USING VALUE STREAM MAPPING TO IDENTIFY WASTE IN THE MANUFACTURING OF AUTOMOTIVE COMPONENTS AT FEDERAL MOGUL

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DECLARATION

"I, Peter-John Fry, hereby declare that:

1. *This work has not been previously accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.*

2. *This dissertation is being submitted in partial fulfillment of the requirements for the degree of Masters in Business Administration.*

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ABSTRACT

This research addresses the application of Value Stream Mapping in the automotive component industry. The goal of this research is to investigate how Value Stream Mapping can identify waste, and to evaluate its benefits on a specific application instance.

Value Stream Mapping is used to first map the current state and then used to identify sources of waste and to identify lean tools to try eliminate this waste. The future state map is then developed with lean tools applied to it.

A South African company, Federal Mogul South Africa (FMSA), has experienced the impact of globalisation and the need to become globally competitive first hand. FMSA will be used as a case study to illustrate the impact of using Value Stream Mapping as a tool for identify waste and the need for improving the performance of a company's value stream in achieving the international goals set for the company and its supply chain.

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Chapter 1

1. INTRODUCTION

1.1. Background

Waste in manufacturing refers to all efforts that do not add value to the final product from the point of view of the client. Eliminating waste is part of the six flow principles proposed by Koskela (2000:56):

- Reduce the share of non-value-adding activities (waste),
- Reduce lead time,
- Reduce variability,
- Simplify by minimising the number of steps, parts, and linkages,
- Increase flexibility, and
- Increase transparency.

He also highlights that reducing the share of non-value-adding activities is a fundamental source of improvement of waste.

Taiichi Ohno (1988), an engineer and developer of the Toyota Production System that led John Krafcik to coin the term 'lean production' (Womack, Jones & Roos. 1990:13), identified seven sources of waste related to:

- Defects in products,
- Overproduction of goods,
- Excess inventories,
- Unnecessary processing,
- Unnecessary movement of people,

- Unnecessary transport of goods, and
- Waiting time. Later, Womack and Jones (1996:38) established as an additional source of waste:
- Design of goods and services that fail to meet the user's needs.

Early efforts at identifying waste and its causes focused on achieving in-plant process performance improvements. The manufacturing industry, moved from an in-plant perspective to a more global view of its supply chains to reap even greater benefits, including not only first-tier, second and higher-tier suppliers and customers up and down the chain. Despite Industries best efforts, today's practices of supply chain management in many industries are still restricted to achieving greater optimal performance across only a few tiers of their supply chains and few efforts - if any - span the entire length of any one supply chain. Eliminating waste in automotive supply chains, must be a goal for supply chain participants who wish to provide a better customer service.

Supply-chain lead-time depends on various factors such as the complexity of a product which affects the time required to make and inspect it. Supply-chain lead times comprise four elements (Koskela, 2000:58):

- processing time,
- inspection time,
- wait time, and
- move time.

One particular contributor to the element wait time is decision-making time , which may be critical especially when several participants interact, playing different roles for different organisations. The lack of decision making, may cause information by participants to await processing for days or even weeks. The identification and elimination of this wait time is essential to compressing lead-time.

According to Koskela (2000:60), The Benefits of supply-chain lead time compression are : (1) faster delivery of the product or service to the customer, (2) reduced need to forecast future demand, (3) less opportunity for disruption in the supply chain due to design changes, (4) greater possibility that participants will interact in a timely fashion with other supply chain participants, (5) easier synchronisation of one supply chain with others, and (6) less opportunity for products to become obsolete. It is possible to directly attack the most visible waste just by flowcharting the process, then pinpointing and measuring non-value-added activities (Koskela,1992:18).

This set of activities, operations, and associated information make up the value stream. A value stream perspective should span individual functions, activities, departments, and organisations, and focus on system efficiency rather than local efficiency within any one of these. Value streams are mapped and analysed using a tool known as Value Stream Mapping (VSM). VSM was created by practitioners at Toyota to "make sustainable progress in the war against muda" ('muda' is the Japanese word for 'waste') (Rother & Shook, 1999:41).

VSM includes creating a map of the flow of material through production and the flow of information from the customer back to each production process. A current-state map of in-plant value streams then serves as the basis for developing future-state maps that ommit wasted steps while pulling resources through the system and smoothing flow. The difference between the current state and potential future states provides a road map to start the implementation of performance improvements. This leads to the following problem, which will be addressed by this research:

1.1.1. Main Problem

How can Value Stream Mapping be used to identify waste in the Value Stream at Federal Mogul?

1.2. Sub-Problems

1.2.1. How does the literature explain the basic concepts of the Value Stream Mapping (VSM) tool for documenting and visualizing the complete order realization process used by a company to satisfy a typical customer?

1.2.2. How do you measure the success of value stream mapping?

1.2.3. What are the limitations of value stream mapping?

1.3. DESCRIPTION OF KEY CONCEPTS:

1.3.1. Value Stream Mapping

A value stream is all the actions (both value-added and non-value-added) currently required to bring a product through its essential main flows : (1) the production flow from raw material into the arms of the customer, and (2) the design flow from concept to launch (Rother & Shook,1998: 3).

VSM is a pencil and paper tool that helps visualise and understand the flow of material and information as a product makes its way through the value stream (Rother & Shook,1998:4). Time delay between activities and how data and information are transmitted is identified. When the value stream map is developed based on current information, it is usually referred to as the current state map. This initial pass will identify value-added time vs. non-value added time.

1.3.2. Supply Chain Management (SCM)

Supply chain management covers the flow of goods from all levels of supply through manufacturing and distribution chains, to the end user. The supply chain of a company can be seen as a network of organisations, that are involved, through upstream and down stream linkages, in the different processes and activities that produce value in the form of products and services for the final customer (Christopher, 1992:12).

Internationally Womack, Jones and Roos conducted one of the most important and influential studies undertaken in the area of supply chain management within the motor industry. This five year study was done at a cost of five million dollars and concluded that the automotive industries of North America and Europe were relying on techniques little changed from Henry Ford's mass production system. These techniques were simply not competitive with those adopted by the Japanese. They undertook to study the ' lean production' techniques adopted by the Japanese in partnership with the motor manufacturers (1990:4). The key to a competitive parts supply chain was how the assemblers worked with their suppliers (Womack, Jones & Roos, 1990: 140). The writers concluded that the success of the lean production system was that all the pieces were successfully assembled from product design planning through production, through the supply system co-ordination, to the customer delivery. Lean production was seen to combine the best features of craft and mass production providing the ability to reduce costs per unit and dramatically improve quality (Womack et al. 1990:277).

1.3.3. Waste

Waste or non-value-added activity is a term that was born within the Toyota Production System (TPS) (Womack & Jones, 1996:38). They identify seven kinds of waste in a factory area:

- overproduction,

- waiting
- time, transporting,
- over-processing,
- inventory (WIP), scrap and rework,
- and excess motion of operation.

Waste is any work that does not add value to a product or service. If the customer does not benefit from it, it is waste.

1.3.4. SMED

SMED is an acronym for Single-Minute Exchange of Die. The term refers to the theory and techniques for performing set-up operations of tools in fewer than ten minutes (Shingo,1985:1). There are two types of set-ups: internal and external. Internal set-up activities are those that can be carried out only while the machine is stopped. External set-up activities are those that can be done while the machine is running. The idea is to move as many activities as possible from internal to external.

1.4. DELIMITATION OF THE RESEARCH:

This research focused mainly on Federal Mogul (FM) South Africa analysing the order fulfilment process for at least one major automotive gasket product being manufactured for the Ford engine plant in the Eastern Cape.

1.5. THE IMPORTANCE OF THIS RESEARCH:

Federal Mogul division adopted a global manufacturing strategy of moving production of low technology, high labour cost product, to low labour cost

countries. Consequently, FM had been identified as the manufacturing site for high labour content, low technology products for the European automotive component market. These improved business prospects have highlighted the need for increased commitment to flexibility, on time delivery, productivity and quality standards.

The research into VSM as an improvement tool to identify and eliminate waste will help reshape the company into a more efficient, focused and effective provider of world-class products to world markets.

1.6. SIGNIFICANT PRIOR RESEARCH:

1.6.1. Competing against ignorance: Advantage through knowledge.

This research describes the use of a technique called the Value Stream Analysis Tool (VALSAT) and discusses its advantages and disadvantages.
Hines, Rich & Hittmeyer begin by discussing the types of improvements companies want to make. Fourteen large UK organisations were given a list of ten propositions and asked to rate the importance of each. The results were tabulated to determine the average importance of each improvement to the group of organisations as a whole. It was noted that the importance ratings would change over time, and therefore "a dynamic analysis, prioritisation and focusing tool, which if possible should be capable of using both tacit and subjective information as well as explicit or quantifiable information" (Hines, Rich & Hittmeyer ,1998:18), is needed. This tool will provide an organisation with detailed knowledge of its value stream or supply chain. The tool VALSAT described in the paper, , meets all the above criteria.

This tool is a modification of Quality Function Deployment (QFD) whereby the *WHATs* represent the improvements required based on customer needs, and the *HOWs* represent possible techniques to achieve these improvements.

The article is effective in detailing all the steps to follow in using the tool to determine which of the *HOWs* to undertake so that the most important *WHATs* are resolved. In short, the selection of the appropriate *HOWs* is determined by the importance of the *WHATs*, customer assessments on how the company is currently performing on each of the *WHATs*, how good the *HOWs* have to be and how difficult it is to implement each *HOW*. The article provides a case study of a Kenyan textile manufacturer describing the practicality of the tool. It was shown that using the tool resulted in great benefits to the company. Current research projects utilising the VALSAT tool are listed showing the wide range of industries supported by it. These include both manufacturing and service industries. The article concludes by listing some of the advantages and disadvantages of the VALSAT. It can be seen from the article that the advantages far outnumber the disadvantages, further proving the usefulness of the tool.

The author expects to gather in-depth knowledge of this tool, including its purpose, applications and advantages.

1.6.2. <u>The seven Value Stream Mapping tools</u>

This article describes a toolkit consisting of seven tools that, when used together, provides an effective framework for identifying and eliminating wastes.

Hines and Rich (1997:46) recognise that the difference between a supply chain and a value stream is that a supply chain encompasses all of the activities of all the companies involved, whereas a value stream only refers to the specific activities which actually add value to the product or service. The three types of activities, non-value-added and value-added, with examples, are presented, followed by an excellent description of each of the seven basic wastes.

Hines and Rich (1997, 59) discusses problems with existing tools for analysing value streams. The main problem identified was that each was too limited in scope and did not integrate well with one another to provide a comprehensive view of the value stream. The seven tools presented in the article were specifically designed to eliminate this problem.

- The first tool, process activity mapping, aids in developing solutions to reduce waste.
- The second tool, supply chain response matrix, aids in identifying the activities constraining the process so that these activities can be targeted for improvement.
- The third tool, production variety funnel, helps one understand how products are produced.
- The fourth tool, quality filter mapping, aids in identifying where quality problems occur.
- The fifth tool, demand amplification mapping, aids in analysing the increase in demand variability as one travels up the supply chain, otherwise known as the bullwhip effect.
- The sixth tool, decision point analysis, aids in identifying "the point in the supply chain where actual demand pull gives way to forecast-driven push" (Hines and Rich, 1997 : 57).
- Finally, the seventh tool, physical structure, aids in developing a high-level understanding of the supply chain.

The selection of "which tools to use in what circumstances is done using a simplified version of the value stream analysis tool (VALSAT)" (Hines and Rich, 1997 : 59). Weightings are developed to determine the usefulness of each tool for identifying each waste. The weightings utilised in the analysis are dependent on the industry being considered, with some wastes being more relevant in some industries than on others.

