques according to the cause of increased lead-time. The implementation did not take place for this study but these selected techniques were recommended to the company which are going to be implemented in the near future.

Simplification

One of the recommendations, which have been made to Hephaestus S.A. for the material conversion chain, included re-arrangement of the machine layout on the shop floor in order to improve material flow. Factory layout is a vital factor in reducing the manufacturing lead-time and the impact on company performance from an improved layout can in most cases, be substantial. A good layout will minimise the need for transportation, material handling and will provide a smooth material flow in the factory (Suzaki, 1987). In the current movement of the material identified much route complexity consisting of back flow and cross flow. After identifying the complex material flow route, an attempt was made to improve this flow and a new layout was designed. The main problem that was identified was the location of the punching machines, which caused the main disruption in the flow of material. Although this process was necessary for every part of the product its location was far away from the other machines and not in continuous form according to the order of the processes. The attempt for designing a new layout was based on the streamlining of the flow on the shop floor and elimination of all the unnecessary motion. The new layout designed to have I-shape and rejected the U-shape that had before. In the new movement of the flow the punching machines are placed between the cutting and the rolling in order to eliminate the back flow in the movement. In the designing of the new layout an important factor was taken into account. The machine that performs the corrugations to the tube must be placed outside the shop floor due to the fact that this operation is generating a big amount of fumes. So this machine remained at the same position outside the factory in the new movement of the material. The new layout is shown in the Appendix J. It is believed that this new form of the movement of the material can achieve a reduction of a part of the moving time and therefore the reduction in the total lead-time of the product.

The solution seems to be very suitable for the case of Hephaestus S.A., because this change can be achieved relatively easily with no high extra costs for the company and within a very short period of time. This solution can be further improved by taking into account also other techniques available such as Group Technology and organise the layout in product centres according to some product families.

Automation-Quality

One major reason for the increased lead-time arises from the x-ray inspections, which are performed at predetermined stages of the processes on the shop floor. The increased lead-time is not only a result of the inspection time. As noted in stage 2 of the tool the problem is getting worse, because of difficulties that emerge in the scheduling of these operations between the out-sourcing company and Hephaestus S.A. and also from the evacuation of the shop floor which causes production to cease. One solution which, has been recommended to Hephaestus S.A. is the promotion of quality and automation by the replacing the existing welding machines in order to eliminate the need for some intermediate stages of inspection and additionally to speed up the manufacturing processes. The type of welding operations, which are currently used, is Gas Shielded Metal Arc Welding (GMAW). These welding machines are operated manually and are extremely portable. However the productivity of these welding methods is relatively low due to the time required to remove the slag from the weld and the necessity to change electrodes frequently. Also the quality of this welding operation is strongly related with the skills of the worker (Manufacturing Technology Module, 1999). The recommendation that has been made was the replacement of the existing welding machines by new Gas Metal Arc Welding machines. This type of welding process is much quicker than the GMAW because it is a continuous operation since the arc is formed between the tip of a consumable, continuously fed filler wire. Also this process can be suitable for automated operations in contrast with GMAW. The quality of Gas Metal Arc Welding is much higher than that one obtained with GMAW because it has lower hydrogen potential which reduces the risk of cold cracking (Manufacturing Technology Module, 1999). This replacement would mean the reduction or even the total elimination of the inspections which will improve the lead-time of the product. Additionally this replacement of the technology would also provide faster welding operations which would further achieve reduction in the lead-time of the steam boiler. Another alternative solution that could be proposed for tackling this problem is the in sourcing of these x-ray inspections so to enabling Hephaestus S.A to better synchronise these inspections with its internal activities. This solution requires the purchasing of x-ray inspection equipment. By this way the scheduling of these operations would be much easier and it would enable the company to schedule these activities outside the normal working time. Further research is necessary in order to evaluate this investment which it would be necessary for the company to adopt these solutions.

Attention to bottlenecks

Another recommendation that has been made to Hephaestus S.A. was the installation of an external "kanban" system as a method of ordering consumables. The basic concept behind the kanban philosophy is that sufficient components are stored and a trigger mechanism is activated at a certain reduced stock level to enable these components to be replenished before stock out occurs (S&I, Workbook 1999). Two external kanban methods are commonly used; the first one depends on the supplier who comes and replenishes the predetermined level of components and the second one is dependent on the shop floor employees who send a predetermined ordering form by fax-machine to the supplier with the specific requirements (S&I, Workbook 1999). External Kanban eliminates the planning loop of the information because the responsibility is transferred to the suppliers who monitor the levels of components or to the shop floor employees. The installation of external kanban will enable Hephaestus S.A., to eliminate the stock out of the consumables. The installation of these consumables can be placed in the two assembly areas of the company where the main welding operations take place and the installation of components to the steam boiler. By this method stoppages due to bottlenecks will be eliminated in the shop floor. The installation of an external kanban is a very simple in concept and attractive because no extra costs will be necessary for the company. The only requirement for this installation is an agreement between the suppliers operating in the Greek market place or the installation of fax machines in the shop floor.

One final recommendation that concerns the material conversion chain at Hephaestus S.A. aims at the elimination of bottlenecks in manpower resources. Hephaestus S.A. has noticed that since the time they replaced the highly skilled workers, the flexibility of the company has declined. One of the recommendations that have been made is the introduction of training. With the adoption of a cross training programme of the personnel the factory would be able to increase the flexibility of the company and thereby eliminate the bottlenecks in manpower. For this type of manufacturing companies such as Hephaestus S.A. flexibility can play a vital role. This programme of training could be organised internally by the same workers on the shop floor which will introduce job involvement in the area of the shop floor and will support even more the situation of the company.

Integration

The procurement department of the company was recommended to obtain an information system in order to eliminate the long delays associated with the long delivery of the specialised raw materials from foreign countries.

The problems with the overdue deliveries of raw materials can be addressed by a solution based on information technology. Data exchange and communication are important areas for improvement and reduction of lead-time. Information plays a key role in enabling a company to be more responsive to customer needs. Companies that use these information systems, are more flexible both internal and external to the organisation (Daugherty and Pittman, 1995). One solution based on the information system is the use of Electronic Data Interchange (EDI). This method is used for speedier information exchange in the whole supply chain. EDI is one method of information technology/systems that involves the use of computer and telecommunications to transmit and receive standard electronic messages in place of paper documents (Lucas Engineering, workbook). EDI enables manufacturing companies to conduct their business through communications links with the supply chain. The use of these systems allows major companies to exchange documents such as orders and invoices electronically with their suppliers. Fallows (1999) argues that the use of information systems such as EDI can be a significant advantage for the companies. It has been estimated that through using electronic documents, administration can be reduced to about 20% of the cost of the equivalent paper based methods. Furthermore greater accuracy and significantly shorter lead-times can be achieved (Fallows, 1999).

