

**APPLICATION OF VALUE STREAM MAPPING AS A METHOD TO REDUCE
CYCLE TIME TO SUPPORT LEAN MANUFACTURING SYSTEM**

AHMAD NUR AIZAT BIN AHMAD

**A project report submitted in partial fulfillment of the
requirement for the award of the degree of
Master of Engineering (Manufacturing)**

**Faculty of Mechanical and Manufacturing Engineering
University Tun Hussein Onn Malaysia**

APRIL 2011

ABSTRACT

In the manufacturing industry, lean manufacturing becomes popular as a beneficial way in the pursuit of better system efficiencies. The purposes of this study were to identify waste using lean manufacturing technique, determine causes to the waste through the value stream mapping method and to propose solution to improve workplace environment. Asian Composite Manufacturing Sdn. Bhd. (ACM) has been chosen as the company to conduct case study for this research. ACM is a joint venture company based in Bukit Kayu Hitam, Kedah, Malaysia owned equally by The Boeing Company and Hexcel Corporation. The business of the joint venture is the manufacturer of flat and contoured primary (Aileron skins, spoilers and spars) and secondary (flat panels, leading edge, trailing edge and MISC component) structure composite bond assemblies and sub-assemblies for aerospace industries. There are some waste activities identified during observation including unnecessary transportation, excessive motions, inventories and waiting. In order to reduce this waste, some of lean manufacturing tools are used. Examples are Just-in-Time manufacturing (kanban system, continuous flow and takt time production planning), 5S, kaizen improvement, value stream mapping and production preparation process (3P). As a result of the use of these tools reduces lead time, increase efficiency of value added activities and eliminates some non value added activities. The tools suggested to be use in this study are pull system, takt time planning, visual control, kaizen, 5S and continuous flow. The results of this study indicated that implementing lean manufacturing system can improve the process performance by eliminating 7 types of waste. The main tool to be used in this study is Value Stream Mapping (VSM).

ABSTRAK

Dalam industri pembuatan, *lean manufacturing* menjadi popular sebagai cara yang menguntungkan dalam menghasilkan sistem yang lebih cekap. Tujuan kajian ini adalah untuk mengenalpasti pembaziran dengan menggunakan teknik *lean manufacturing*, menentukan penyebab segala pembaziran melalui kaedah Peta Aliran Nilai (*Value Stream Mapping*) dan untuk mencadangkan penyelesaian terbaik untuk meningkatkan persekitaran tempat kerja. Asia Composite Manufacturing Sdn. Bhd (ACM) telah dipilih sebagai sebuah syarikat untuk dilakukan kajian kes untuk kajian ini. ACM merupakan syarikat usahasama yang berpusat di Bukit Kayu Hitam, Kedah, Malaysia sama-sama dimiliki oleh Syarikat Hexcel dan Boeing Corporation. Asas kepada penggabungan ini adalah pengilang *flat and contoured primary* (aileron, spoiler dan spar) dan sekunder (*flat panels, leading edge, trailing edge* dan komponen-komponen MISC) struktur gabungan komposit dan separa gabungan untuk industri penerbangan. Ada beberapa aktiviti pembaziran dikenalpasti selama pengamatan termasuk pengangkutan yang tidak perlu, gerakan yang berlebihan, persediaan dan menunggu. Dalam proses mengurangkan pembaziran, beberapa kaedah-kaedah *lean manufacturing* digunakan. Contohnya adalah pembuatan *Just-in-Time* (sistem kanban, aliran berterusan dan perancangan masa pengeluaran), 5S, kaedah kaizen, pemetaan aliran nilai (*value stream mapping*) dan proses persediaan pengeluaran (3P). Hasil dari penggunaan alat-alat ini akan mengurangkan masa pengeluaran (*lead time*), meningkatkan kecekapan aktiviti dan menghilangkan beberapa kegiatan yang tidak menambah nilai. Kaedah digunakan dalam kajian ini adalah pull system, perancangan masa pengeluaran, kawalan visual, kaizen, 5S dan aliran berterusan. Keputusan kajian ini menunjukkan bahawa pelaksanaan sistem *lean manufacturing* dapat meningkatkan prestasi pengeluaran dengan menghilangkan 7 jenis pembaziran yang dikenalpasti. Alat utama yang akan digunakan dalam kajian ini adalah Peta Aliran Nilai (*Value Stream Mapping*).