The article provides an effective framework for identifying and eliminating wastes. The author expects to develop an understanding of these tools and how they can aid in the journey towards lean manufacturing.

1.6.3. From current state to future state: Mapping the steel to component supply chain

This article describes current state and future state mapping and how they can aid in lean improvement. Information is provided in the form of a case example, in this case a steel to component supply chain, hence the title.

Brunt (2000, 259) describes that the main weaknesses with the tools described in Rich and Hines (The seven Value Stream Mapping tools) article are its micro-perspective and "its lack of visual nature" (Brunt, 2000,260). Brunt integrates the tools described in the Rich and Hines article with others and depicts the information gathered in the "learning to see" style (Rother & Shook,1998:4) to provide a visual picture of the value stream. This is known as material and information flow value stream mapping. There are four steps to this approach.

- The first step is to select a product family.
- Secondly, a current state map is developed.
- The third step is to develop a future state map.
- Finally, a plan to achieve the future state is constructed.

A current state map is developed over four stages, described in detail in the article. These are: "(1) gather details about the customer's requirements; (2) detail the physical flow with all processes, data boxes and inventory triangles; (3) map the supply of materials; and (4) map the information flows and determine push and pull system" (Brunt, 2000:263). These stages are

described in detail in the article, and a diagram listing all the different mapping symbols utilised is provided.

The current state map and future state map are provided with their details, for the first-tier component supplier in the case example is provided, with details thoroughly explained. (Brunt, 2000:265).

Brunt (2000:270) describes the process of developing current and future state maps for the entire steel to component supply chain, before concluding by listing five issues to be considered when moving from current state to future state. These are described in detail in the article and act as an effective guide to achieving the desired future state. The only things lacking in the article are information on which product family to select and how to account for different cycle times in the product family.

The author gained an in-depth knowledge of value stream mapping and will be comfortable with developing current state and future state maps.

1.7. PROPOSED RESEARCH APPROACH OR METHODOLOGY:

In this section the broad methodology that will be followed in the study, to solve the main and sub problems, is discussed.

1.7.1. Literature Survey

An in-depth literature search will be conducted in the areas of Value Stream Mapping. The results of the literature survey will provide guidelines to determine the effectiveness of using Value Stream Mapping as a tool for the identification and elimination of waste.

1.7.2. Empirical Study

In line with the second and third sub problem stated above, interviews and workshops will be conducted with the selected component manufacturer (FM). First VSM mapping is used to map the current state for FM. This is used to identify sources of waste and to identify lean tools to try reduce the waste. Secondly the future state map is developed for a system with lean tools applied to it. A subjective evaluation of the benefits and limitations is provided.

1.8. KEY ASSUMPTIONS:

It is assumed that by utilising VSM as a tool to create a future state map, improvement opportunities will be identified in the elimination of waste.

It is assumed that by applying VSM to a representative product that has similar process steps to the majority of the products that go through the system will deal with similar issues (transportation, information exchange, dispatching, etc.) as the majority of the other products.

1.9. The Study is arranged as follows:

Chapter 1	Research Proposal
Chapter 2	Literature Study
Chapter 3	Research Design
Chapter 4	Research Results – Current State Map
Chapter 5	Analysis and recommendations – Future State Map
Chapter 6	Conclusion

Chapter 2

2. Literature Study

2.1. Lean History

The characteristics of lean manufacturing where first identified and encapsulated in a 1990 book entitled, *The Machine that Changed the World*, written by James P. Womack, Daniel T. Jones, and Daniel Roos. The lean concept is based on an earlier five year study of the automobile industry by the International Motor Vehicle Program (IMVP) at the Massachusetts Institute of Technology (Womack:1990:4). The book presents a cautionary treatise warning that companies in the United States must adopt "lean" production process and practice policies to compete successfully with Japanese companies.

This concept is further formalised in a subsequent book by Womack and Jones (1996:15) entitled, *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. As implied by the title, lean is, in its basic form, the manufacture of a product with a minimum of waste. The treatise by Womack and Jones (1996:19) takes a broader view of "waste" than just that of material scrap and unnecessary overhead and proposes that a lean implementation address all aspects of value-creating activities. The concept of lean production represents the natural evolution of "Just in Time" (JIT), a production concept pioneered by Toyota.

2.2. Lean Principles

In *Lean Thinking*, Womack and Jones (1996:16) define lean thinking as “a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively.” There are five key principles vital to lean thinking, these are specify *value*, identify the *value stream*, make value *flow*,

organise customer *pull*, and pursue *perfection*. These principles are expected to be addressed in order, with each one building on the one before it, as shown in Figure 1. This research will concentrate on the identification of the value stream and the identification of the value adding actions within this framework of lean principles

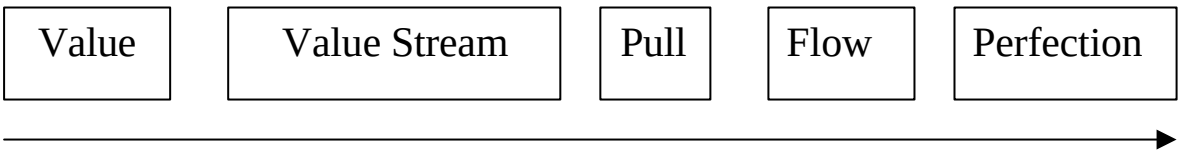

Figure 1: Steps of Lean Thinking (Womack & Jones, 1996)

Specify Value - Value is expressed in terms of a specific product or service, delivered at a specific price at a specific time, which meets the needs defined by the customer (Womack & Jones,1996:16).

Identify the Value Stream – Value stream is a macro view of the entire door-to-door perspective of a production, from raw materials to product delivery. It includes the determination of all actions necessary to produce a product and the separation of those necessary activities from the identified non-value-added steps. This includes not only the physical transformation of the product from raw materials, but also the information system necessary to produce the right quantity at the right time (Womack & Jones,1996:19).

Flow – Once waste has been eliminated, 'flow' can be accomplished. Flow, the opposite of batch production, requires the movement of products from one value-creating step to the next with no waiting or scrap (Womack & Jones,1996:21).

Pull - The production of customer requirements against specified delivery dates., Information travels upstream from the customer, signaling production only when

a need is shown instead of pushing products from raw materials to the customer (Womack & Jones,1996:24).

Perfection – This step is a reminder that reducing waste is never ending. Continuous improvement of a system is vital to perfection, where waste is constantly being eliminated. It is necessary to understand that lean is not a specific control tool, improvement tool, floor layout, or principle. It is the methodology or framework that focuses on the ideas of value, waste, and meeting customer demand. It is clear from this why Value Stream Mapping resulted as a method of determining where the value and waste are located and aiding in the reduction of lead-time to help make the right product at the right (Womack & Jones,1996:25).

2.3. Getting Started

2.3.1. Defining the Team

A team of one may suffice for a simple enough problem. Typically, a variety of perspectives are needed to reveal the often difficult-to-see product value stream (Millard, 2001:130). The team should embody a balance of enterprise perspectives, whether they come from multi-skilled people, or multiple people. These perspectives might include:

Lean Experts: for knowledge and experience in Lean theory, as well as the methods and tools used for the process improvement.

Process Owner(s): for knowledge and experience in the process to be improved, and authority to change it.

Process Participants: for detailed, on-the-ground knowledge of the process, its strengths and weaknesses, and how it is currently executed.

System/Enterprise Thinkers: for thinking "outside the box" and considering the needs of the greater enterprise and continuity with upstream and downstream processes.

Customer(s) and Supplier(s): internal and/or external, for understanding of the value of process outputs; the availability, flexibility, or improvements of process inputs; and the correct design and improvement of friction free interfaces (McManus,2003:14).

The Team must be at least minimally trained in Lean Manufacturing. Upper management must be explicitly behind the effort (McManus,2003:15). The team must take ownership of the process, and be empowered to change it with reasonable but minimal management oversight.

2.3.2. Defining the Problem

Rother and Shook (1999: 3) define a manufacturing value stream bounded by the walls of a single facility—a "door-to-door" value steam. The improvement team must define several critical elements of the value stream (Millard, 2001:65). The *process bounds* include the beginning and ending point of the process, and its organizational boundaries. The *product* or products on which the process operates should be specified. The *owner* will provide the point for direct responsibility for the stream, whether it is a group or an individual. The *output* provides reason for the stream to exist—it is the packaged value generated by the given process. The *customers* receives the product from the owner at the end of the Value Stream. They do not necessarily represent someone external to the organization; they can include internal customers. The *initial inputs* as well as the additional knowledge and information that are pulled into the process are the raw materials on which the process operates. The *constraints* place many

source of limits on the process (McManus,2003:15). Figure 2 illustrates the defined to apply value stream mapping to the process.

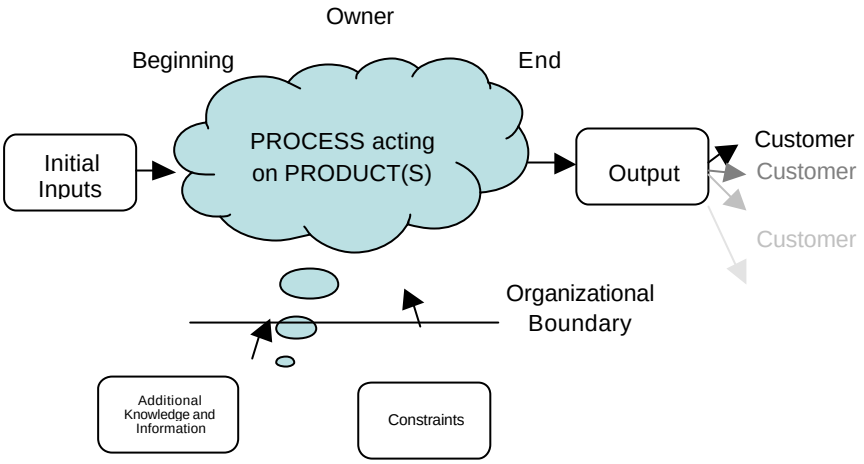

Figure 2: Bounding the problem to which VSM will be applied (McManus,2003:15).

2.3.3. Defining The Value

The customer can only define value (Womack & Jones, 1996:16). It is only meaningful when expressed in terms of a specific product (goods or a service, and often both at once) which meets the customers needs at a specific price at a specific time.

We cannot guide our improvement effort without a working definition of the value created by the process we are mapping, and an appreciation for how that value is created. It is important not to get involved up in an essentially philosophical debate over the details of value. The author, assumes that the overall process being analysed, is in fact, value added.

If the process been analysed is necessary for the larger enterprise to create value, the goal must be to do it effectively, efficiently, and in a timely fashion.

This goal should be made as explicit as possible. A template for such an explicit goal is summarised below.

Produce the required outputs, without defects, as efficiently as possible, and in a timely fashion.

2.3.4. Understanding the value creation

Assuming a goal has been defined, a basis for evaluating how tasks within the process contribute to that goal is needed. The question is expressed graphically in Figure 3, which shows an example process under consideration decomposed into a series of individual tasks.