An alternative solution, based on information technology is E-commerce. This system has similar characteristics to EDI. The difference is based on the fact that E-commerce is based on the movement of the information through the web site. E-commerce allows the company to be connected through the Internet to an already installed EDI system of the supplying company. This system enjoys the same advantages as EDI like reduced lead-times and greater ordering accuracy. It is believed that adoption of E-commerce at Hephaestus S.A. is more suitable than EDI. This derives from the fact that the installation and running costs of EDI, it's greater than E-commerce. That's because E-commerce is based on the links that the Internet Web provides (Fallows, 1999). Hephaestus S.A. is a medium size company and probably may find this type of expense an insurmountable barrier. Another disadvantage of EDI compared with to E-commerce is the installation of EDI requires long-term relationships between two parties since it has been initially designed for the constructions of permanent electronic links. The installation of E-commerce for the case of Hephaestus S.A. could be very helpful because it could minimise the percentage of overdue deliveries of sheet metal and tubes from European countries. Also this information system could improve the sales channels by providing open channels of information to new customers (Fallows, 1999)

Performance measures

It is recommended that an accurate method of evaluating the results of the various recommendations made to Hephaestus S.A, should be introduced. Monetary control is the only factor which Hephaestus S.A, currently use to monitor company profitability. Barker (1995) argues that financial performance measures have become obsolete because these are unable to record the impact of reducing the throughput time or reject rates because both value-added activities and both non-value-added activities cause cost in an organisation. More accurate records such as the percentage of on-time deliveries or inventory turns must replace the crude performance measures currently used by Hephaestus S.A.. This replacement will enable the company to monitor its capability for on-time deliveries of the steam boilers and finally to compete through time.

It is believed that all the recommendation that have been made to the company can make a significant contribution to the reduction of the lead-time for the manufacturing of steam boilers. Some of them are relatively straightforward and cost-effective solutions and the only thing that is required is the commitment from the management team of the company. However solutions that include replacement of the existing welding operations which will promote the quality and simultaneously speed up the existing processes, require further cost evaluation because they may involve considerable new investment.

CHAPTER 7

REFINEMENT OF THE TOOL

The objective of this Chapter is to identify all the necessary aspects of the project and to present the updating of the tool with reference to the application that has been made.

In the first phase of this approach was the identification of business objectives of the company in order to determine its current strategy. This stage was important since it is directly linked to the requirements of the customer. In this case it was observed that these requirements were represented as the ability of the company to respond quickly to customer demands.

The second stage of the tool included the selection and the application of a method of analysis appropriate to the area of the company that has been determined in the previous stage. This phase of the tool allowed the identification of problems of lead-time and also provided the support for the following stages of the application. The method of analysis that was selected revealed a huge amount of waste within this area and additionally a large potential for improvement. This output, with a combination of qualitative data gathered from the shop floor gave guidelines for the identification of solutions for lead-time reduction.

The third stage of the tool was not involved with the application because it has been developed only for reference purposes. This stage includes the theoretical framework, which is based on the classification of techniques available for reducing the lead-time.

The last stage of the application included the selection of a set of techniques for tackling the problem of lead-time. This selection was based on two elements. Firstly, on the output of the method of analysis which revealed problems with lead-time and secondly on the theoretical framework. The solutions were based on some principles like simplification and integration, which can minimise the lead-time of the company.

The limitations of the application derive mainly from external reasons. One of these is that although the method of analysis which was applied was the appropriate one for the material conversion chain, because of the unique functionality of the product it did not give so accurate results.

Since there is no evidence yet from the implementation of this approach the output of this application of the tool in Hephaestus S.A. can be considered as successful one although the existence of some limitations. Firstly because it was broad enough, since it considered both the business and operational level aspects that were necessary in order to give a justified solution to the problem of lead-time and took into consideration all the necessary aspects of this project. Secondly because the company is going to implement these solutions in the near future.

This application of the tool, in Hephaestus S.A. supports the following two elements that have been mentioned previously in this thesis. First the importance of lead-time analysis as method of identifying causes of increased lead-times because without this in the material conversion chain it would be impossible to guide actions for reducing the lead-time. Secondly the fact known from the literature that within the manufacturing systems there exists a big percentage of waste which is usually caused from unnecessary complexity and lack of control. The evidence of existence of big waste within Hephaestus S.A. was enough to convince managers of the company that there was a big potential for improvement and to take action to this direction.

Additionally one point can be added to this generic tool is the extension of the literature survey in the direction of the area of system analysis tools. By this way the generic tool is going to include more system analysis tools that can be useful for capturing all the possible needs coming from all the areas of the company.

CHAPTER 8

CONCLUSIONS

This Chapter has the objective to summarise the work described in this thesis and to present the limitations of this work described in this thesis. Additionally it addresses the issues for future work in this subject.

The aim of this thesis was the creation of a generic tool for reducing the lead-time for a variety of fields and additionally to apply this for the case of Hephaestus S.A.. The first step was to review current literature on lead-time and time-based frameworks. This phase was very difficult to be executed because of great inconsistency in the terminology used for defining time-based frameworks. However this phase of the thesis enabled the establishment of the foundation behind the creation of the generic tool. The initial intention was to develop the tool in such a manner that it could be applied to a variety of fields. The foundation of the tool developed, is formed around two points. This first point was generated by taking a business level view which is that companies should realise that they need to provide fast delivery where the customers appreciate it. This means that companies need to investigate all aspects of lead-time so that these may be reduced for those customers for which are important. The second one was the necessity of reviewing frameworks of analysis, which can support to analyse and control the dynamics of the supply chain. These frameworks aim to understanding the cause of total lead-time of the whole supply chain and that without these frameworks it is very difficult to achieve lead-time reduction of the whole system. The aid of the frameworks can be represented as the guidance and justification for taking action. Taking the operational level view generated this second point. Additionally through the work that has been carried out in this thesis, it has been established that lead-time reduction can provide the means for enhancement of the competitive position of a company in the market place. Additionally it has been highlighted the fact that focusing on time improves other parameters, such as cost, quality, and productivity.

The next stage of the thesis was involved with testing the tool for a real situation, a steam boiler manufacturing company in Greece. The objective was to exemplify how problem areas can be addressed with reference to the generic tool that has been developed. The application of the tool was made by following all of the stages and having as an output the identification of a large waste of time within the material conversion chain and big delays with the on-time deliveries. This indication pointed out a large potential for improvement for the company. Finally some recommendations have been made for reducing the lead-time of the product. Some of the recommendations that have been made are relatively straightforward and easy to implement. Additionally most of the recommendations do not require a high extra cost and they need only the commitment of the management team in the company.

However some limitations became evident from applying the generic tool to the activities of Hephaestus S.A. These limitations did not arise from the methodology that is adopted within the generic tool but from the fact that limited data was available. In a more substantial case the results presented, would have been more accurate.