CHAPTER I

INTRODUCTION

1.1 Introduction

Lean is defined as the systematic removal of waste by all members of the organization from all areas of value stream. Lean is often referred to as a cost reduction mechanism. Lean strives to make organizations more competitive in the market by increasing efficiency, decreasing costs incurred due to elimination of non value added (NVA) steps and efficiencies in the processes as well as reducing cycle times and increasing profit to for the organization. An organization can achieve these results while not sacrificing effectiveness if it produces exactly what is needed in the right amount needed and when is needed. Lean manufacturing is aimed at the elimination of waste in every area of production including customer relations, product design, supplier networks and factory management.

Value Stream Mapping (VSM) is an excellent tool for any enterprise that wants to become lean. VSM as a powerful tool that not only highlights process inefficiencies, transactional and communication mismatches but also guides about the improvement.

According to Hines and Rich (1997), value stream is a collection of all actions value added as well as non-value added that are required to bring product or a group of products that use the same resources through the main flow, from raw material to the hand of customers. Jones and Womack (2000) explained VSM as the process of visually mapping the flow of information and material as they are preparing a future state map with better method and performance. A VSM consist of everything including the NVA and provides a pictorial view of what elements of the process that customer is willing to pay.

The purpose of this paper is to explore how VSM can be helpful in lean implementation and to develop the road map to tackle improvement areas to bridge the gap between the existing state and the proposed state of manufacturing firm. At present time, manufacturing firms need to redefine and redesign their production systems to tackle the competitiveness demanded by the challenges of current markets. As a result, it is necessary to have practical tools that will support the redesigning and improving process for manufacturing systems. In the situation, the lean production system developed and presented the VSM tool as a functional method aimed at reorganizing production system with a lean vision.

1.2 Problem Statement

There are seven types of waste that occur in any manufacturing system. The wastes are idle, overproduction, space, defects, unnecessary human motion, inventory and transportation. In order to reduce all these waste, there are lots of process improvements concept combined a used together such as just in time, kaizen, heijunka and jidoka.

ACM Sdn. Bhd. is currently applying the continuous improvement method to deal with their problems in manufacturing process. Even though ACM use lean manufacturing approach to eliminate waste and reduce cycle times, there still a room for continuous improvement at this company. The company highlighted that there are high possibility of producing defects in the production area because lots of processes was handled manually by operator. Based on this situation, researcher felt there is a need to use a technique to further improve the process flow which will lead to increase in efficiency of the whole operations.

1.3 Objective

There are three main objectives if this study. There are:

- 1) To identify waste using lean manufacturing concept and technique.
- 2) To determine causes to the waste through the application of VSM.
- 3) To propose future state of VSM for the operation that reduce production cycle time.

1.4 Scope of the Research

This research focuses on lean manufacturing application and using VSM to conduct improvement. The focus is about creating the future state of VSM for the case study of the company. The basic ideas are:

- 1) The lean manufacturing practices of the company.
- 2) Identify areas of improvement.
- 3) The main area of the study will be Layup and Cure Department
- 4) Create new improved method.

All the related waste will be identifying and process improvement will be analyzing using VSM as a method to eliminate waste. All the results of the studies will propose to ACM Sdn. Bhd.

1.5 Research Significance

All research in this thesis is done to assist the company to identify waste produced, find the root cause of the problem and find solution of that problem within the scope chosen.

1.6 Thesis Outline

The first phase of this study is to decide the project scope. This will made through discussions and consultation with lean expert of the company and thesis supervisor. Among the activities carried out are defining suitable objectives and the scope for this project, deciding method to use for the thesis and develop plan of the project.

Chapter II deals with the literature review of the project. It will describe the definition, concepts, principle and tools used in lean manufacturing system. Literature review provided the background of the research, provide guidelines and direction to this research.

Chapter III is for research methodology. This chapter describes the method that used by researcher to conduct the study. There are also some explanations on value stream mapping as a tool to conduct improvement. This chapter also includes current data collection and current manufacturing low for the study company.

Chapter IV is for company profile and core business. Chapter V presents the result and data analysis that finally figure out from current state of VSM, chapter VII deal with data analysis for future state of VSM. Chapter VIII are the discussions based on conclusion, research limitation and recommendations for future research.