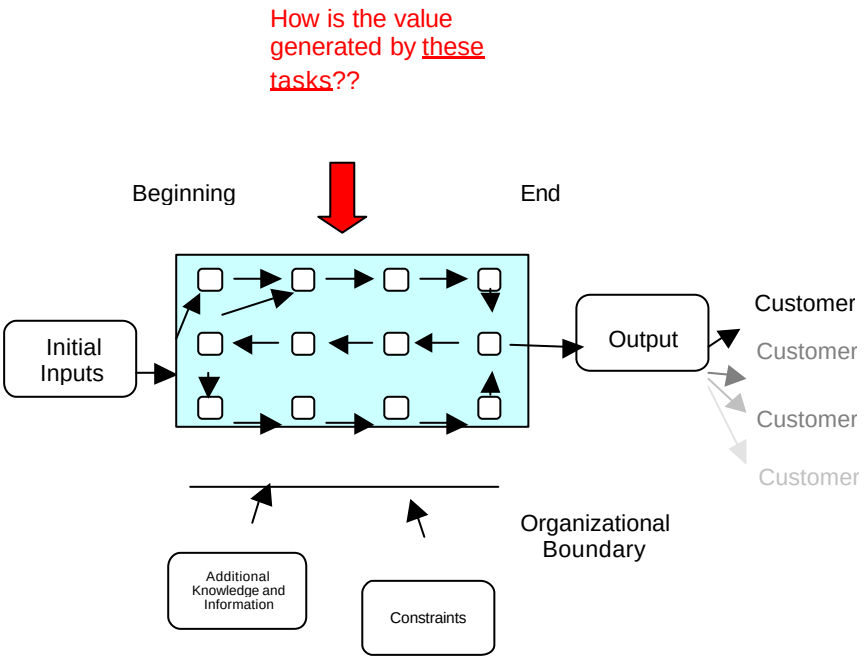

Figure 3: Value Creation (McManus, 2003:15).

A simple judgement, in manufacturing, is made whether an action contributes to the form, fit, or function of the material flow . If so, the action is judged to be value-added, and if not, waste is either a necessary or unnecessary sort.

2.4. Mapping the current State Value Stream

2.4.1. Current State

Rother and Shook (1999: 16) states that the current value stream should be developed as a snapshot of current findings and include such information as inventory levels, total lead-time, machine uptime, and machine reliability. Table 1 shows the typical metrics included for a specific process box on a value stream map. A current value stream map allows someone to view the flow of the entire production process from supplier to customer, something management are unaware of. People gain understanding of how their job or function affects the critical path operation. A common language is available to understand the situation through the use of the common symbols

A current value stream map, seen in Figure 4, is read from left to right. The first production step is placed in the bottom left corner and shipping is in the bottom right corner. The top left corner contains the supplier , and the top right is the customer. The bottom of the chart is reserved for production steps, and the top for information flow between the company, the individual production steps, the customer, and the supplier.

Metric	Description
Cycle Time	Time required to complete a process
Changeover Time	Time required to change a process from one product to another
Uptime	Percentage of time station is processing parts
Available Time	Amount of time machines and employees are free to work
Batch Size	Number of same part that goes through a process step at one time
Yield	Percentage of good parts produced in a process

Table 1: Typical Value Stream Metrics (Rother & Shook, 1999: 18-20)

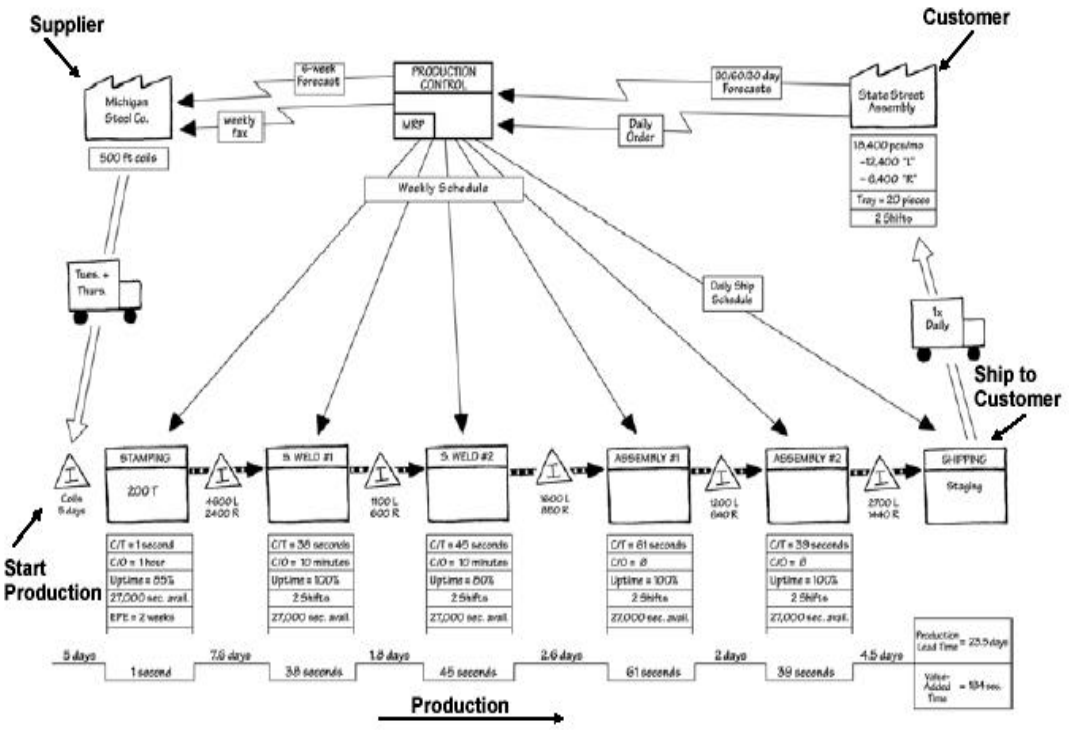

Figure 4: Current Value Stream Map (Rother & Shook, 1999:33)

2.4.2. Tasks and flow

McManus (2003:28) suggests that the first step is to identify the tasks that compromise the process, and the basic flows of information between them.

Appendix A contains a set of process mapping symbols that are applicable to a typical manufacturing process and Value Stream Mapping exercise.

2.4.3. Data

Data collecting and use requires a balance between the effort involved and the payoff expected. Although collecting task data is difficult, the easiest mistake is to collect too much. The aim is to achieve a lean process, not build a complete model of the process.

Trischler (1996:75) calls the latter tendency "Paralysis by Analysis". The other key mistake identified by Trischler (1996:76) is the tendency to start with a pre-existing theory and collect the data necessary to validate it. This kind of bias should be avoided.

The data collected is appended to the value stream map using data boxes. This is illustrated in figure 4. The aim of the map is to include the data that will provide insight into the process, not simply to display everything. In the example, a Rother-and-Shook-style time line across the bottom captures the time data in compact form. See Figure 5.

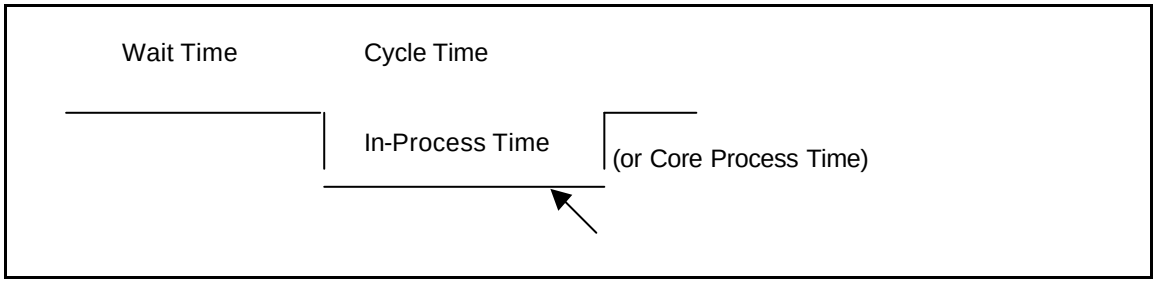

Figure 5: Timeline notation

2.4.4. Evaluation of value

Womack and Jones (1996:35) emphasise that lean enterprises must continually revisit the value question with their product team to obtain if they have the optimum solution The "5 Why tool" can be used to produce steady results along the path to perfection (Shingo,1989:82).

Traditional categories of "value-added", "necessary non-value-added" and "pure waste", are not always useful when taking an initial look at the value of the current state tasks. Time and effort can be wasted arguing the nuances of "value-added" versus "necessary non-value added" in ways that do not add value to the value stream map!

2.5. Identifying and eliminating waste

In the previous section a vision of the process has been created, the literature research in this section will investigate ways of identifing and improving it. The rationale, according to Hines and Rich (1997:46) underlying the collection and use of this suite of tools is to help researchers or practitioners to identify waste in individual value streams and find an appropriate route for removal, or at least reduction, of this waste.

Toyota's chief engineer, Taiichi Ohno, and *sensei* Shigeo Shingo (1989:76) made waste removal a criteria to drive competitive advantage inside organisations. Ohno and Shigeo are more fundamentally oriented towards productivity rather than towards quality. The reason for this suggested by Hines and Rich (1997:47), is that improved productivity leads to leaner operations which helps expose further waste and quality problems in the system.

2.5.1. The Seven Wastes

The products made in each factory may be different, but the typical wastes found are very similar (Suzaki,1987:12). Toyota identified the following seven types of waste as the most prominent (Hines & Rich, 1997:47).

1) **Overproduction** is regarded as the most serious waste as it discourages a smooth flow of goods or services. It is likely to inhibit quality and productivity. Overproduction waste is typically created by getting ahead of the work. When this occurs, more raw materials are consumed and wages are paid for unneeded work, thereby creating unnecessary inventory (Suzaki, 1987:13). The pull or kanban system was employed by Toyota as a method of overcoming this problem.

2) The waste of waiting occurs in a factory setting, this waste occurs when **time** is being used ineffectively whenever goods are not moving or being worked on. This affects both goods and workers, each spending time waiting. The ideal state is no waiting time with a consequently faster flow of goods. Waiting time for workers can be used for training, maintenance or kaizen activities and should not result in overproduction (Hines & Rich, 1997:48).

3) The third waste, **transport**, involves the necessary movement of goods. Taken to an extreme, any movement in the factory could be viewed as waste. Transport minimization rather than elimination is usually implemented by improving plant layout (Shingo,1989:192).

4) Inappropriate **processing** occurs in situations where overly complex solutions are found to simple procedures such as using a large inflexible machine rather than several small flexible ones. This over-complexity generally

discourages line ownership and encourages the management to overproduce to recover the large investment in the complex machines. This approach encourages poor layout, leading to excessive transport and poor communication. The ideal is to have the smallest possible machine, capable of producing the required quality, located next to preceding and subsequent operations. Inappropriate processing occurs when machines are used without sufficient safeguards, such as poka-yoke or jidoka devices, so that poor quality goods are able to be produced.

5) Unnecessary **inventory** tends to increase lead time, preventing rapid identification of problems and increasing storage space, thereby discouraging intra-operator communication. Problems are hidden by inventory. To correct these, they first must be discovered. This can be achieved only by reducing inventory. Unnecessary inventories create significant storage costs and lower the competitiveness of the organization or value stream wherein they exist.

6) Unnecessary **movements** (motion) involve the ergonomics of production where operators have to stretch, bend and pick up when these actions could be avoided. Such waste is tiring for the employees and is likely to lead to poor productivity and to quality problems.

7) The bottom-line waste is of defects as these are direct costs. The Toyota philosophy is that defects should be regarded as opportunities for improvement rather than a trade off against poor management. Defects are seized on for immediate kaizen activity.

2.5.2. Eliminating Waste

VSM tool is an effective tool for identifing the seven types of waste. There are various methodologies and techniques used to reduce these groups of wastes. These approaches have been the subject of considerable previous work at the Lean Enterprise Research Centre. This would include the application of *the Seven Value Stream Mapping tools* by Hines and Rich (1997: 51-58) to a range of United Kingdom-based industry sectors. The typology of the seven new tools is presented in terms of the seven wastes already described.