This work actually represents an attempt to create a structured approach, which can be used for lead-time reduction in a variety of fields. It is believed that the generic tool developed is a successful one since it considered all the necessary aspects required, both business and operational level ones, providing a justified and structured lead-time reduction approach.

The future work for the generic tool could include its application to other companies, which emphasises a fast to market strategy. This kind of applications will enable the testing of the tool under different circumstances.

Additionally, the implementation of the recommendations, which have been made to Hephaestus S.A., would be the future work of this application. The management team of Hephaestus S.A. will adopt these solutions in the near future and results from this implementation can be monitored and evaluated.

REFERENCES

Baines, T.S., (1994). "Modelling in the evaluation of a manufacturing strategy". PhD Thesis, Cranfield University.

Barker, R. C., (1992:1). "Achieving increased production efficiency- A system approach". Long Range Planning, vol. 25, no. 5, 99-105.

Barker, R. C., (1992:2). "Value adding performance measurement: A time based approach". International Journal of Operations & Production Management, vol.13, no.5, 33-40.

Barker, R.C., (1992:3). "Restructuring productions operations: The applications of time based value-adding models". International Journal of Advanced Manufacturing, vol.7, no.4, 225-230.

Barker, R.C. (1994:1). "Production System Without MRP: A lean time based design", Omega vol.22, no. 4, 349-360.

Barker, R.C., (1994:2). "The design of lean manufacturing systems using time based analysis". International Journal of Operations & Production Management, vol.14, no.11, 88-96.

Barker, R.C., (1995). "Financial Performance Measurement: Not a total solution". Management Decision, vol.33, no. 2, 31-39.

Barker, R.C., (1996). "Value chain development--An account of some implementation problems". International Journal of Operations and Production Management, vol. 16, no. 10, 23-36.

Barker, R.C. and Barber, K., (1997). "Development of time based frameworks: Manufacturing system analysis and value adding performance". Omega, vol.25, no. 2, 349-360.

Barker, R.C., (1998). "An emerging theory of negative loss formation within Manufacturing Operations". International Journal of Production and Research, vol. 36, no 5, 1293-1304.

Bartezzaghi, E., Spina, G. and Verganti, R., (1994). " Lead time models of business process". International Journal of Operations & Production Management, vol.14, no.5, 5-20.

Bauly, J. and Bergh, D., (1995). "Time to Market" Manufacturing Eng, Vol.72, no.3, 136-138.

Benjafar S., (1996). "On productions Bathes, transfer batches and lead times" IIE Transactions, vol. 28 no. 5, 357-363.

Bhattacharya, A. and Jina, J., (1997). "Manufacturing time compression-Not a technique but a philosophy". Production Planning and Control, vol. 8, no. 1, 88-91.

Black, J. T. and Schroer, B. J., (1995). "Simulation of an apparel assembly Cell with walking workers and de-couplers". Journal of manufacturing systems, vol. 12, no. 2, 170-179.

Booth, R., (1995). "In the market -Agile Manufacturing". Manufacturing Eng., vol.74, no.2, 79-84.

Burbidge, J.L. (1993). "Reducing delivery times for OKP Products" Production Planning and Control, vol. 4, no. 1, 77-83.

Buzacott, J. A., (1995). "A perspective of new paradigms in manufacturing". Journal of manufacturing systems, vol. 14, no. 2, 118-125.

Carter, P. L., Melnyk, S. A. and Handfield, R. B., (1995). " Identifying the basic process strategies for time-based-competition". Production and Inventory Management Journal, vol. 36, no.1, 65-71.

Daugherty, P. J. and Pittman, P.H., (1995). "Creation of Distribution Flexibility/Responsiveness". International Journal of Operations and Production Management, vol. 15, no. 2, 54-61.

DTI, (1987). "Manufacturing Excellence", *Conference in Cranfield University.*

Fallows, J., (1999). "Net Profits - E-commerce". Manufacturing Engineer, vol. 78, no.1, 33-36.

Fry, T. and Karwan, K., (1993). "Performance Measurement systems and time-based manufacturing". Production Planning and Control, vol. 4, no. 2, 102-111.

Hallihan, A., Gareth, W. and Sachcet, P., (1995). "Study Case in Aerospace Manufacturing Company". Manufacturing Eng., vol.74, no.5, 79-83.

Hardfield, R.B., (1993). "The role of Materials Management in developing Time-Based Competition". International Journal. of Purchasing and Materials Management, vol.29, no.1, 2-11.

Hise, R. T., (1995). "The implications of time-based competition on international logistics strategies". Business Horizons, vol.38, no. 5, 39-46.

Kay, J. M., (1998). "A review of how computer modelling and simulation may assist the manufacturing system design". Analytical techniques module, Cranfield University

LUCAS, (1989). "The Lucas Manufacturing Systems Engineering Handbook". Institution of Production Engineer, London, England.

Manufacturing Technology Module, (1999). "A Review Of Joining Process". Cranfield University.

Pragman, H., (1996). "J.I.T II: A purchasing concept for reducing lead-times in Time Based Competition (Just in Time Management)". Business Horizons July-August, vol.39, no. 4, p54-59.

Schmenner, R. W., (1988). "The merit of making things fast" Sloan Management Review, vol.30, Iss. 1, 11-17.

S&I Ltd, (1999). "Kanban System Development Team". Switchgear& Instrumentation handbook.

Spanner, G., Nuno, J.P., Chandra, C., (1993). "Time-Based Strategies-Theory and Practice". Long Rang Planning, vol.26, no. 4, 90-101.

Stalk, G. and Instran, R., (1989). "New competitive Age." Executive Excellence, vol. 6, no. 10, 58- 59.

Stalk, G., (1988). "Time - The next Source of Competitive Advantage" Harvard Business Review, (HBR), July-August, 41-51.

Suri, R., (1994). "Common Misconceptions and blunders in Implementing Quick Response Manufacturing". *Proceedings of the SME ATOFACT 94 Conference,* Detroit, MI, November 1994.

Suri, R., (1996). "Using Queuing Models to support Quick response manufacturing". *Proceedings of the International IIE Conference*, Minneapolis, MN, May 1996.

Tersine, R.J. and Humingbrid, E. A., (1995). "Lead-time reduction: The search for competitive advantage". International Journal of Operations & Production Management, vol.15, no.2, 8-19.

Weng, Z. K., (1998). "Lead-time management in a make to order manufacturing firm". Production and Inventory Management Journal, vol.39, no.2, 38-41.

Womack, J. P. and Jones, D. T., (1996). " Beyond TOYOTA: How to route out waste and pursue Perfection" Harvard Business Review (HBR), Sept-Oct, 140-158.

BIBLIOGRAPHY

Krajewski, L. J. and Ritzmann, L. D., (1996). "Operations Management", Addisson-Welsey Publications.

Stalk, G. and Hout, T.M., (1990). " Competing Against Time" New York: The Free Press.