1.7 Summary

This research is about the application of VSM in lean manufacturing environment. The study will enable the researcher to reduce the seven waste factors as recognize in lean manufacturing concept generally. It is hope that improvement in cycle times and the efficiencies in manufacturing of the company can be archived.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

The goal of lean manufacturing is to become highly respond to customer demand while producing high quality products in the most efficient and economical method by reducing various waste in human effort, inventory, time to market and manufacturing space. This approach focuses around the elimination of all kind of waste. Waste takes many forms and can be found at any time and in any place. It may be found hidden in policies, procedures, processes, product designs and in operations. Waste consumes resources but does not add any value to the product. Rusell and Taylor (1999) define waste as anything other than the minimum amount of equipment, effort, materials, parts, space and time that are essential to add value to the product.

2.2 Value Stream Mapping (VSM)

The original concepts and definitions given by Monden (1993) and Womack et al. (1990), about VSM demonstrated that it is necessary to map both inter-company and intra-company value adding streams. Value stream refers to those specifics of the firm that add value to the product or service under consideration. VSM was initially developed in 1995 for the collection and use of the suite of tools as being “to help researcher or practitioner to identify waste in individual value streams and, find an appropriate method to its removal”. The process itself is very simple and straightforward. It usually starts with customer delivery and work its way back through the entire process documenting the process graphically and collecting data along the way. Finally it results in single page map called “Value Stream”, these maps contains data such as cycle time, work-in-progress (WIP) level, quality level and equipment performance data. Depending on the complexity of the process and the number of components involve additional data required may be collected from other sources.

A very important part of the VSM is documenting the relationships between the manufacturing processes and the controls used to manage these processes, such as production scheduling and production information. Unlike most process mapping techniques that often only document the basic process flow, VSM also documents the flow of information within the system. Where the materials are stored (raw materials and WIP) and what triggers the movement of material from one process to the next process are key pieces of information. VSM is about eliminating waste whatever it is. Various terminologies used in VSM are discussed as below:

TAKT time : The rate which a company must produce a product to satisfy its customer demand. It is calculated by dividing available working time per day (in minutes or seconds) to customer demand per day (in relevant units).

$$\text{TAKT TIME} = \frac{\text{Available working time per shift}}{\text{Customer demand per shift}}$$

Production Lead time: It is the total time a components takes in its way through the shop floor, beginning with arrival of raw material to shipment of finished goods to customer.

Value adding time : It is the time which is utilized in adding actual value to the product.

Current state mapping: It is describe the existing/ current position of shop floor of any manufacturing facility.

Future state mapping: It describes the proposed / future position of shop flow af any manufacturing facility in order to bring some improvement.

Kanban : It is a signal in Japanese word that means card and which is used to reduce inventory.

Pull production : Producing exactly according to the pace of customer requirement.

VSM is an excellent tool for any enterprise that wants to become lean (Russell and Taylor, 1999). Rother and Shook (1999) defined VSM as a powerful tool that not only highlights process inefficiencies, transactional and communication mismatch but also guides about the improvement. According to Hines and Rich (1997), value stream is a collection of all actions VA as well as NVA that are required to bring a product or a group of products that use the same resources through the main flow, from raw material

until receive to the customer. Jones and Womack (2000) explained VSM as the process of visually mapping the flow of information and materials as they are and preparing a future state map with better methods and performance.

A VSM consist of everything including the NVA and provided a graphic view of what elements of the process the customer is willing to pay for (Tapping and Shuker, 2003). Jones and Womack define VSM as “the simple process of directly observing the flows of information and materials as they now occurs, summarizing them visually, and then envisioning a future state with better performance. Volkel and Chapman (2003) have designed a VSM and lean approach to supply chain improvement. Brunt (2000) has made an attempt to expand VSM across the whole supply chain. Current state and future state maps have been highlighted to illustrate the benefits of a lean system pictorially and method of constructing an action plan has been discussed.

The lean communication provider explains the contribution that service management can make towards reducing costs and focusing on customer value (Adam and Willet, 1996). Gallone and Taylor (2001) made the attempt to develop a lean logistics strategy from VSM. An application of VSM was also found in the distribution industry (Hines et al. , 1998). There are lots of researchers have contributed the role of VSM to improve of supply chain process of organization. Hines (1999), Lamming et al. (2000), Taylor and Brunt (2001), Seth and Gupta (2005) have made a successful attempt to us VSM as a technique to archive productivity improvement in production output per person, reduction of work in process and finished goods inventory.