- **Process activity mapping** has its origins in industrial engineering. The technique is known by various names. Although process analysis is the most common. There are five stages to this general approach:
  I. The study of the flow of processes;
  II. The identification of waste;
  III. A consideration of whether the process can be rearranged in a more efficient sequence;
  IV. A consideration of a better flow pattern, involving different flow layout or transport routing; and
  V. A consideration of whether all tasks executed at each stage is really necessary and what would happen if superfluous tasks were removed.

- **Supply chain response matrix** is the time compression and logistics movement and goes under a variety of names. This mapping approach seeks to portray in a simple diagram the critical lead-time constraints for a particular process.

- The **production variety funnel** originates in the operations management area. It's use allows the mapper to understand how the firm or the supply chain operates and the accompanying complexity that has to be managed.

- The **quality filter mapping** approach is a new tool designed to identify where quality problems exist in the supply chain. The resulting map itself shows where three different types of quality defect occur in the supply chain:
  I. Product defect;
  II. Quality defect and
  III. Internal scrap.

- **Demand amplification mapping** , which is a simple analytic tool that can be used to show how demand changes along the supply chain in varying time buckets. This information then can be used as the basis for decision making and further analysis to try to redesign the value stream configuration, manage the fluctuations, reduce the fluctuation or to set up dual-mode solutions where regular demand can be managed in one way and exceptional or promotional demand can be managed in a separate way.

- **Decision point analysis** is of particular use for "T" plant layouts or for supply chains that exhibit similar features, It may be used in other industries. The decision point is the item in the supply chain where actual demand-pull gives way to forecast-driven push. It is the point at which products stop being made according to actual demand and are made against forecasts alone.

- **Physical structure mapping** is a new tool, which has been proved to be useful in understanding what a particular supply chain looks like at an overview or industry level. It's similar to the application of the process activity mapping tool. Attempts can be made to eliminate activities that are unnecessary, to simplify others, combine yet others and to seek sequence changes that will reduce waste.

Kobayashi in his book " 20 keys to workplace improvement". Highlighted four steps to eliminate waste in the work environment (Kobayashi,1995:133-142) these are:

Step 1: Get the people to understand what waste is ie. They need to understand that all operations which do not add value, are waste.
Step 2: Identify all non value adding (waste) activities in your work area (Create a treasure map).
Step 3: Develop action plans to reduce or eliminate the waste.
Step 4: Measure and visualise successes to re-inforce the efforts and illustrate the gains (Creating a perpetual cycle).

2.5.3. Other Waste Reduction Techniques

2.5.3.1. Set-Up Time Reduction

Ohno at Toyota developed Single Minute Exchange of Die (SMED) in 1950. Ohno's idea was to develop a system that could exchange dies rapidly. By the late 1950's Ohno and Shingo where able to reduce the time that required to change dies from a day to three minutes (Womack et al,1990:52). This method has dramatically reduced Set-Up times promoting the reduction of lot sizes and ultimately to the concept of One Piece Flow manufacturing.

Set-Up time can be broken into two components; first there is External set-up time which is the time available to begin the set-up which does not interrupt production. Once a set-up is planned, all the tools and fixtures needed to perform the set-up should be available at the machine before it is shut down (Shingo,1985:36). Set-up time can typically be reduced by 50% or more just by focusing on the external issues. secondly there is Internal Set-Up time which is the time the machine must be switched off to complete the Set-Up. Some of the techniques used to reduce Internal set-up time include using "quick disconnect"

type fittings, using hydraulic clamps instead of bolts and standardizing the size of all the molds, dies and fixtures used (Shingo,1985:53). Both Internal and External times must be thus to reduce Set-Up times .

Shingo (1985:126) viewed the results of SMED as exceeding shortened Set-Up times. He believed that producers who adopt the SMED system can obtain fundamental, strategic advantages by eliminating inventories and revolutionising the basic concept of production.

2.5.3.2. The 5S process

5S was originally developed by Toyota to eliminate hidden factory waste by describing a set of actions to maintain an organized work place (Monden,1998:199). The following are the Japanese words that describe those actions:

- Seiri (Sort),
- Seiton (Set in Order),
- Seiso (Shine),
- Seiketsu (Standardize),
- Shitsuka (Sustain).

Hirano (1995:28) states that the application of 5S should not be circumscribed to the plant floor and that it could be used in areas of sales and accounting. 5S provides the structure and discipline for organization of a work area as aptly summarized by this statement:

"A place for everything and everything in its place" (author unknown).

2.5.3.3. Poka-yoke

Human beings invariably make errors. When errors are made and not caught then defective parts appear at the end of the process. If the errors can be prevented before they occur then the defective parts can be avoided. One of the tools that the zero-defect principle uses is Poka-yoke. It was developed by Shingo, is an autonomous defect control system that is put onto a machine that inspects all parts to make sure that there are zero defects. Shingo (1986:92) states that people are under the false impression that simply putting in such devices will eliminate defects. He maintains that a Poka-yoke system is a "Means and not an end", that combined with successive checks and 100% inspection makes it possible to establish zero defects.

2.5.3.4. Total Productive Maintenance (TPM)

Machine breakdown is an important issues that concerns the people on the shop floor. Equipment realiability on the shop floor is very important since if one machine breaks down the entire production line could be stopped. An important tool that is necessary to account for or predict sudden machine breakdowns is TPM. A TPM program is very important in almost any lean manufacturing environment setting.

Suzaki (1987:122) defines TPM as a concept that involves all employees. He states further that the goal of TPM is to achieve overall effectiveness of the production system through employee participation in productive maintainance activities. Futher, the benefits of implementing TPM will be described later.

2.6. Establish a Takt time

Shingo (1989:105) defines Takt time as the time it takes to produce one piece of product. This time is equivalent to total working time divided by production quantity. All tasks in the process must then proceed at this pace, or the demand cannot be met (at least without expensive and inefficient expediting and/or overtime). Rother and Shook (1999:44) states that the Takt time used is to synchronise the pace of production the pace of sales and productivity at the "pacemaker process" (which is discussed later in Chapter 5).

Producing to Takt sounds simple, but it requires concentrated effort to:

- Provide fast simple response (within Takt to problems)
- Eliminate causes of unplanned downtime
- Eliminate changeover time in downstream, assembly-type processes (Rother & Shook,1999:44)

2.7. The future state map

After a current value stream is developed, the next phase is a future value stream. A future state is developed using the principles of lean manufacturing and a set of important questions vital to lean manufacturing as supplied by Rother and Shook. The eight questions, listed below, should be answered in order for a system perspective

Questions seen in Learning to See (Rother & Shook,1999:58):

(1). What is the Takt time?

(2). Will we ship directly to the customer, or to a finished goods warehouse?

(3). Where can we use continuous flow?

(4). Where will we need supermarket pull systems?

(5). Where will our pacemaker be?

(6). How will we level the production mix at the pacemaker?

(7). What increments of work will you consistently release and take away at pacemaker?

(8). What process improvements will we need to achieve our future state design?

It should be noted that these questions link to the ideas of flow and pull mentioned in the lean principles, and illustrate how creating a Value Stream Map is vital to determining where processes can be improved. Figure 6 shows a future state map that has been developed using the principles of lean manufacturing. A pull system from shipping has been implemented through the use of kanban cards and supermarkets. The welding steps and assembly steps have been combined for a continuous flow cell. Through these identified improvements, there is a change in lead-time from 23.5 days to 4.5 days in this example.

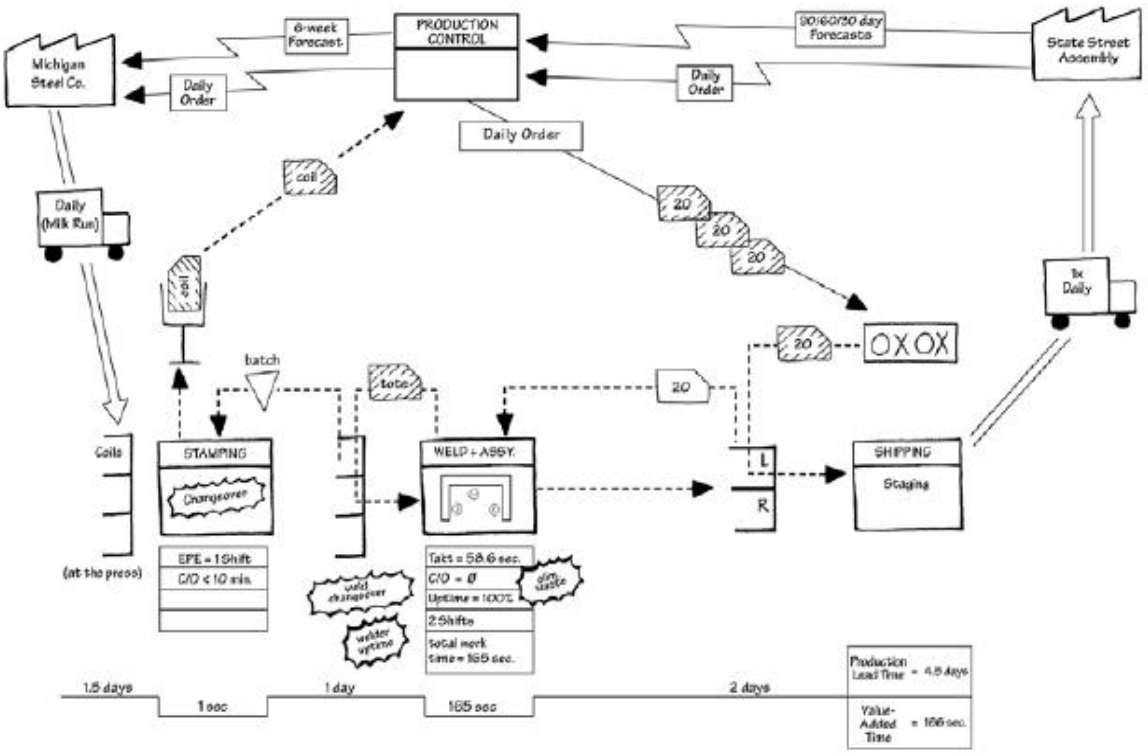

Figure 6: Future Value Stream Map (Rother & Shook,1999:79)

2.7.1. Achieving The Future State Map

The final step of value stream mapping is creating an Implementation Plan to help achieve the future state from the current state. Learning to See suggests the use of a value stream plan worksheet and a review worksheet (Rother & Shook,1999:90). It is recommended that follow-up meetings, weekly or bi-weekly, are held These are continually updated to gain progress on the implementation plan. This regular meeting format stresses the importance of the initial value stream mapping event and the actions that were identified. Holding people accountable for certain action items will help rapidly implement the process. An example of the value stream plan can be seen in Appendix B.

2.8. Summary

The main principles of lean manufacturing have been reviewed. It is seen that it is from the five main lean principles that value stream mapping was developed. Value stream mapping plays an important role in developing a system view of the problem and determining ways of eliminating waste. The steps to creating a VSM were discussed. To understand the tool in-depth, the analysis on its appropriateness in the automotive component industry is discussed in the next chapters.

Chapter 3

3. Research Design and Methodology

The researcher's goal is to deduce and test the implications of performed hypotheses (quantitative research) or to induce hypotheses from his or her own observations (qualitative research). The research method would involve different methods of sampling, data collection, data analysis, styles of writing and result communication to accomplish these different goals (Leedy,1997:105).