Suzaki, K., (1987). "The New Manufacturing Challenge" New York: The Free Press.

APPENDICES

APPENDIX A

PERCENTAGE OF SALES

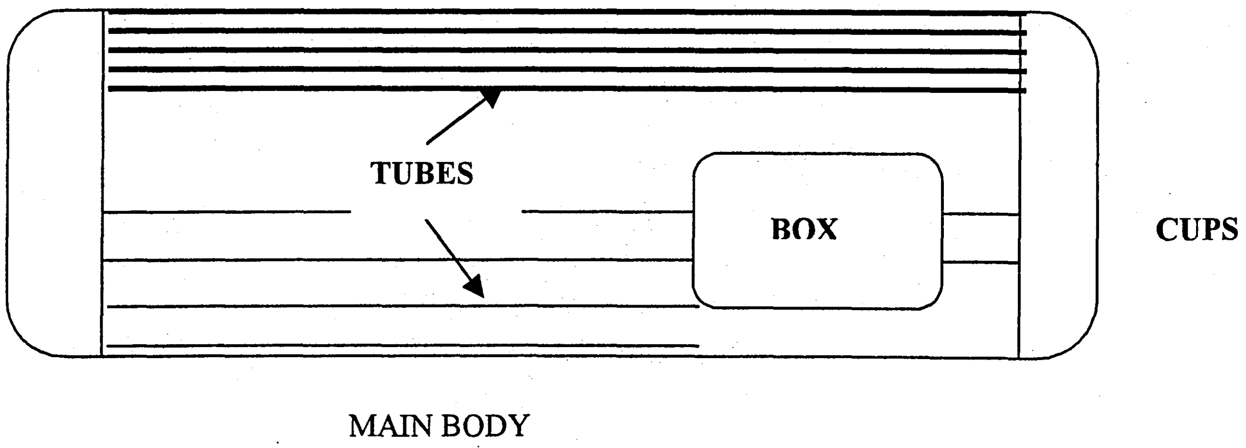
NAME OF PRODUCT	% OF TOTAL SALES
1.Steam Boilers	56
2. Seam boilers for solid fuels	8
3. Steam Generators	10
4. Pressure Vessels	5
5. Tanks	5
6. Corrugated Furnaces	7
7. Heat Exchangers	5
8. Double Jacket Boilers	1
9. Food processing machinery	3
TOTAL	100

APPENDIX B

PRODUCT RANGE OF THE SPECIFIED PRODUCT

TYPE	HEATING SURFACE M2	HEATING CAPACITY		STEAM OUTPUT KG/H
		Kcal/h	K.W	
K 10	10	240,000	278	400
K 16	16	384,000	445	640
K 25	25	600,000	696	1000
K 40	40	960,000	1113	1600
K 50	50	1,200,000	1393	2000
K 60	60	1,440,000	1673	2400
K 80	80	1,920,000	2230	3200
K 100	100	2,400,000	2786	4000
K 125	125	3,000,000	3488	5000
K 150	150	3,600,000	4186	6000
K 200	200	4,800,000	5572	8000
K 250	250	6,000,000	6976	10000
K 300	300	7,200,000	8372	12000
K 400	400	9,600,000	11162	16000
K 450	450	10,800,000	12558	18000

ROUGH DRAWING OF THE PRODUCT



APPENDIX C

RESULTS OF TIME-BASED ANALYSIS

1. CASE STUDY (1988-1989)

Barker (1992) presents the results from the implementation of the time-based analysis model. The first case study is referring to a company that manufactures electronics components with 350 employees, which is located in England and has a £18 million turnover. The company uses MRP II and sales ordering processing (SOP) systems. The trial took place in the assembly department, with 200 employees, and a £ 70,000 per day target output.

Problems

The problems of the company were high work in process, low velocity production and value added in small percentage of the total time goods spend in the total material conversion chain. The manufacturing costs were too high and high overdue orders to customer.

Method

Attempts were made to reduce the lead-time in the assembly department, since it was a bottleneck in the organisation with 708 overdue orders.

Time when value was not added identified through the implementation of the time-based analysis model. The throughput time was reduced by change to cell assembly methods, improved system of communications, reduction at all bottlenecks, and improved scheduling of materials.

Results

After 15 months were overdue orders to customers, previously numbering 708, were reduced to 125. The throughput time per assembly per assembly works order (date in-date out) was reduced from 15 to 6 days.

2. CASE STUDY (1991-ongoing)

Another case (Barker 1994) describes a company, which competes on a global market where value adding capability, stock levels, and quality must be at a world class standard.

The total manufacturing process and supply chain was analysed by product group to determine the organisation's ability to add value. Data was gathered relating to component deliveries and internal production processes at a given time to calculate the existing total throughput time. This information was imposed in the time-based analysis model. The model revealed where improvements to the existing J.I.T system could be made in a structured basis.

Results

The following results were realised:

- Reduction by 60% of purchased components stock holding
- Reduction in stock work in progress in assembly by 80 %
- Reduction in total throughput time in assembly cells from 20 hours to less than 2 hours

APPENDIX D

MATRICES

	Hallihan A., Williams G., and Sachet P. (1995) "In the market" Study Case in Aerospace Manufacturing Company, Manuf.Eng. vol. 74 No. 5 A
MOTIVES Why it is important to reduce the lead-time?	➢ Competitiveness ➢ Productivity Improvement ➢ Flexibility
PROCESS ➢ How do you analyse the lead-time? ➢ How do you make the decision? ➢ Stages of lead-time reduction methodology	**SUPPLY CHAIN** Concurrent, not sequential product design process—integration of Marketing, Design, Manufacturing (all supply chain) Simultaneously design and manufacturing process (supply chain) **Communications /Information systems** (cheaper every year) Integration of order entry, design, manufacture, distribution. (Supply chain) **Change performance measures** **MANUFACTURING** *Use of cellular manufacturing* Concurrent engineering (manufacturing) J.I.T. techniques Selective implementation of J.I.T techniques for each manufacturing cell) Set up reduction at bottleneck facilities generating capacity to allow a reduction in batch size Reduction in batch sizes /run small batch sizes Create concurrent teams in operating in cells and promote accountability and improved quality, responsiveness Condensing operations reducing queues Parallel operations eliminating bottlenecks *Mixed and levelled production ensure output closely follow demand* **DESIGN** Deployment of a modular design, to allow customised features to be contained to a single part of design. Deployment a product structure that allows a variety to be introduced at the end of the manufacturing process as opposed to the beginning Deployment reusable design, both to improve the productivity of the designer and to maximise the benefit of learning curves in the production operations
CONTENT ➢ What is the outcome of the *process?* ➢ What is recommended?	Flexibility and Reduction in Lead time (use of cellular manufacturing) Reduction of inventory, Reducing W.I.P (J.I.T techniques) Economy (run small batch sizes/reduce set-up times) *Improved quality (concurrent teams operating in cells)* Reduced cost of scheduling (concurrent teams operating in cells) Reduced lead time (concurrent teams operating in cells) No fragmentation among people/ workstations (concurrent teams operating in cells) Integration of the departments-order entry, design, manufacturing, distribution (information systems)
Possible strategies of implementation	Reengineering: Achieving Agility cannot be done through gradual change. Instead that can be done through reengineering. Only radical change can achieve the necessary scale of improvement in the short time available.
CONTEXT *What is the situation* within the company?	For every manufacturing company the solution is to become Agile. The objective *for Agile companies is to design a product that meets the needs of the market and* the manufacturing to make it very quickly. Companies emphasise Responsiveness and Customisation