Although several researchers like Forza et al. (1993), Beesly (1994), Jessop and Jones (1995) have used VSM for different areas, lots of research need to be done. That is why newer classification an application area is emerging. Over the years, many lean manufacturing tools to support value stream have been developed and many more are

being proposed (Schonberger, 1982; Dillon, 1985; Womack et al. , 1990; Lamming, 1993; Barker, 1994; Liker et al. , 1995; Cusumono and Nobeoka, 1998; Liker, 1998; Taylor and Brunt, 2001).

This mapping is done with a pencil and paper using various process symbols of VSM to visualize the flow of materials and information as a product takes its way in manufacturing line. Mapping is done keeping in view of the lean manufacturing principles which are the backbone of VSM (Seth and Gupta, 2005). These principles are:

1. Define value from your customer's perspective
2. Identify the value stream
3. Eliminates the seven waste in production
4. Make the process flow
5. Pull the process rather than push it
6. Pursue to perfection level

2.3 Current State of VSM

A current state map shows work processes as they currently exist. This is to understand the need for changes and to understand where opportunities can be found. While VSM appear complex, their construction was easy, taken in logical steps. The current state maps should take a snapshot of the current practices and materials usage rates for all processes. A current state map should also record where environment impacts occur in the production line. A current state of VSM will enable you to see the

complete door-to-door flow in your facility and identified the value stream wanted to analyze (Emiliam and Stec, 2004).

2.4 Future State of VSM

VSM is a planning tool. The future state map is a picture of the lean transformation process for a specific value stream. Before create a future map, a current state of VSM should already created. A future map identifies improvement to be made to the value stream that will shorten the overall lead time (Lamming, 2000). In the most literature, the time from which raw materials enter a facility until the time they ship to the customer as a finished goods is termed lead time, most manufacturing persons called this cycle time. Figures 2.1 show the example of value stream mapping.