There are a number of differences between the two approaches that need to be examined in determining which approach to use. These differences are:

- Purpose: Quantitative research seeks explanations that will generalize to other people and places. Whereas qualitative research adopts to lead to an attitude of discovery that leads to discovery, building or enhancing a theory as opposed to the testing of it.
- Process: As the qualitative approach represents the mainstream approach it becomes more structured and follow a set guidelines.
- Data Collection: Quantitative research uses experimental or correctional design to reduce errors, bias and extraneous variables. There is a belief that due a situation of stable reality, situations can be measured by well designed questionnaires or instruments. Qualitative research is dependent on the personal involvement of the researcher and be inclined to concentrate on a few select participants rather than a wide range, to gain a more in depth understanding of the situation.
- Data Analysis: All research requires a logical study. Quantitative research relies on a deductive form of analysis. Qualitative research uses an inductive form of analysis whereby observations of particular cases can be generalised to a class of cases.
- Communication of findings: Quantitative researchers typically reduce their data to numbers which are then present as the results of statistical tests,

qualitative researchers construct interpretative narratives from the data and employ a more literary style.

The purpose of the comparison above is to illustrate the relative strengths and weaknesses of the two research types. The two methods can be used together although novice researchers may not have the time, resources of expertise to effectively combine these approaches for initial research attempts (Leedy, 1997: 105-108).

In deciding on which approach to adopt the writer is of the opinion that a more qualitative approach would be adopted due to:

- Purpose: The research will adopt an attitude of enhancing theory as opposed to testing it.

Data Collection: The proposed research will tend to be dependent on personnel involvement of the researcher and concentrate on a few select participants focusing on a more in depth understanding of the situation. In line with the main problem stated above, interviews will be conducted with the Production Manager of Federal Mogul and workers on the shop foor. An informal questionnaire was developed, the questions can be viewed in Appendix C.

- Data Analysis: The proposed research will lend itself more to a inductive form of analysis whereby observations of particular product family may be generalised to range of product families.
- Communication of findings: The findings of the research will be better communicated by being represented in a narrative rather than a numerical form.

An in-depth literature search will be conducted in the areas of Value Stream Mapping and Lean Manufacturing. The research in VSM is limited, so Rother and Shook's model will be used in practice and the literature will be reviewed.

Chapter 4

4. Research Results – Current State Map

This chapter will present the analysis of the current system at Federal Mogul. The analysis includes a study of utilisation in order to determine improvement opportunities. Improvement opportunities for the current system will be described and mapped. The information acquired here will be used also in Chapter 4 for the future state map.

4.1. Company Background

The company focus of this work is on Federal Mogul (FM); formerly Payen Components SA Ltd situated in Port Elizabeth, Eastern Province, South Africa. Set out below is a summary of the company's structure, development and future plans.

FM is a wholly owned subsidiary of the Federal Mogul Corporation of America. Federal Mogul is a multinational company registered in the United States of America with it's world headquarters in Detroit Michigan. The corporation has interests in 23 countries worldwide. It has a turnover in excess of five billion dollars and operates in the manufacturing and distribution of automotive components for both the original equipment (OE) and aftermarket sectors of the global automotive market. The corporation operates through three product divisions being: powertrain systems, sealing systems and general products. FM forms part of the sealing systems division.

FM was established in 1959 and started with the manufacture of cork automotive gaskets and cork heals for ladies shoes. The company enjoyed strong financial performance during its growth phase increasing its market share and product

offering. This performance continued even though the company had reached the mature stage of it's like cycle in the local market. By 1999 it occupied a dominant position in the local aftermarket sector for sealing system products, having 85 percent of this sector. The high market share prevented any further significant future market share gains and was recognised by the company as a threat to it's future. The reasons for the company's growth and profitability were attributed to strong customer focus and branding. The strength and main company focus was on the area of marketing rather than manufacturing. The level of competition from imports had increased over this period at a fast rate. This increase was due mainly to the South African government's commitment to deregulating the economy and its support for the General Agreement on Tariffs and Trade policies (GATT).

The company served three main market channels, split as follows:

1998	**Market Share**
Domestic Aftermarket	**50**
OE/OEM Market	**5**
International gasket market	**0**
No. of Employees	**210**

- The above analysis indicates the large portion that the aftermarket represented of the company's total turnover. The aftermarket was also the most profitable sector of the company's business.

The FM group believed that its corporate strength was in manufacturing and therefore its main concentration was focused in this area. The move by FM into the more competitive export markets in the mid 1990's necessitated the improvement of the company's manufacturing standards and quality ratings. This

focus on manufacturing standards and logistical expertise provided the company with a good fit into the group strategy.

In keeping with the strong manufacturing emphasis the Sealing Systems division adopted a global manufacturing strategy of moving production of low technology, high labour cost product, to low labour cost countries. As a result of this strategy, FM had been identified as the manufacturing site for high labour content, low technology products for the European automotive component market. With these improved business prospects has come the need for increased commitment to flexibility, on time delivery, productivity and quality standards.

Forecasted Position 2004	**Market Share**
Domestic Aftermarket	**52**
OE/OEM Market	**6**
International gasket market	**1**
No. of Employees:	**260**

4.2. Getting started

4.2.1. Defining the Team

As Rother & Shook (1999:7) suggests a value stream manager needs to be appointed, for the purposes of this research the author will assume responsibility of this role. As this research and the VSM tool will play an important role into the future of the company, the author included the production manager as he has an overall responsibility and understanding of the product family's value stream and for improving it. The Author believes that the team embodies a balance of enterprise perspectives, a Process Owner who has the knowledge and experience in the process to be improved and a Enterprise Thinker, for thinking

“outside the box” considering the greater needs of continuity of upstream and downstream processes.

Both team member’s are sufficiently trained in Lean and the methods and tools chosen for VSM. The research has been communicated to upper management, who is explicitly behind the effort.

4.2.2. Defining the problem

Federal Mogul produces a wide range of automotive gaskets. This case concerns one product family – Exhaust Manifold –, which is produced in three configurations. Federal Mogul’s customer for this product is an original-equipment engine builder.

The Exhaust Manifold’s are “make to order” business, it currently takes a customer order 7 days to get through FM’s production processes. The significant order backlog and fluctuations in demand have prompted FM to quote a 14-day lead-time to its customer. FM’s customer cannot accurately predict their requirements more than two weeks in advance, and thus make adjustments to their orders 2 weeks before shipment. These order adjustments have lead to FM holding additional buffer stock in raw materials, work-in-progress (WIP) and finished goods.

FM’s production scheduling releases orders to production in pre-defined economic batch quantities to reduce set-up times. The reason for this is that different product families are produced on the same resources. This also results in a need for order expediting.

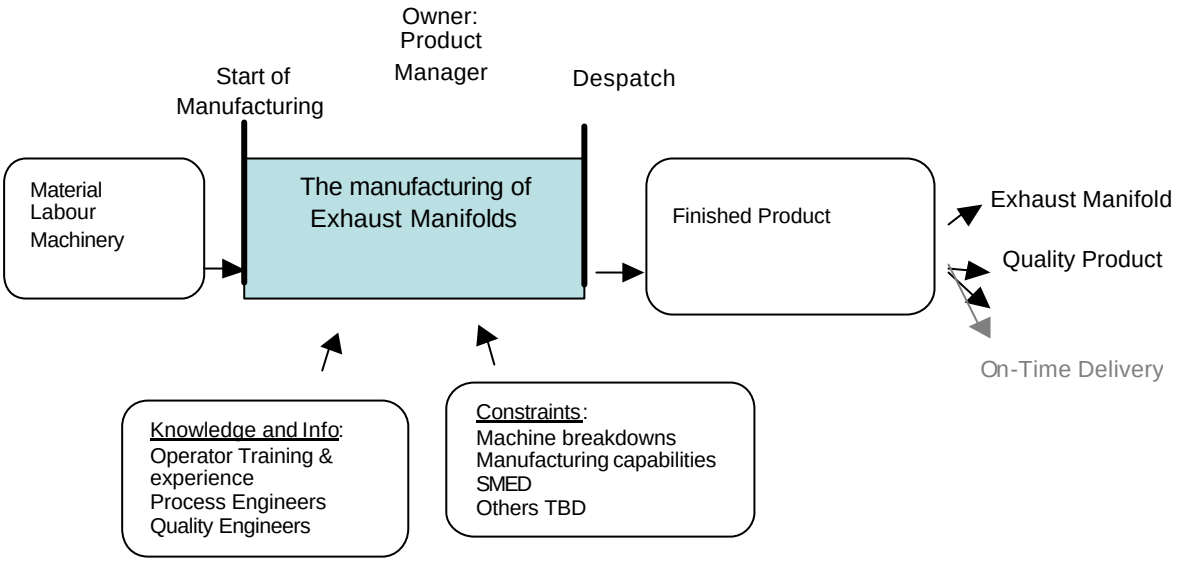

Figure 7: Bounded Exhaust Manifold Problem

4.2.3. Defining the value

In Figure 7 the output is valuable if the product specification of the Exhaust Manifold meets requirements, Note that *unneeded* outputs are waste. If an output is not "pulled" by the larger enterprise, it should not be produced! If outputs do not fall into one of the following categories stated in Figure 7,Quality, On-time delivery and competitive price they may not be needed.

The phase "On-Time delivery" may, especially in bottleneck processes, mean "as fast as possible." This is not always the case in FM, however. In a perfectly lean process, outputs would be handed off to downstream processes the moment they were needed. In FM case Exhaust manifolds are created before they are needed which sits in "excess inventory," with some risk that they will become obsolete before they are used.

Defective products will always result in rework for downstream processes; inefficient processes will always imply waste. These are not compatible with a goal for a lean process. Defects need to be interpreted in the correct context, however. Defective Exhaust Manifold products have mistakes or missed steps in them that cause unnecessary rework. A lack of defects in, say, development does not imply that the product or process specifications will not need to be revisited. It does imply these changes will be due to the increased knowledge that comes with manufacturing maturation, not due to avoidable mistakes in the development process.

4.2.4. Understanding the Value creation

As a product is transformed, each task increases the value that will ultimately contribute to the output package. In the exhaust manifold process value is created, but it is not realised until the process outcome is created. The value that is created is illustrated in Figure 8, although value is accumulating, it is very difficult to measure at intermediate steps. We've illustrated the value creation as the cycle time per machine, a total of 37.92sec per part. Currently an order takes 7 days to go through this process versus a total cycle time of 37.92 sec per part, we now get an understanding of the non-value-added time.

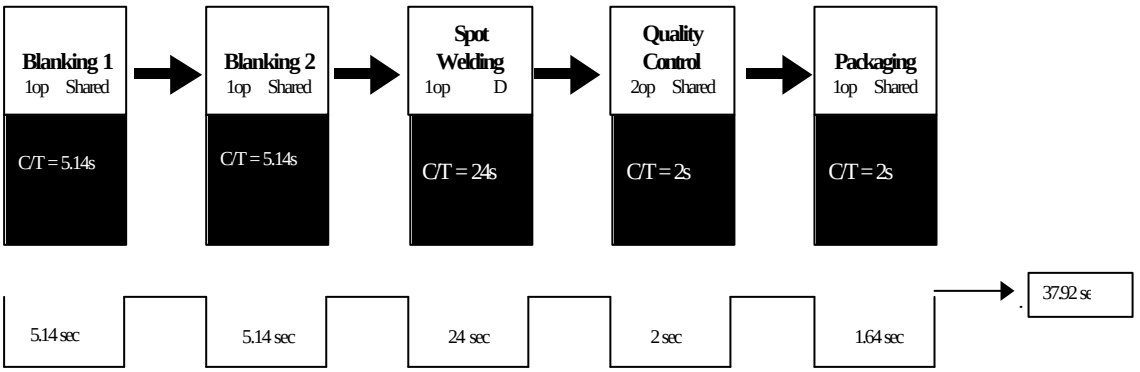

Figure 8: Value creation time line.