	"Lead time Management in a make to order Manufacturing Firm" Weng Z.K. (1998)., PHD, Production and Inventory Management Journal, Vol. 39, No. 2, second quarter
MOTIVES Why it is important to reduce the lead-time?	➢ Reducing cost and avoid delay penalties/delivery on time Major problem for delay was the suppliers (3 days delivery) ➢ Stay in the market as a new competitor appeared in Florida/competitiveness ➢ Survival of the company/gain competitive advantage
PROCESS ➢ *How do you analyse the lead-time?* ➢ How do you make the decision? ➢ Stages of lead-time reduction methodology	**1. STAGE (very small improvement)** • *Replace suppliers with local in order to reduce transportation lead time* (previous supplier-tree days delivery • When the suppliers cannot be found locally, a premium would be offered to suppliers in order to get the suppliers on time • The firm instead of being delivered would pick up hazardous materials. This move would eliminate filling tedious paperwork with the Environmental protection **2. STAGE (more improvement because appeared problems in quality and also no major improvements with 1st stage)** • Improvement in the shop floor by examining the existing cells and discovering two bottlenecks. • *Improvement in capacity by changing some processes* • Replace again the suppliers into one unique for each product • Rethinking the inventory policy
CONTENT ➢ What is the outcome of the process? ➢ What is recommended?	➢ Very flexible company ➢ No inventory
Possible strategies of implementation	• Replace the existing supplying system
CONTEXT What is the situation within the company?	• Responsive to market changing demands • In the region was unique the company (others companies focused on mass production-their delivery times 6 months) • Layout was very efficient (manufacturing cells)(with exception of 2 small *bottlenecks)* • Printed circuit board manufacturer in Georgia (looser laws about hazardous material usage giving an advantage to that special company and also of limited competition) • Firm's Product span narrow (only single or double sided circuits boards) • Special penalties for different delays in the delivery time

	Saifallah Benjaafar 1996 "*On production batches, transfer batches, and lead times*"*(Scheduling and Logistics)* IIE Transactions, May 1996 Vol.28, n5 p357(6)
MOTIVES **Why it is important to reduce the lead-time?**	• Improve performance
PROCESS ➤ How do you analyse the lead-time? ➤ *How do you* make the decision? ➤ Stages of lead-time reduction methodology	• **Queuing theory** • Examining the relationship between batch size (production and transfer) and lead time • Analysing the model by modelling a machine as a single-server • Queuing theory gives the average flow time We can estimate the optimal batch size in order to take optimal results (minimum *time of processing)* • The optimal results that we take are depending strongly on the different set up time that we can achieve • After analysis we have concluded that smaller transfer batches than production ones can significantly improve system performance 1. Maximum benefits are realised when transfer batch size is one 2. The impact of transfer batches is particularly important when either set up times or batch sizes are large or when processing times are long.
CONTENT ➤ What is the outcome of the process? ➤ What is recommended?	• Reduce costs • Reduce inventory
Possible strategies of implementation	
CONTEXT *What is the situation* within the company?	Companies that emphasise responsiveness to the customer

	Black, J. T, Schroer B. J.,(1995). Simulation of an apparel Assembly cell with walking workers and de-couplers . Journal of Manufacturing Systems Vol. 12/ No .2.
<u>MOTIVES</u> *Why it is important* to reduce the lead-time?	• Competitiveness
<u>PROCESS</u> ➢ How do you analyse the lead-time? ➢ How do you make the decision? ➢ Stages of lead-time reduction methodology	Modelling tool of analysis: Simulation STAGES OF LEAD TIME REDUCTION Use of Manufacturing cells-U-shape, Use of Assembly cells-U-shape 1. Use of walking multifunctional workers 2. Make parts at one time lot=1 (difference of manufacturing and assembly Cells is that within the assembly Cell almost everything is being manually) 3. Assembly cells. (Main problem is line balancing) The time in the assembly cell *is being totally dictated from the operator* (skills) <u>SOLUTION:</u> Kanban squares (visual production control system very fast and accurate) Working workers, multi-skilled, within the cell because it eliminates the problem for precise balancing within the cell. The workers are cross-trained for every operation. So the cell can operate with even 1 operator when we have lees work or with the maximum number of operators when we have a lot of work. Re-balancing the cell Alternative solution rapid chase is about the same but the problem is that faster workers catch up the slowest. Material handling (within manufacturing) Inventory links ➔small lot basis Between cells-parts moved in small lots➔(limited buffers are placed) Between stores➔within the cells the one part piece movement eliminates queues (storage banks) between the processes and saves floor space—with the combination of de-coupler Minimising the distances between the machines Minimising the information within the cell Control of the quality –in the cell-U Cell manufacturing (I.P.M.Ss) Set-up reduction
<u>CONTENT</u> ➢ What is the outcome of the process? ➢ What is recommended?	Control of quality (U-SHAPE CELL) / (multi-functional workers) Machine tool maintenance (U-SHAPE CELL) / (multi-functional workers) Continuous improvement (U-SHAPE CELL) / (multi-functional workers) Elimination of material handling Reduction of inventory Reduction of space needed Minimising the information needed for control
Possible strategies of implementation	
<u>CONTEXT</u> What is the situation within the company?	Company is seeking Flexibility/responsive to changes to market