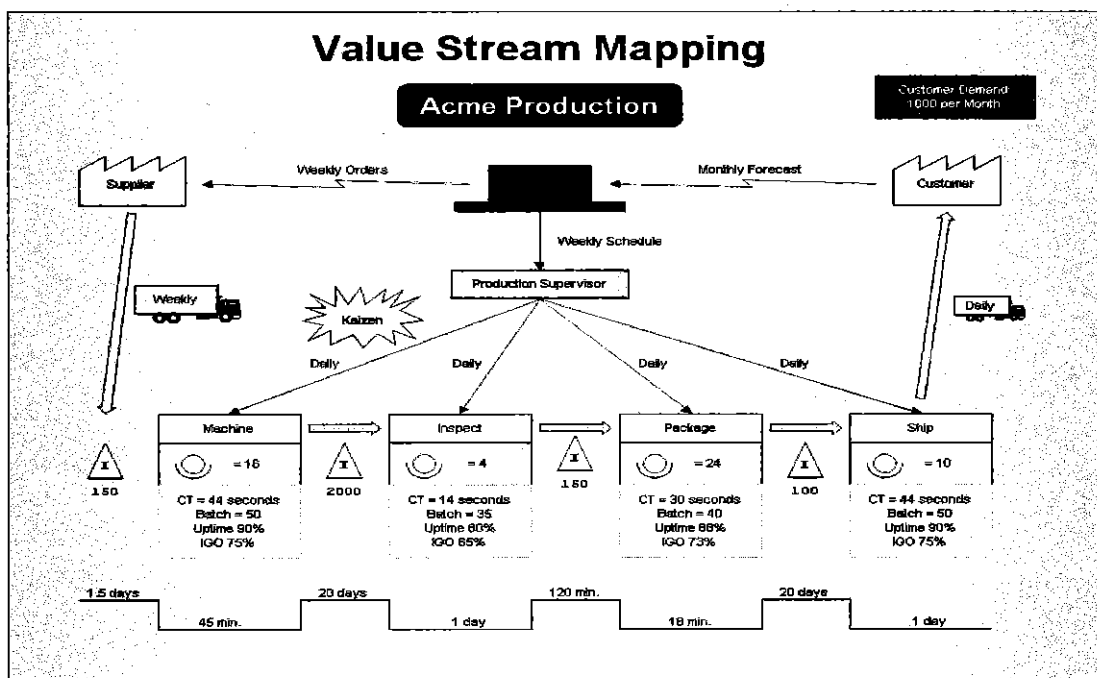


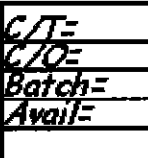


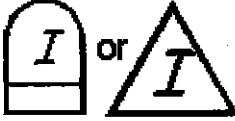


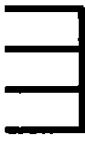
Figure 2.1: Example of VSM





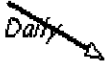

2.5 VSM symbols




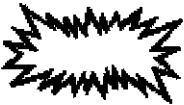


Types of VSM symbols that indicates the actions to take place or the locations where production processes occur. Value Stream mapping symbols are not standardized and there are many variations. Here are the most common symbols. You may also wish to create your own symbols for specialized applications. VSM symbols are shown in Table 2.1.

Table 2.1: VSM symbols

 Customer/Supplier	<p>This icon represents the Supplier when in the upper left, the usual starting point for material flow.</p> <p>The customer is represented when placed in the upper right, the usual end point for material flow.</p>
 Dedicated Process	<p>This icon is a process, operation, machine or department, through which material flows. Typically, to avoid unwieldy mapping of every single processing step, it represents one department with a continuous, internal fixed flow path.</p> <p>In the case of assembly with several connected workstations, even if some WIP inventory accumulates between machines (or stations), the entire line would show as a single box. If there are separate operations, where one is disconnected from the next, inventory between and batch transfers, then use multiple boxes.</p>
	<p>This icon goes under other icons that have significant information/data required for analyzing and observing the system. Typical information in a Data Box underneath MANUFACTURING PROCESS icons: · C/T (Cycle</p>

<p>Data Box</p>	<p>Time) - time (in seconds) that elapses between one part coming off the process to the next part coming off, · C/O (Changeover Time) - time to switch from producing one product on the process to another · Uptime- percentage time that the machine is available for processing · EPE (a measure of production rate/s) - Acronym stands for "Every Part Every___". · Number of operators - use OPERATOR icon inside process boxes · Number of product variations · Available Capacity · Scrap rate · Transfer batch size (based on process batch size and material transfer rate)</p>
 <p>Inventory</p>	<p>These icons show inventory between two processes. While mapping the current state, the amount of inventory can be approximated by a quick count, and that amount is noted beneath the triangle. If there is more than one inventory accumulation, use an icon for each. This icon also represents storage for raw materials and finished goods.</p>
 <p>Shipments</p>	<p>This icon represents movement of raw materials from suppliers to the Receiving dock/s of the factory. Or, the movement of finished goods from the Shipping dock/s of the factory to the customers</p>
 <p>Push Arrow</p>	<p>This icon represents the "pushing" of material from one process to the next process. Push means that a process produces something regardless of the immediate needs of the downstream process.</p>
	<p>This is an inventory "supermarket" (kanban stockpoint). Like a supermarket, a small inventory is available and one or more downstream customers come to the</p>

<p>Supermarket</p>	<p>supermarket to pick out what they need. The upstream workcenter then replenishes stocks as required.</p> <p>When continuous flow is impractical, and the upstream process must operate in batch mode, a supermarket reduces overproduction and limits total inventory.</p>
 <p>Material Pull</p>	<p>Supermarkets connect to downstream processes with this "Pull" icon that indicates physical removal.</p>
 <p>Safety Stock</p>	<p>This icon represents an inventory "hedge" (or safety stock) against problems such as downtime, to protect the system against sudden fluctuations in customer orders or system failures. Notice that the icon is closed on all sides. It is intended as a temporary, not a permanent storage of stock; thus; there should be a clearly-stated management policy on when such inventory should be used.</p>
 <p>External Shipment</p>	<p>Shipments from suppliers or to customers using external transport.</p>
 <p>Production Control</p>	<p>This box represents a central production scheduling or control department, person or operation.</p>
 <p>Manual Info</p>	<p>A straight, thin arrow shows general flow of information from memos, reports, or conversation. Frequency and other notes may be relevant.</p>
 <p>Electronic Info</p>	<p>This wiggly arrow represents electronic flow such as electronic data interchange (EDI), the Internet, Intranets, LANs (local area network), WANs (wide area network).</p>