4.3. Mapping the Current state Value Stream

4.3.1. Current State

This section breaks down the process of mapping out a value stream into three basic steps: 1) Arranging the process steps (tasks) and information flows 2) collecting performance data on the tasks, and in some cases the information flows as well, 3) evaluating how value is created.

Womack and Jones (1996:37-43) advises, to uncover the true value stream, strap oneself to the product. Lacking a physical part to ride on, one must strap oneself to the work—the information package that starts with the process inputs and accumulates and transforms until it becomes the process output. Doing this will require some creativity. The team had enough time to follow the Exhaust Manifold through the process. The author found this process to be a lot easier and quicker.

On the other hand, Rother and Shook (1999:14) advise starting at the conclusion of the process (the shipping dock) and walking the line backwards. In practice, we found the need to trace the flow both ways because of complex flows with interdependencies and iterations.

4.3.2. Tasks & Flow

The Exhaust Manifold process is broken down into the following action tasks.

- Blank left hand side
- Blank right hand side
- Spot-weld the left and right hand side together
- Quality control
- Packaging

For the purposes of this research, a decision was made on how detailed the process breakdown was going to be. Excessively high-level breakdowns (not enough identified tasks) will not provide much insight into the process; excessively detailed ones (too many) will become intractable. The five identified tasks mentioned above will be both tractable and of sufficient depth to provide useful insight. The results of the first mapping step are presented in Figure 8. The blanking 1 task gets no input, which needs to be investigated. Quality control and packaging are concentrated near the end of the process. All possible rework paths are not shown on the map, as it would become too confusing.

4.3.3. Data

According to Theunis Lombard, Production Manager, FM (personal communication, 22 October, 2003), he suggested that we treat the mean values as estimates, and variations as rough estimates. The data will be affected by the act of observing and by the bias of the data takers. Quantitative data will probably exist in "small numbers," making formal statistical analysis dubious. If the data leads the research to the critical problems, it is adequate, and all the data pertaining to non-critical issues will be rightly ignored anyway.

The data collected that was collected by informal interviews appended to the value stream map using data boxes. This is illustrated in the Figure 9. The aim on the map is to include the data that will provide insight into the process, not simply to display everything.

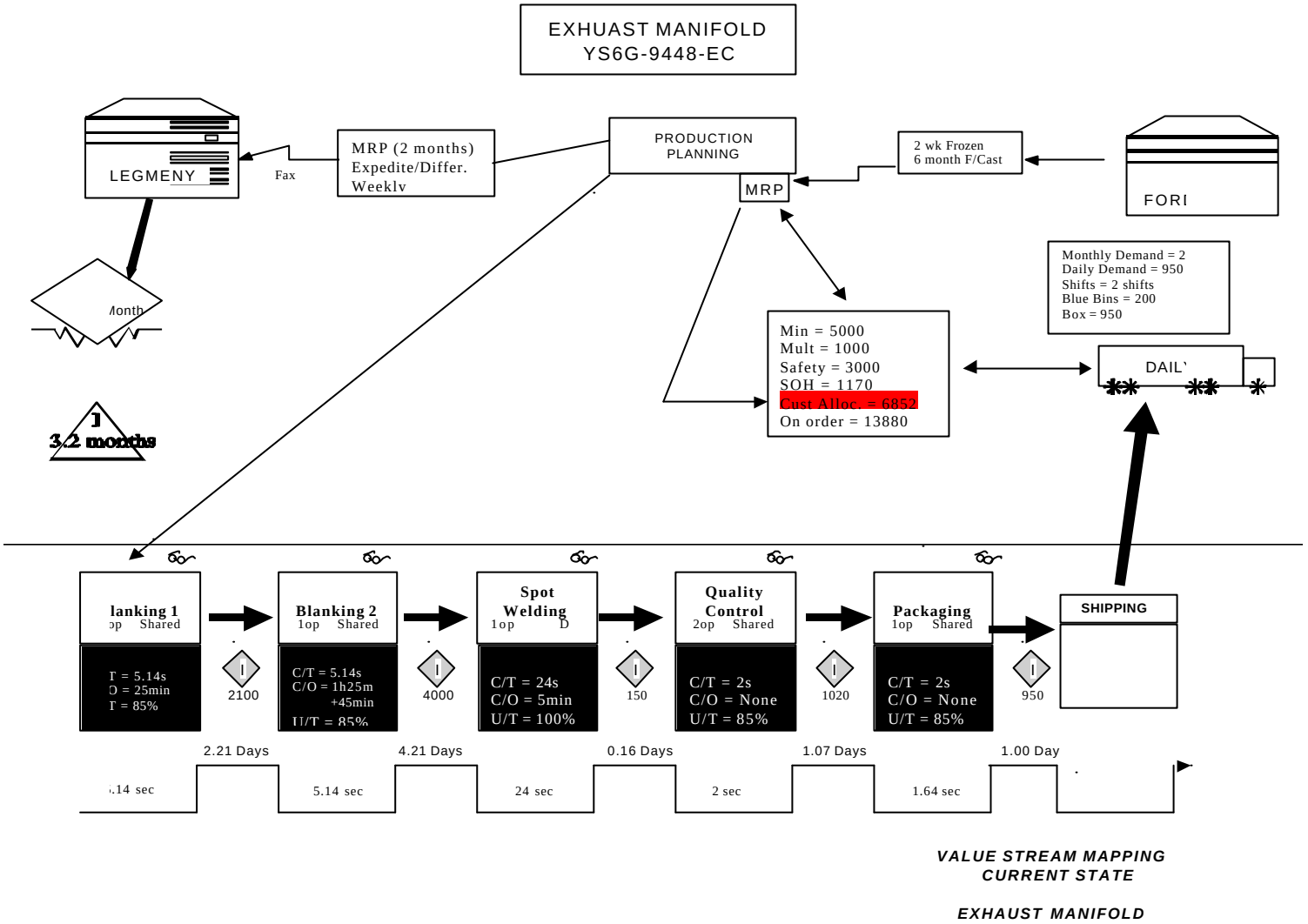

Figure 9: Current State Map

4.3.4. Evaluation of value and Identifying waste

Sales receives orders through Electronic Data Interchange (EDI) The repeat schedule is received on a weekly basis where FM customer sends through EDI their requirements for the weeks 2 weeks ahead and six month forecast. When an order comes in, business planning puts it in and estimates the date by which

they can make it. They rough-schedule it on the production units on a weekly basis. This schedule is sent out to the Rocam department so that it can be scheduled and produced. Business planning also includes making sure that enough raw material is available, in the observations there was 3.2 months of raw material. With the supplier delivering every month this inventory seemed way in excess of what was required. and that there is enough capacity on each unit.

This schedule on the operating side becomes the basis to monitor day-by-day and week-by-week increments again how well they are in accordance with the schedule. The schedules can then be updated further on an as-needed basis to daily or even bi-daily schedules. These are then used to push orders through the production facility.

On average, the customer demands for the exhaust manifold adds up to a total of 24000 parts per month. FM uses three types of transportation modes: truck, air, and sea. The shipments for this value stream are delivered by truck on a daily basis. The plant works on a single shift, 8 hours a day all year long except for major shutdowns and public holidays in all production departments except for Rocam, which runs two shifts in the need of urgent orders and the elimination of overdues.

All data for the current state map (Figure 9) were collected according to the approach recommended by Rother and Shook (1999). Data collection for the material flow started at the shipping department, and worked backward all the way to the blanking 1 process, gathering snapshot data such as inventory levels before each process, process cycle times, number of workers, and changeover times (the data can be seen in figure 9). Except for the inventory levels, all other times recorded on the current state map are based on average time. As shown in the map, inventory levels are very high for raw materials, 3.2 months and 12.31 days waiting between processes. This is due to the fact that the Blanking 1 and 2 produces faster than the spot welding can process them.

In fact according to the workers there, 60% of the exhaust manifolds are waiting an average of 2 days between those two processes.

The spot welding, which starts with the blanking 1 and 2 extends all the way through shipping (as indicated in the current state map), is the other part of the material flow. Here again the product is pushed through different processes (QC and packaging) until it is ready for shipping, which is the last process shown in the map. Looking at the current state map, the small boxes in the map represent the process and the number inside the box is the number of workers at each process. Also, each process has a data box below, which contains the process cycle time (CO). It should be noted that these data where collected while walking the shop floor and talking to the production manager in this area.

Looking at the current state map one observes that there are only one-inventory triangles ahead of some processes, one for the exhaust manifold products. The map doesn't indicate the other products that use the process in addition to the exhaust manifold products considered herein so that the total inventory is actually higher. After collecting all the information and material flows, they are connected as indicated by arrows in the map, representing how each workstation receives its schedule from business planning.

The first component is the production lead-time (in days), which is the sum of each inventory triangle before each process. The lead-time for one inventory triangle is calculated by dividing the inventory quantity into the daily customer requirements. For example, the lead-time for the inventory triangle ahead of spot welding is 4.21 days; this is calculated by dividing 4000 parts, which is the total inventory ahead of the spot welding by 950, which is the daily average demand rate for the exhaust manifold. The total observed production lead-time is 3.2 months + 12.31 days.

The second element of the timeline is value-added time (or processing time), which is 37.92 seconds. This cycle time for each process is the average cycle time, which is determined by using actual data form the company. Therefore, the percentage of value added time to the non-value-added time (lead- time) is approximately .001%.

The total change over time for exhaust manifolds is 2.6 hours. The need for a Set-up reduction program would surely eliminate the wasted time, but surely reduce the batch sizes and overproduction that is currently being experienced.

Chapter 5

5. Analysis and Recommendations: Future State Map

Describing and defining the future state map actually starts while developing the current state map, where target areas for improvement start to show up. Looking at the current state map for FM several things stand out: (a) large inventories, (b) the huge difference between the production lead-time (3.2 months + 12.31 days) and the value added time (37.92 sec), which is only about 0.002% of the total, and (c) each process producing to its own schedule. The goal of lean manufacturing is to aid in improving the satisfaction of customer requirements through the whole value stream. In the current state map we view inventory and lead-time as two equivalent things and try to identify lean manufacturing tools to drive them down and create the ideal state map. The basic philosophy is that the more the inventory, the longer any item must wait for its turn; therefore, the reduction of lead-time and inventory will expose and force other kinds of wastes to surface, creating the opportunity for their removal.

Reducing inventory and attaining on-time completion will automatically generate quality improvements. For example, reducing work in process will reduce the amount of defects to be repaired, which in turn will improve quality. Also less WIP means that tracing the root cause of a defect will be easier. In order to address these issues we follow a systematic procedure where we try to answer a set of questions. This allows one to come up with an ideal future state map that will help in trying to eliminate the different types of waste in the current manufacturing system at FM.

5.1. Takt Time

Question 1: What is takt time?

“Takt time” refers to the rate of production to the rate of sales to customers (Womack & Jones, 1996:55), i.e., the unit production rate that must be met to match customer requirements.

Takt time is calculated as follows:

$$\text{Takt time} = \frac{\text{Available work time per day}}{\text{Customer demand per day}}$$

The throughput required for the Exhaust Manifolds is an average of 19950 parts per month. Assuming that FM runs 21 days per month, the average daily requirement is 950 parts per day. FM only runs a single shift per day, which translates to 29100 working seconds per day.