	Barker R.C., 1992,1994,
MOTIVES Why it is important to reduce the lead-time?	• World class competition • Flexibility (more responsive to market demand changes) • High performance • Elimination of non-value adding activities and also every kind of waste through the total material conversion chain.
PROCESS ➢ How do you analyse the lead-time? ➢ How do you make the decision? ➢ Stages of lead-time reduction methodology	Time-based framework ➢ Analyse production operations by time provides a strategic insight developing positive activities with customer demands. ➢ The total value adding process must be documented (mapping) by tracking a single product or for example a customer order through its natural path in reduction to calendar time. ➢ Elements of (positive) core value adding and (negative) non-value adding time are then identified. ➢ Questions are raised relating to the reasons why non-value adding gaps exist. ➢ Actions are taken to Reengineer/Reconstruct the system and remove these gaps. ➢ Elimination of push type system. ➢ Pull systems of control, which are demand triggered, are adopted such as Kanban. ➢ Post audits are conducted following development actions to measure and record improvements.
CONTENT ➢ What is the outcome of the process? ➢ What is recommended?	1. Purchased component stock holding cost reduction reducing storage areas required as suppliers deliver quickly to cells controlled by a pull system. 2. W.I.P reduction in assembly cells 3. Shop floor saving 4. Total throughput time 5. Labour reduction 6. Improved quality 7. Overhead reduction 8. Improved customer service levels with minimal finished goods stock 9. Not any more poor cash flow 10. Reduction of fixed costs 11. Reduction of variables costs 12. Reducing cost (throughput time linked directly factory's cost)
Possible strategies of implementation	After analysing the value chain and identification of the problem we reengineer with J.I.T. techniques, cellular manufacturing, close coupling of operations, job involvement-empowerment
CONTEXT What is the situation within the company?	Companies emphasises responsiveness to the customers This framework (time-based framework) has been constructed and designed to be effective within the batch-manufacturing sector of industry but also can be used in other value adding environments.

	Tersire R.J., Hummingbrid E. A (1995): Lead-time reduction: The search for competitive advantage International Journal of operations Production Management, Vol.15 no: 2 year, 8-19
MOTIVES Why it is important to reduce the lead-time?	1. Gain competitive advantage over the competitors 2. Lead to enhanced products (fosters product environment which can lead to enhanced products)
PROCESS ➢ How do you analyse the lead-time? ➢ How do you make the decision? ➢ Stages of lead-time reduction methodology	Mapping the process and identify the waste, waiting time Eliminate non-value adding activities Elimination of: 1. Serialisation of independent activities 2. Non synchronisation of dependent activities 3. Production of parts that are rejected/reworked 4. Inefficient workflow (poor layouts) • Simplifying the flow • Relating the flow to value and by increasing the effectiveness of the flow • Looking for ways to speed up the process, unearths numerous causes of inefficiency and their elimination results in manifold benefits NEW PRODUCT INTRODUCTION Solution ➔ concurrent engineering For concept to customer process Instead of performing activities in a series, it combines them in a simultaneous or parallel manner usually with the assistance of a multidiscipline project team. HOW (STEPS) 1. View the entire chain form a transvenctional orientation (as opposed to a series of upstream- depended transaction) 2. *Identify and attack lead-time bottlenecks* throughout the transvections, beginning with the largest bottlenecks in the firms owns functions and expanding to bottlenecks in contracted functions and expanding to bottlenecks in contracted functions. 3. Monitor the system for continuous improvement. Problems with the supply chain (except manufacturing) cause problems to manufacturing and limit it to operate J.I.T.
CONTENT ➢ What is the outcome of the process? ➢ *What is* recommended?	Improved quality Overhead reduction
Possible strategies of implementation	
CONTEXT What is the situation within the company?	New product introduction Responsiveness for existing products

	A PERSPECTIVE OF NEW PARADIGMS IN MANUFACTURING JOURNAL OF MANUFACTURING SYSTEMS Vol 14 , no 2, 1995 pp118-125
MOTIVES Why it is important to reduce the lead-time?	Essential for competitiveness
PROCESS ➢ *How do you analyse the lead-time?* ➢ How do you make the decision? ➢ Stages of lead-time reduction methodology	SOLUTION➔ *INTEGRATED MANUFACTURING* COOPERATIVE MANUFACTURING Workers use their intelligence Staff helps workers Worker form the team Managers as educators and coaches
CONTENT ➢ What is the outcome of the process? ➢ What is recommended?	-
Possible strategies of implementation	
CONTEXT What is the situation within the company?	

	Roger W Schmenner Sloan Management Review, 11-17, Fall (1998) *"The merit of making things fast"*.
MOTIVES **Why it is important to reduce the lead-time**	1. Profitability 2. Productivity
➢ How do you analyse the lead-time? ➢ How do you make the decision? ➢ Stages of lead-time reduction methodology	SOLUTION is the JIT related techniques Company A: European Parts manufacturer J.I.T techniques • Production planning revamped • Layout rearranged around manufacturing cells Company B: Chemical operations J.I.T techniques • Group technology (product families) • Responsibility of flow of process to supervisors for product families (not for departments as previous) Company C: Swiss machinery company • Responsibility to teams to shorten the lead times (job involvement) 1. Good quality All the orders must be made first time so throughput time to reach its lowest value. *Problem solving skills must be quick and solution timely.* Layout –set-up reduction —vendor relationships—-production controls 3. Process rationalisation Removal of unnecessary steps Focus on steps that truly add values 4. Attention to bottlenecks 5. Diminished chaos and confusion 7. Quick response to the market 8. Improved capital appropriations Change performance financial measures and replace them with inventory turns, throughput time <u>GENERALLY: Implementation of J.I.T techniques</u> ➢ Use of manufacturing cell (group technology concepts)/ Multi-model lines for particular classes of products /U-shaped lines/ Get rid of "De-coupling Inventory" whose purpose is to keep labour and to machine utilisation high/ Set up time reduction /small batch sizes/ Process simplification /Better to keep labour idle to produce what the market really wants than to keep busy to produce what the market may not need (to produce to forecast)/ Get rid of conventional financial performance measures or labour efficiency, machine utilisation, and replace them Quality control (no rework-sit idle for scrap to be replaced) Vendor relationships/ H. Issues Policies (charging teams for keeping items in the department)
<u>**CONTENT**</u> ➢ What is the outcome of the process? ➢ What is recommended?	Company A • Total manufacturing area reduced in half • Inventories slashed in half • Lead time reduction (12 weeks to 3 weeks) • Gaining in profitability Company B • Inventory down • Quality improved • Workforce enthusiastic • Linking directly batch operations to line flows (improved productivity, flexibility, *space utilisation)*
Possible strategies of implementation	
<u>**CONTEXT**</u> What is the situation within the company	Emphasise responsiveness to customer needs.