	<p>You may indicate the frequency of information/data interchange, the type of media used ex. fax, phone, etc. and the type of data exchanged.</p>
 <p>Production Kanban</p>	<p>This icon triggers production of a pre-defined number of parts. It signals a supplying process to provide parts to a downstream process.</p>
 <p>Withdrawal Kanban</p>	<p>This icon represents a card or device that instructs a material handler to transfer parts from a supermarket to the receiving process. The material handler (or operator) goes to the supermarket and withdraws the necessary items.</p>
 <p>Go See</p>	<p>Gathering of information through visual means.</p>
 <p>Kaizen Burst</p>	<p>These icons are used to highlight improvement needs and plan kaizen workshops at specific processes that are critical to achieving the Future State Map of the value stream.</p>
 <p>Operator</p>	<p>This icon represents an operator. It shows the number of operators required to process the VSM family at a particular workstation.</p>
 <p>Timeline</p>	<p>The timeline shows value added times (Cycle Times) and non-value added (wait) times. Use this to calculate Lead Time and Total Cycle Time.</p>

2.6 Lean Manufacturing

The roots of lean manufacturing originate with early automobile manufacturing. The master craftsmen that first built individual cars possessed a wide range of skills and abilities, but with low efficiency and at high cost. Henry Ford recognized these limitations and broke the assembly process down into 30-second tasks, which were performed almost a thousand times a day (Krafcik, 1988). In the 1950's, Ieji Toyoda and Taiichi Ohno merged the knowledge and skill of master craftsmen with standardization and efficiency of the moving assembly line and added the concept of teamwork to create the Toyota Production System (TPS) (Womack et al. , 1990). John Krafcik introduced the term "Lean Production System" in 1998 in his review of the TPS, and the term "Lean Manufacturing" was popularized by Womack et al. (1990), in *The Machine That Change the World*.

Lean manufacturing has many definitions on it. Some researchers' provide definitions specific to manufacturing processes while others employ a more general definition that could be applied to a variety of industries. For this research lean manufacturing was defined as the systematic removal of waste by all members of the organization from all areas of the value stream (Worley, 2004). The value stream is defined as all of the activities that contribute to the transformation of a product from raw materials to finish product including design, order taking, and physical manufacture (Womack and Jones, 1996). Waste is a non-necessary activity that does not add value for the customer.

Lean manufacturing is often related with benefits such as reduce inventories, reduced manufacture times, increase quality, increase flexibility and increase customer satisfaction (Ahls, 2001; Alavi, 2003; Emiliani, 2001; Ross and Francis, 2003; Womack and Jones, 1994, 1996). Some of the practices of lean manufacturing include 5S events,

kaizen events, kanban system, pull production system, quick changeover and VSM. Convincing managers and employees to think and act in way that are foreign may be difficult. Employees may resist the tools of lean manufacturing or may experience difficulty thinking in new terms such as customer value and waste. It may also be difficult to manage external relationships with customers and suppliers. Suppliers may be unable to deliver the smaller quantities of parts or subassemblies that are required for pull production. Customer may be unable to place predictable orders, causing the organization to prepare inventory to meet demand (Womack and Jones, 1994).

Lean is dynamic process of change driven by a systematic set of principles, and best practices aimed at continuous improving. Lean refers to the total enterprise:

- The shop floor to the executive suite, and the supplier to customer value chain.
- Lean requires rooting out everything that is NVA activities.
- Become lean is a complex business.
- There is no single thing that will make organization lean.

Lean production makes optimal of the skills of the workforce, by giving workers more than one task, by integrating direct and indirect work, by encouraging continuous improvement activities. As a result, lean production is able to manufacture large variety of products, at lower cost and higher quality, with less of every input, less space, less investment and less development time (Dankbaar, 1997). In order to be competitive, companies have come to the realization that they must have:

1. Quality beyond the competitor;
2. Technology before the competitor; and
3. Cost below the competitor (Watson, 1993)

In other words, companies must strive to be better, faster, and cheaper than their competitors. These are some of the lean characteristics of the lean approach. Lean production is a complex organization principle that requires major changes in a company. In many areas of the company, difficulties in implementation may happen. Karlsson and Ahlstrom (1995) found that difficulties in applying the system can be a problem to lean production and changes need to be made in the system. In looking at the time element of lean production, Bower and Hout (1988) revealed that the concept of fast cycle time can be providing a substantial competitive advantage. Their research indicated that companies need to take several steps to become fast cycle firms:

1. Examine the company's cycle time and set tough new standards;
2. Explore slow cycle time until the root of the problems found;
3. Develop information system to track VA activities; and
4. Accelerate employees training.