The result is approximately 31 seconds takt time per manifold:

$$\text{Takt time} = \frac{29100}{950} = 31 \ \frac{\text{Sec}}{\text{Part}}$$

This takt time does not mean that a manifold has to be made in 31 seconds, but rather that one must be completed every 31 seconds on average. Customer demand is met in 31 seconds, but the process time is dependent upon the sum of process times at each workstation. For example, for a manifold that has to go through blanking at the beginning of the spot welding process every 31 seconds; however, it will take approximately 1 hour for the manifold to pass through all the workstations and finish processing. So every 31 seconds a manifold is taken in FIFO order at the start of the spot welding.

5.2. Finished Goods Supermarket

Question 2: Will we produce directly to the shipping or to a finished goods supermarket?

A "supermarket" is nothing more than a buffer area (space allocated for product storage) for products that are ready to be shipped, located at the end of the production process (Rother & Shook, 1999:47).

The shipping department can use a kanban signal to authorise the movement of the product from the supermarket. The amount of space designated would depend on the number of kanbans allocated to the supermarket. For example, each kanban is attached to a limited number of manifold trolleys or allowable space in the supermarket; whenever the inventory level in this space falls below a certain level it sends a signal to replenish the supermarket.

On the other hand, producing directly to shipping requirements means that only the units that are ready to be shipped are produced. Currently FM produces all the exhaust manifold products and sends them directly to a shipping area where they are stored with other products waiting to be shipped. However, this is done "on the fly" where products are stored based on a push system.

The manifolds can wait a long time in the warehouse before being shipped. Even though the manifolds are bulky, it is believed that FM should produce to a supermarket (warehouse); moving the manifolds is not a significant issue due to the existence of the manifolds being stored on moveable trolleys. FM should designate an area at the warehouse (which would be called the supermarket) and store the manifolds based on a kanban system. Whenever the supermarket inventory is below a certain level this would trigger the spot welding to schedule the blanked products to replenish the supermarket according to the pitch, which will be addressed in more detail in Question 7.

5.3. Pull System Supermarket

Question 3: Where will FM need to use a pull system supermarket inside the value stream?

A pull system supermarket is a system for “all seasons”, meaning that it can work in the manufacturing industry as well as any other discrete industry regardless of the scheduling restrictions encountered. As we will explain in the next question, FM is a continuous flow process by design, so that there is no need to introduce a supermarket, but the introduction of a supermarket is necessary mainly because these lines are shared resources (i.e., other products can use them).

FM will produce the manifold products to a finish-goods supermarket as indicated in Question 2. Once a shipment of manifolds is withdrawn from the shipping supermarket, the corresponding kanban is sent to the spot welding where it is placed in a load-leveling (or heijunka) trolley. This will be further addressed and explained in Question 7. Two additional supermarkets are needed to create a continuous flow, one before the Blanking 1 & 2, and the other before the spot welding process.

The first supermarket will be used ahead of Blanking 1. The bulk-store pushes raw material coils to the production line, which makes the inventory accumulate in front of the blanking operation. This line is a shared resource, so a kanban pull system will be used to regulate the replenishment of this supermarket. The pull system requires a customer and suppliers (Rother & Shook, 1999:48). The customer here is the blanking and the supplier is the bulk-store. A pull signal from Blanking 1 (addressed in Question 7) is utilised here to move the kanbans (essentially a coil for each kanban) from the supermarket to blanking.

The same pull signal will be sent to bulk-store to replenish the supermarket whenever the number of coils in the supermarket drops to a trigger point.

The second supermarket is designed to stabilise the production of the manifold products in the spot welding area. The inventory between Blanking 2 and spot welding is large and both workstations are shared resources. Also, FM runs its schedule in batches according to economic batch quantities (EBQ), so it is necessary to set up a supermarket to accommodate schedule changes. A kanban pull system will be used to regulate the replenishment of this supermarket. One should note that whenever the supermarket is full, the blanking 1 & 2 could run other products so that it is not idle. Also, blanking 1 & 2 no longer receives a schedule from business planning for the exhaust manifold products.

The last supermarket will be placed behind spot welding, quality control (QC) and packaging. This supermarket is made up of finished product which is packaged and ready to be shipped. Once product is shipped a withdrawal kanban signal will be used to trigger spot welding, QC and packaging to replenish stock. This will then signal blanking 1 & 2 to build and the same signal will be sent to the bulk-store to issue raw material to restock the supermarket.

Please refer to Figure 27 (the Future State Map) on page 137 for the location of each of the above supermarkets. The supermarkets or the kanban system that will be used will enable FM to reduce its inventory and as a result, its lead time. The working conditions for the kanban system are simple though effective. For example, the blanking operation (supplier) is allowed to process the next coil in line as long as there is an empty trolley spot in the supermarket before spot welding. By definition, if the supermarket is at its capacity then this means that the spot welding does not need blanked parts. In this case there are two things that can be done; either the blanking line should slow its production rate to match that of the spot welding or it should be halted.

The second option is costly in a manufacturing environment. Therefore in this case what can one do? Of course, the supermarket is only designed for the manifold products and in the following questions we will address how a production order will be released and the time increment at which those orders will be released. The answer to the question is that if the supermarket is full the blanking line can be switched to satisfy other product types until the time of the next order for the manifold product is reached. In doing so we prevent producing more than the capacity shutting down the blanking line.

Our next step is to decide how each supermarket that is controlled by a kanban pull system should look. First, a simple rule is that manifolds are not allowed to be piled on top of each other, nor are they allowed to be placed on the floor. Each manifold must be placed on a specially designed trolley, where the number of trolleys depends on the number of kanbans for that supermarket (the number of kanbans will be addressed in Question 7).

Requiring every manifold in a supermarket to be on a trolley puts an upper limit on the amount of inventory in the supermarket and in turn, lead time will go down. If inventory is limited to a predefined number of trolleys (kanbans), the space between manifolds will be increased and thus handling damage, which is one of the most common types of defects in a manufacturing environment, will be reduced. Also, when lead time goes down, this means faster delivery and more satisfied customers. Besides reducing the number of defects on the shop floor, the supermarket will speed up the discovery of defects, and thereby the probability of finding the root cause of a defect early in the process will increase. It is very critical to discover the defect early, particularly in the manufacturing industry, because as a product moves downstream in the process, more value is added to it and discovering the defect late can be very costly. Another benefit of the supermarket is that it provides a visual means for the people on the shop floor to control the inventory and take immediate action if unexpected things

happen. It is clear that a kanban controlled supermarket system can unveil many types of waste that exist on the shop floor, so that remedial action can take place to reduce or eliminate these wastes.

5.4. Continuous Flow

Question 4: Where can continuous flow be used?

The manufacturing assets at FM are such that they can easily be moved into the classical cellular arrangement and batch sizes are often variable. However, the gasket manufacturing industry itself is based on continuous flow manufacturing. Aside from the non-restriction that FM does lend itself to cellular flow, the different cycle times and down times of the workstations make it difficult to introduce a continuous flow (see Figure 10). Also, many of the workstations are restricted to different schedules depending on product type so that it is unrealistic to join these workstations at exhaust manifold line to obtain a continuous flow. Therefore, developing a flow is not the issue. Rather, developing a system to enable pull by the customer should be the focus.

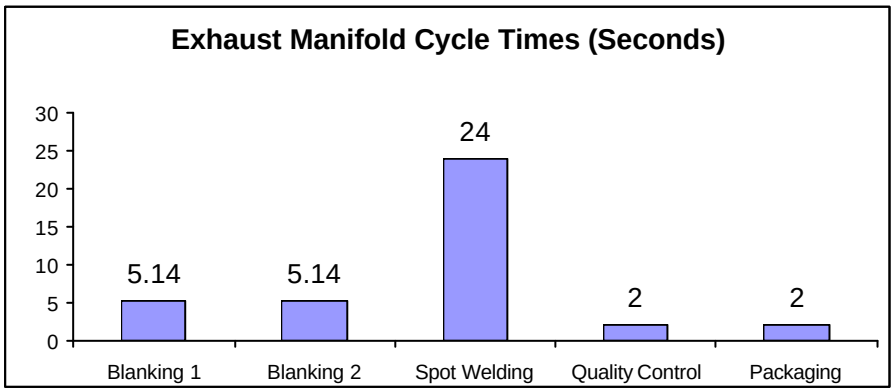

Figure 10: Exhaust Manifold Cycle Times (Seconds)

The introduction of supermarkets that are controlled by a kanban system forces the whole production line to pace every workstation to the speed of the bottleneck, which is the spot welding process with the longest cycle time of 24 seconds. It was observed that three operators were required to perform the task of spot welding, QC and packaging. These tasks can now be done with one highly trained operator performing the 100% inspection and packing the manifolds directly into the boxes situated next to the spot welding machine. Not only will this improve the flow, but reduce the waste in double handling, labour and inventory between operations.

An average time check with the combined operation (spot welding, QC and packaging) brings the total cycle time to 27.62 seconds. Although spot welding is the bottleneck operation, the total cycle time (27.62 seconds) is below the required takt time of 31 seconds, making it possible to introduce the improved continuous flow process.

It was explained in the previous question that whenever the supermarket between the blanking 2 and spot welding is full, the blanking line could switch to making other product types. This is true for all supermarkets in the system. By doing so, we are creating continuous flow and trying to maintain this flow by switching to other products which, by definition, means that no machine is stopped and no product is waiting. The manufacturing workstations are required to communicate and synchronise like never before, shifting the focus from optimising individual processes to optimising the manufacturing operation.

5.5. The Pacemaker

Question 5: What single point in the production chain (the “pacemaker” process) should FM schedule?

To stop over-production at any workstation in the value stream, only one point in the supplier-to-customer value stream needs to be scheduled. This point is called the pacemaker process, because this point sets the pace of production for all the upstream processes and it ties the downstream and the upstream processes together. Every workstation upstream produces by a pull signal from the next downstream process and flow downstream from the pacemaker must occur in a continuous manner. The pacemaker process is usually the most downstream continuous flow in the value stream, so there should be no supermarket downstream of the pacemaker process (Rother & Shook, 1999:49).

In the future state, a heijunka box or level loading box (Rother & Shook, 1999:53) will be placed near the spot welding. Kanbans will be inserted in the box coming from business planning according to the planned schedule. The schedule is determined according to a production sequence for the manifold products. The production sequence to match the daily demand will be explained in the next question.

5.6. Production Leveling

Question 6: How should FM level the production at the pacemaker process?

The basis for addressing this question is to distribute the production of the three annealing processes uniformly over the production time at the pacemaker process. This means that several batches of the same sequence must be scheduled. This will allow FM to avoid long lead times, large amounts of in-process and finished goods inventory and quality problems, and in general, avoiding wastes related to over-production.

FM manufactures three variations of rubber coated multi-layered steel manifold products. They are 1.3 (A), 1.4 (B) and 1.6 (C) (variations in capacity for Ford Rocam engines). FM should send a schedule to the pacemaker process (spot

welding) that would ensure making every part at a constant rate. A formula will be used (Monden, 1993) that determines the product sequence that levels the mix and has a constant rate for the three different products. The formula is:

$$D_{ij} = (j = 0.5) * (T \,.\, D_i) \qquad I = 1,2,\ldots,n \text{ and } j = 1,2\ldots D$$

Where:

n = the number of different products to be made.
D_{j_i} = the integral number of units demanded per day for product i.
T = D1 + D2 + …. Dn be the total number of units of all products to be made.
J = the index for the job (unit) of product I.
Dij = ideal completion or due date for the job (unit) j of product I.