	DTI, 1987 "Plant Performance Audit
MOTIVES Why it is important to reduce the lead time	Manufacturing excellence
PROCESS ➤ How do you analyse the lead-time? ➤ How do you make the decision? ➤ Stages of lead-time reduction methodology	• Identify the value adding activities and non value adding activities (cost adding activities) • Elimination of the cost adding activities or make them simple and precise without any additional organisational complexity • Elimination of Queue time (No sequential of operations but parallel) • Identification of bottlenecks putting there extra effort • Elimination of Route complexity
CONTENT ➤ What is the outcome of the process? ➤ What is recommended?	Reduction in inventory (in first stage R.M, WIP, Finished items)
Possible strategies of implementation	Re-engineering
CONTEXT What is the situation within the company?	Responsiveness to Customers (flexibility)

	RAJAN SURI, 1994"Common Misconceptions And Blunders In Implementing Quick Response Manufacturing" *Proceedings Of Sme Autofact 94 Conference*, Detroit
MOTIVES Why it is important to reduce the lead-time?	Reduction in lead-time is a key element of competitiveness as well as quality.
PROCESS ➢ How do you analyse the lead-time? ➢ How do you make the decision? ➢ Stages of lead-time reduction methodology	1. NEW PRODUCT INTRODUCTION TIME—LEAD TIME OF EXISTING PRODUCTS 2. Identification why lead-time is long. There is planning loop. Planning loop is the direct outgrowth of the scale and cost management strategies Planning loop is a legacy of the SCALE BASED and COST-BASED Management. 3. Taking time out of the system requires looking at three areas • Implementing quick response in NEW PRODUCT INTRODUCTION • Implementing quick response in SALES AND DISTRIBUTION • Implementing quick response in PRODUCTION (this includes everything from order entry to the shipping doc.) IMPLEMENTING QUICK RESPONSE IN PRODUCTION STEPS 1. The organisation of process components needs to be changed from a functional basis to a product-oriented basis. 2. As the factory is transformed into a number of product oriented cells, it is found that complex, centralised scheduling and control systems can be replaced by simpler, local scheduling procedures. 3. Finally as each cell begins to operate smoothly, efforts are focused on how to run smaller and smaller batches. 3.1. Each cell is responsible for a single product, or small family products. Thus set-up on each of the machines can be tailored more closely to this family and set-ups times can be made much smaller that they were in the functional layout 3.2. Proximity of the machines –overlapping processes 3.3. Cross-trained multi functional workers.
CONTENT ➢ What is the outcome of the process? ➢ What is recommended?	What is the outcome of the process 1. Quality improvement 2. Cost reduction 3. Rapid delivery BENEFITS TO NEW PRODUCT INTRODUCTION Obtain substantial market share. Your firm and its competition can hit the market at the same time with similar products, yet your firms will contain NEW technology. Reductions in overheads **BENEFITS TO DELIVERY OF EXISTING PRODUCTS** 1. *Customer with urgent needs you can charge a price premium and further add* to profits 2. More integration of the organisation /undercover wasted efforts, quality problems, lower operating costs less W.I.P., streamline your operation and you improve everything Searching for ways of squeezing out time uncovers all the sources of inefficiency and quality problems and destroys the misconception that if you speed up the quality is going down and the cost up.
Possible strategies of implementation	Re-engineering
CONTEXT *What is the situation* within the company?	Responsiveness to changes of the market-Flexibility *Quick development of products*

APPENDIX E

VALUE-ADDED TIMES

TOTAL AVAILABLE TIME

AVAILABLE WORKING HOURS/WEEK	**46 hours /week**
AVAILABLE WEEKS/MONTH	**4.3 weeks/month**
TOTAL THROUGHPUT TIME	**3.5 months**
Total available working time for 3.5 months	**692.3 hours**

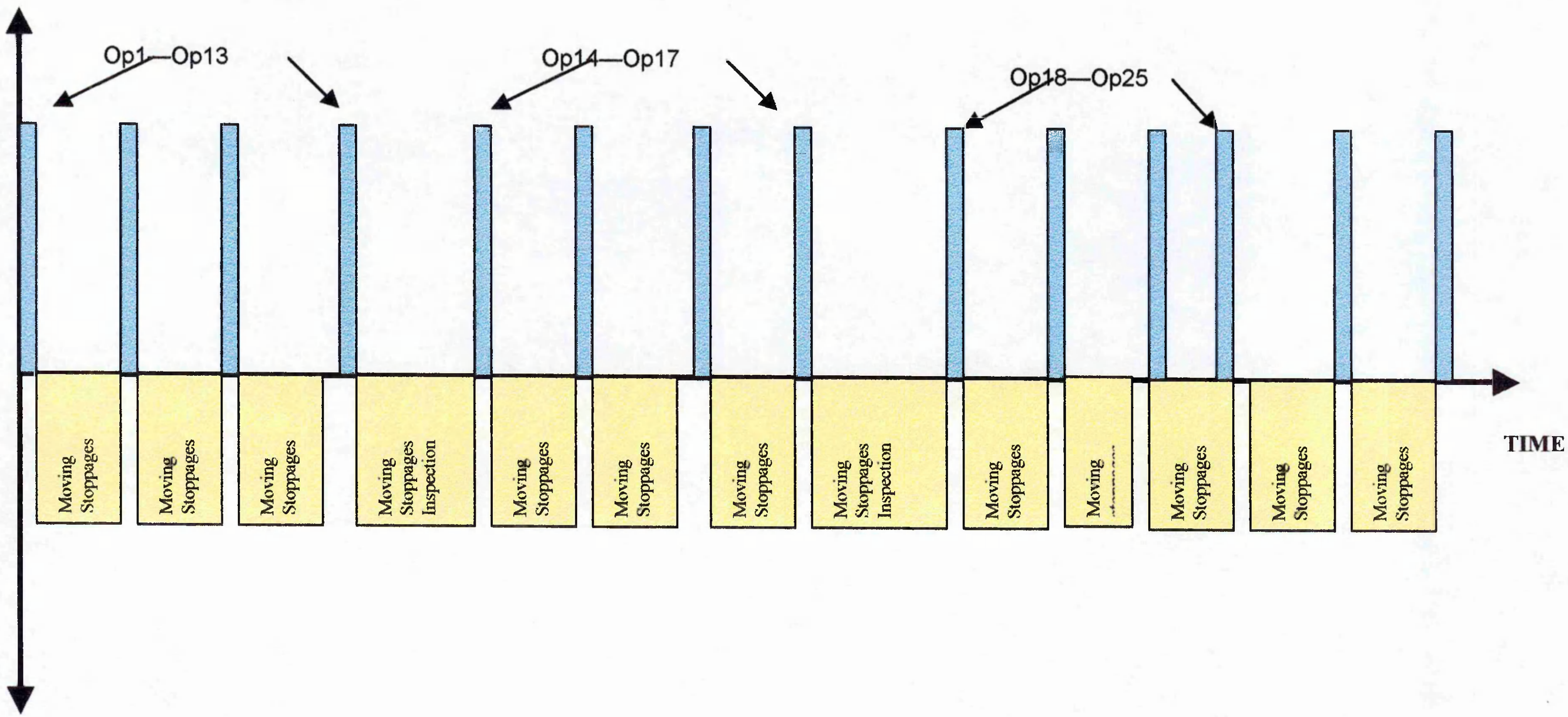
For type: K100

	OPERATIONS		Times	
Op 1	**Cutting**	**Cups**	**10min**	
Op 2	**Punching**	**Cups**	**26 min**	
Op 3	**Sharpen**	**Cups**	**101 min**	
Op 4	**Drilling**	**Cups**	**50 min**	
Op 5	**Cutting**	**Round parts**	**13 min**	
Op 6	**Cutting**	**Box**	**13 min**	
Op 7	**Punching**	**Round parts**	**4 min**	
Op 8	**Punching**	**Box**	**4 min**	
Op 9	**Rolling**	**1st main round part**	**12 min**	
Op 10	**Rolling**	**Box**	**5 min**	
Op 11	**Cutting**	**Corrugated tubes**	**4 min**	
Op 12	**Rolling**	**Corrugated tubes**	**4 min**	
Op 13	**Welding**	**Corrugated tubes**	**40 min**	
Inspection	**X-ray**	**Corrugated tubes**		
Op 14	**Creation of corrugations**	**Corrugated tubes**	**33 min**	
Op 15	**Rolling**	**2nd main part**	**4 min**	
Op 16	**Small Welding**	**Box -cups**	**5 min**	
Op 17	**Welding**	**Box**	**33 min**	
Inspection	**X-ray**			
Op 18	**Small welding assembly**	**Cup 1st main part**	**12 min**	