Lean also describes as a pull system. The system promotes conditions necessary to manufacture high quality products to meet market demand with relatively small levels of inventory. Holding costs are decreased because materials do not arrive until needed and items are only produced to meet the forecasted demand. As a result, "companies have substantially cut lead time, drastically reduce raw material, work-in-progress, finish goods inventories and effectively increased asset turnover" (Claycomb et al., 1999). Thus, there are five basic steps in the lean process (Nave, 2002; Snee, 2004; Womack 2006):

1. Define value and all of the VA features in a given process;
2. Identify the "value stream", the process flow of activities that add value – people are visual by nature, and they place value on seeing a process flow visually;

3. Force the activities to flow without interruption. Any NVA activities should be removed or minimized;
4. Allow the customer to “pull” the product or services through the process, through JIT manufacturing; and
5. Continuous try to perfect the process by revisiting the step again in a continuous loop. Go through the step repeatedly to ensure that the process is as improved as it can be.

2.7 Seven Manufacturing Waste

A fundamental element of implementing lean is the ability to recognise and eliminate (or at least reduce) all forms of waste within the value stream. Often in practice, most activities create waste. Waste is anything which does not add value to a product or service, in any office or manufacturing activity. Waste elimination is one of the most effective ways to increase the profitability of any business. Processes either add value or waste to the production of a good or service.

The seven wastes originated in Japan, where waste is known as “muda. ” “The seven wastes” is a tool to further categorize “muda” and was originally developed by Toyota’s Chief Engineer Taiichi Ohno as the core of the Toyota Production System, also known as Lean Manufacturing. To eliminate waste, it is important to understand exactly what waste is and where it exists (Womack and Jones, 1994). While products significantly differ between factories, the typical wastes found in manufacturing environments are quite similar. For each waste, there is a strategy to reduce or eliminate its effect on a company, thereby improving overall performance and quality. The seven wastes consist of:

2.7.1 Over-production

Over-production refers to producing more than what is needed. Far too often a company will manufacture an item before it is needed. Over-production is considered a waste because it costs the company money to produce it and it lowers the quality of the product if it sits on the shelf. Generally over-production occurs due to high changeover times, unreliable equipment, or the process is unreliable. Over-production results in higher costs for storage, excessive lead times, and it makes detecting the defects quite difficult. The solution for over-production is to stop producing materials and only produce what can be immediately sold or shipped. Poor information flow is another reason that over-production occurs, hence why communication is so important in the lean manufacturing process.

2.7.2 Waiting

Whenever goods are not moving or being processed, the waste of waiting occurs. Typically more than 99% of a product's life in traditional batch-and-queue manufacture will be spent waiting to be processed. Much of a product's lead time is tied up in waiting for the next operation; this is usually because material flow is poor, production runs are too long, and distances between work centers are too great. Waiting refers to the waste of goods that are not moving. As you already may be aware, much of a product's life is spent waiting for the next phase. The reason this is considered a waste is because the good should never be waiting. If they are waiting it is due to poor material flow, long production runs, or travel distances.

2.7.3 Transportation

Transporting product between processes is a cost incursion which adds no value to the product. Excessive movement and handling cause damage and are an opportunity for quality to deteriorate. Material handlers must be used to transport the materials, resulting in another organizational cost that adds no customer value. Transportation can be difficult to reduce due to the perceived costs of moving equipment and processes closer together. Furthermore, it is often hard to determine which processes should be next to each other. Mapping product flows can make this easier to visualize.

2.7.4 Inappropriate Processing

Many organizations use expensive high precision equipment where simpler tools would be sufficient. This often results in poor plant layout because preceding or subsequent operations are located far apart. In addition they encourage high asset utilization (over-production with minimal changeovers) in order to recover the high cost of this equipment. Toyota is famous for their use of low-cost automation, combined with immaculately maintained, often older machines. Investing in smaller, more flexible equipment where possible; creating manufacturing cells; and combining steps will greatly reduce the waste of inappropriate processing.