Op 19	Welding	Cup 1st main part	51 min	
Op 20	Machining of nails	Box	8 min	
Op 21	Small Welding, Welding	2nd main part	13 min	
Op 22	Fixing of comp.		28 min	
Op 23	Small welding	1st cup	12 min	
Op 24	Welding	Middle juncture	42 min	
Op 25	Welding	1st juncture	5 min	
Inspection	X-ray			
Op 26	Cutting of tubes		35 min	
Op 27	Placing of tubes		9 min	
Op 28	Welding of tubes		98 min	
Op 29	Welding of ribs		14 min	
Op 30	Welding	Manhole	9 min	
Op 31	Welding	Corrugated tube-main body	16 min	
Inspection	X-ray			
Op 32	Base of boiler		33 min	
Op 33	Construction	Smoke box	336 min	
Op 34	Construction	Chimney	101 min	
Op 35	Put heat insulation		140 min	
Op 36	Built in firebricks		34 min	
Op 37	Place burner		11 min	
Op 38	Place valves		11 min	
Op 39	Place pumps		11 min	
Total Value-Adding Time			1390 min	
Total available time		3,5 months, from Op1-Op2	41538 min	
% Percentage of total time value added			3,334%	

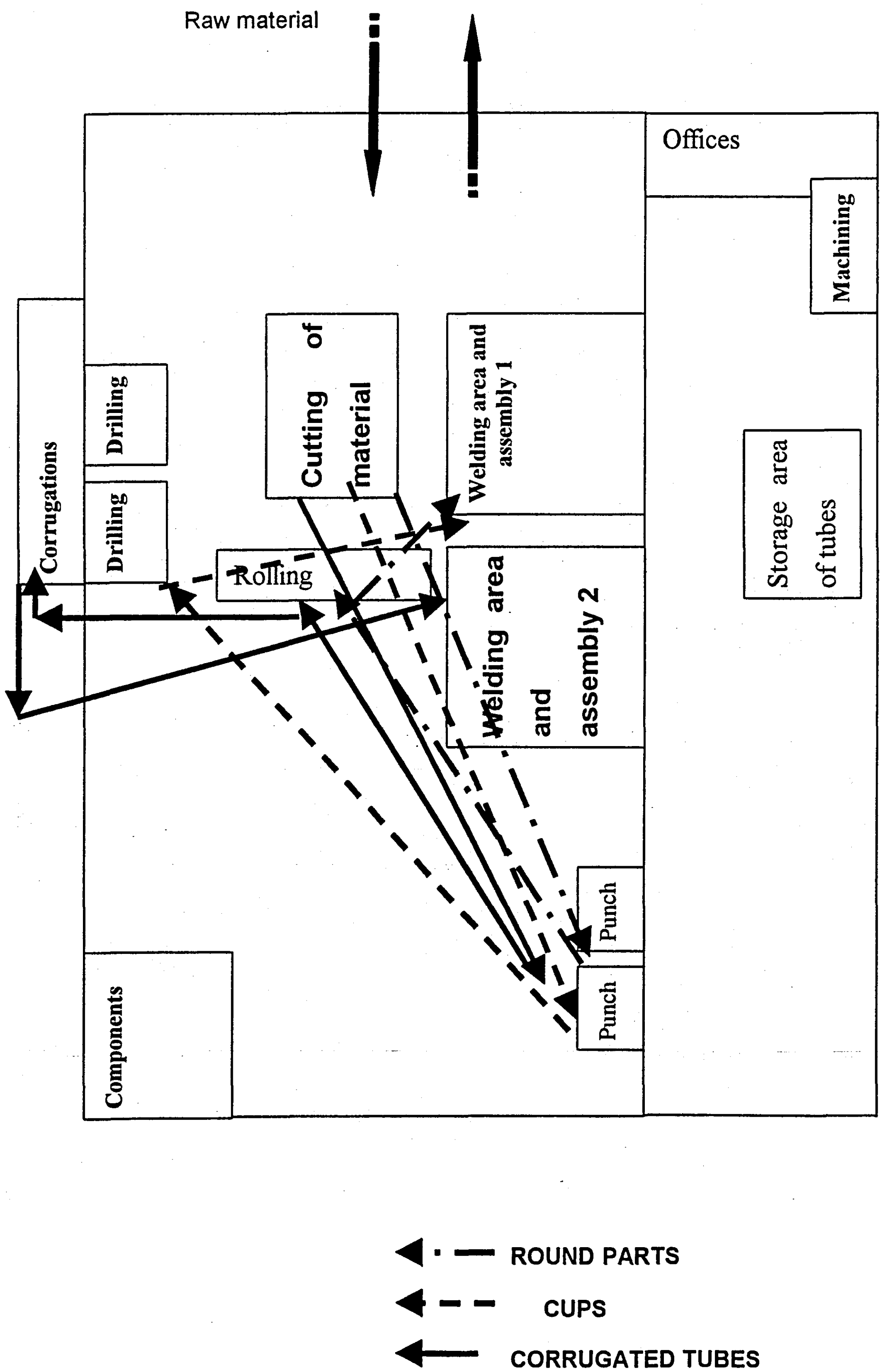
APPENDIX F

ROUGH CUT ANALYSIS IN MATERIAL CONVERSION



APPENDIX G

CURRENT LAY-OUT



APPENDIX H

SHOP-FLOOR SKILLS BREAKDOWN

	SKILL LEVEL	No. of shop-floor employees
OPERATORS	**Trainee**	4
	Unskilled/semiskilled	22
	Highly skilled	4
	Total	30

APPENDIX I

PROCUREMENT RELIABILITY

BASIC MATERIALS	% OF ORDERS OVERDUE
Sheet metal H1	25%
Sheet metal H2	30%
Sheet metal 17Mn 4	35%
Tubes	25%

APPENDIX J

NEW LAYOUT