2.7.5 Unnecessary Inventory

Excessive inventory is a direct result of overproduction and waiting. Having excessive inventory will lead to increased lead times, limited floor space, and poor communication. Too much inventory often masks problems from other areas as well. Work in Progress (WIP) is a direct result of overproduction and waiting. Excess inventory tends to hide problems on the plant floor, which must be identified and resolved in order to improve operating performance.

Excess inventory increases lead times, consumes productive floor space, delays the identification of problems, and inhibits communication. By achieving a seamless flow between work centers, many manufacturers have been able to improve customer service and slash inventories and their associated costs.

2.7.6 Unnecessary Motion

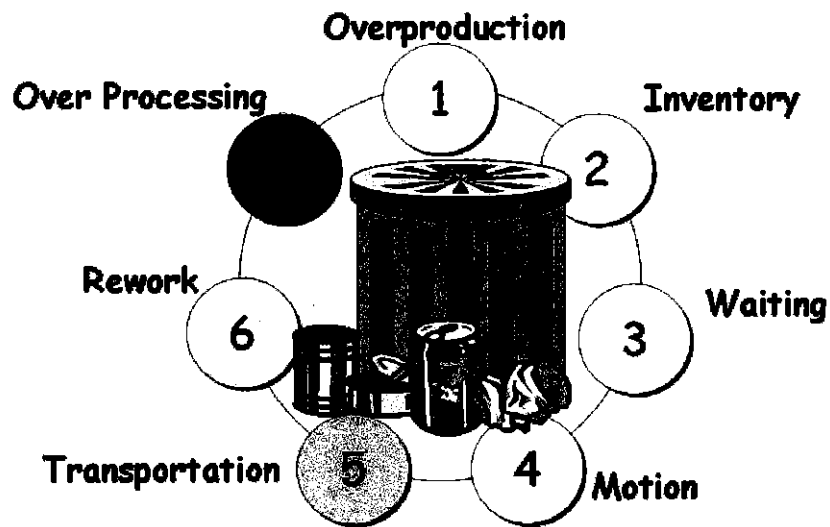
This waste is related to ergonomics and is seen in all instances of bending, stretching, walking, lifting, and reaching. These are also health and safety issues, which in today's litigious society are becoming more of a problem for organizations. Jobs with excessive motion should be analyzed and redesigned for improvement with the involvement of plant personnel. This waste leads to health and safety issues, which obviously lead to bigger problems.

2.7.7 Defects

Defects in the manufacturing process are a tremendous cost to a company. Any small defect directly impacts your bottom line and effects inventory, scheduling, inspection, and other factors. A minor defect can cost your company more than the entire manufacturing cost to begin with. Having a direct impact to the bottom line, quality defects resulting in rework or scrap are a tremendous cost to organizations. Associated costs include quarantining inventory, re-inspecting, rescheduling, and capacity loss. In many organizations the total cost of defects is often a significant percentage of total manufacturing cost. Through employee involvement and Continuous Process Improvement (CPI), there is a huge opportunity to reduce defects at many facilities (Krafcik, 1998).

In the latest edition of the Lean Manufacturing classic *Lean Thinking*, **Underutilization of Employees** has been added as an eighth waste to Ohno's original seven wastes. Organizations employ their staff for their nimble fingers and strong muscles but forget they come to work every day with a free brain. It is only by capitalizing on employees' creativity that organizations can eliminate the other seven wastes and continuously improve their performance. Many changes over recent years have driven organizations to become world class organizations or Lean Enterprises. The first step in achieving that goal is to identify and attack the seven wastes. As Toyota and other world-class organizations have come to realize, customers will pay for value added work, but never for waste. Figures 2.2 illustrated the seven wastes identified in lean production system.

The 7 Wastes



Figures 2.2: 7 wastes in manufacturing

2.8 Lean Manufacturing Tools

Prime objective of waste elimination from the system is achieved with lean manufacturing technique and all tools. Based on this requirement, Just In Time (JIT) techniques, Total Quality Management (TQM), Total Productive Maintenance (TPM), Flow charts, Workplace Redesigning techniques are used.