For our case n=3, Di which is the average daily requirements for the exhaust manifold products are 145 (A), 950 (B), and 150 (C). Thus T is equal to 1245. Ordering theses jobs according to Dij one can see a pattern start to develop, yielding the following schedule (B,B,B,B,B,B,B,C,A)- (B,B,B,B,B,B,B,C,A)…etc. This schedule is the optimal sequence to smooth production.

5.7. The Pitch

Question 7: What increment of work (the “pitch”) will be consistently released to the pacemaker process?

Depending on the sequence determined by the last question, how often should be release and withdraw (the “pitch”) the increment of production from the pacemaker process? The pitch is the basic time unit of the production schedule for a product family. In other words, it is the material transfer interval at the pacemaker process. The pitch is calculated by multiplying the takt time by the

finished-goods transfer quantity at the pacemaker process. Table 2 shows the number of kanbans required.

Product	Daily Demand	Transfer Lot Size	Required Number of Kanbans
A	145	145	1
B	950	190	5
C	150	150	1

Table 2: Number of kanbans required by product:

Given the takt time of 31 seconds, and considering that the transfer lot size is 1245 parts, the pitch is approximately 485 mins. This means that FM will perform paced release of work instructions according to the pitch and paced withdrawal of finished goods at the spot welding. This means that the material handler will arrive at spot welding and remove the required kanbans from the load leveling box (the next increment of work) of the spot welding and move the just finished parts from the previous pitch to the shipping area supermarket (two day's worth of inventory will be available in the future state map in the shipping supermarket and this can be adjusted as needed at FM).

5.8. Process Improvement

Question 8: What process improvement will be needed to achieve the future state design?

In order to accomplish the material and information flow envisioned by FM, improvement actions must take place to implement the future state. It is unrealistic to expect to obtain the benefits of the supermarket, kanban control, takt time, the pitch, production leveling, continuous improvement and other

changes discussed in the previous question without process improvement steps involving specific lean tools.

The following sections address which lean tools are feasible to implement at FM in order to achieve the desired gains and the future state map. The lean manufacturing tools appear as "kaizen bursts" in the future state map.

5.8.1. Setup Reduction

Setup reduction at different workstations is one of the major tools that FM must implement. The changeover times required at different Rocam processes at FM are shown in Table 3. Changeovers take place at two workstations as shown in the table.

The SMED workshop was conducted in the Rocam area, for all areas and not just the exhaust manifold area. Some of the critical findings in the area were that machinery consists of mechanical presses and hydraulic presses.

Currently the average setup times are:

Machine	Setup time (Min)
Mechanical Presses	27.48
Hydraulic Presses	26.53

Table 3: changeover times required in the Rocam Area

Efforts were focused on the mechanical presses. The objective was a 25% reduction on setup time. In order to achieve this, provisions were made for an in and out square by each of the mechanical presses. This permitted better

workflow and cut down on waiting time before the next tool was loaded. After monitoring, the new setup time was found to be:

- Mechanical Presses = 17.85 minutes.

This indicates a 35% reduction in the setup time for the Rocam area.

After the initial implementation, a secondly workshop and training session were conducted on the 4th and 5th November 2003. Video footage was taken of a common setup, which allowed us to study current procedures and actions. Through operator awareness, commitment and an ongoing focus on setup time reduction from the operators, further studies were done on setup time in the Rocam area. With the awareness that was created, the following areas have been streamlined:

- Preparation of all parts needed for setup prior to commencing setup (focus on external setup).
- Conducting parallel setup procedures between two operators.

Setup times were measured again:

1. Setup Time (Toss 2 on 20/11/2003) = 15.50 minutes
   Removed 1.3 exhaust manifold, loaded 1.6 exhaust manifold

2. Setup Time (Toss 1 on 21/11/2003) = 11.20 minutes
   Removed 1.4 exhaust manifold and loaded Arvin corrugating tool

This indicated a further 37% reduction, but currently there is no consistency and in order to standardise the changeovers for the different processes at FM, the following steps are suggested:

9.1. Separate the external and the internal setup. The goal is to divide tasks that can be accomplished while the machines are still running (external setup) from the tasks that must occur when the machine is stopped (internal setup). For each changeover operation, a checklist including every single item necessary for running the next operation such as tools, necessary workers and standards, is documented. Then it is determined what must be done when the machine is stopped (internal) and what can be done while the machine is running (external). For FM, this means preparing the next tool to be placed next to the machine while it is running. The next tool to be setup must be polished, hoses and wires must be placed on it, and bolts must be prepared. Rather than waiting to do this wile the machine is stopped (internal setup), we suggest carrying out those activities while the machine is running as an external setup.

9.2. Use an automatic roll changer for the raw materials; currently at FM the changeover for raw material rolls is done manually by using a fork truck that takes most of the time spent during the movement of the rolls. A suggestion is to use an automatic roll changer, which will place the roll on a panel and move it from the raw material kanban to the required machine. Using an automatic roll changer can cut a lot of the time involved in the changeover.

9.3. Transporting of parts and tools to the machine should also be identified and reorganised. These can be externalised, cutting the time even more, meaning that tools and parts can be gathered while the machine is still running, whereas previously they were gathered after the machine was shut down.

9.4. Finally, preparing tools should be ready to be placed on the machine adjacent to the process. For example, if a tool is to be placed on the Toss

press next, the tool must be within a short distance of the Toss press. This means bringing the tool from the tool store before the machine is stopped.

5.8.2. Total Productive Maintenance (TPM)

One of the major causes of machine breakdowns is the lack of a total productive maintenance program. Many factories do not have the luxury of replacing equipment due to the high cost involved. Manufacturing environments often load their equipment to maximum capacity, leaving long times between necessary regular maintenance. For example, at FM a schedule shutdown is every two months, to carry out maintenance activities in the Rocam department. Table 4 shows planned maintenance times for the Rocam department at FM. The longer the time interval between scheduled maintenance, the higher the probability of having machine failures, and thus the higher expected number of quality defects. Table 5 shows the distribution of failure times at FM. If any of the mechanical or hydraulic presses is down due to a breakdown, this would be very costly, not only because orders have to be backlogged, but this cell is dedicated to an OE customer who has severe line stoppage penalties.

PRESS	Maintenance Uptime (min)	Maintenance Downtime (min)
WALSCH	86400	240
WILMAC	87840	240
REEF	43200	240
TOSS	43200	240
SpotWelder1	44640	240

Table 4: Maintenance time for the Rocam Department

PRESS	Unplanned Uptime (min)	Unplanned Downtime (min)
WALSCH	20160	120
WILMAC	20160	120
REEF	24480	1440
TOSS	14480	180
SpotWelder1	20160	60

Table 5: Failures time distribution for the Rocam Department

Another problem that exists is the length of the down periods. Having extensive down times due to scheduled maintenance will cause disruption to the whole process. The success of the kanban pull system heavily depends on the reliability of the equipment. In the future state design, a pitch of 485 minutes was determined to release kanbans to the system, and a scheduled maintenance period of, say, 4 hours, is going to disturb the flow of the system. Therefore, in a lean manufacturing environment, machine downtime becomes an intolerable situation requiring a different approach for maintenance. In order to avoid all the havoc that can be cause by machine failure and long downtimes, the following TPM activities are suggested:

10.1. Split scheduled maintenance. Splitting the scheduled maintenance time means separating the maintenance process into small portions that are done more frequently. For example, instead of scheduling one 4-hour maintenance period for the Toss press every two months, we would like to accomplish the same amount of work in 1 hour done every 2 weeks. By doing this, we would eliminate minor abnormalities in the equipment conditions that are usually overlooked and delayed for a long time. Also,

we would have less frequent failures, improve machine uptime and eliminate costly overhauls.

10.2. Each individual unit requiring maintenance must be sequences so that the inventory shortages created by shutdowns flow down through the process. For example, maintenance on the spot welding causes the kanbans in the supermarket ahead of shipping to be depleted. Therefore, maintenance is then performed on the blanking 1 & 2, permitting the spot welding line to replenish the supermarket ahead of shipping.

10.3 Schedule unplanned downtime as needed. Rather than looking at a calendar and assessing what attention the equipment needs, FM should examine the 'vital signs' and infer what the equipment is trying to tell us. This can be done through constant monitoring, reliability analysis and condition measurement. First, a simple visual observation during machine run time at a predetermined time period can be done at each workstation. Checking a list of items such as machine cleanliness and machine speed can be done. For example, if the blanking line is not running at its normal speed, the line must be stopped and the problem must be investigated. Secondly, reliability analysis can be carried out by collecting data on machine failures and downtime and analysing failure frequencies for each machine. Lastly, condition measurement implies attaching sensors and devices such as vibration analysis equipment and calibration devices on each machine that can detect anomalies. Some critical parameters of each machine can be measured and compared to standards. FM should focus on processes that have more than resource to schedule unplanned downtimes as a start, so that manifolds would not be backed up.

5.8.3. J.I.T.

In order to achieve the full benefits of the supermarket kanban system, FM should utilise the Just-In-Time pull system.

The kanban system explained in Question 3 is based on utilising a pull system for the exhaust manifold products. The procedures necessary to implement the kanban pull system are simple yet powerful in maintaining efficiencies with minimum inventory. The basic idea is that we are only responding to FM's actual customer demand for the exhaust manifold product family. The following steps are required at FM to implement JIT:

11.1. A work centre may produce a part only when a "downstream" work centre signals its need. At FM, the pitch will control this signal. Small amounts of work will be released from the spot welding according to the kanbans in the load leveling trolley and at the end of the day, all actual customer demand is satisfied.

11.2. Effectively, the kanban signal released from the spot welding, pulls parts through the system. Control is maintained by adding and removing kanbans from the load leveling trolley, thereby controlling the amount and type (essentially exhaust manifold product) of WIP held between work centres.

11.3. If any given supermarket has the right amount required by the pitch, then there is no need for the process upstream to produce. Essentially, the parts will be pulled from the supermarket that will allow the upstream product to satisfy other types of products.

For further research, which is beyond the current scope of this research project, it will be useful to use a simulation tool. To evaluate the benefits gained by

implementing the above three tools (setup reduction, TPM and JIT) at FM. The simulation will provide the level of inventory and lead time for the future state map The future state map will no longer be just a snapshot, but a moving picture and simulation model offers outputs that are hard to obtain with only value stream mapping.

5.8.4. 5S

5S is a key component to any lean implementation, complementing all the other tools and helping to eliminate waste. 5S is now seen as widely applicable concept regardless of industry or size of company. 5S can be used to tackle problems without requiring additional engineering and expertise and are practical and simple methods to engage employees in organisational improvement. We can speculate on the benefits that can be gained by implementing this tool in support of other lean tools that have been proposed earlier.

There are two major areas at FM that can use 5S – the shipping area and the packaging area.

While touring the facility, it was observed that the driver of the fork truck has to make occasional stops to remove rolls of plastic packaging that were blocking the way. It was also observed that sometimes when the material handler is ready to pick up the part from the packaging area to move it to shipping, he finds out that it is not the right part.

At the other end of the Rocam Department, the current tools for the blanking 1 and 2 are completely disorganised. Tools scattered all over the place. Here, a 5S program is proposed to designate an area for the tools used in the blanking operation.

First, 5S for the tool and packaging area at the shipping warehouse and blanking area will be explored. The first element of 5S is Sort. Good housekeeping starts with sorting those items that are important from those that are not relevant to the working areas. At the shipping and packaging area only tools that are needed in the packaging operation should stay there; this includes plastic packing and tools used in the packaging operations. The same thing applies to the blanking area where broken fixtures and unnecessary tools should be removed. A good start is to get rid of anything that is not going to be utilised for the next 30 days.

The second element of 5S is Straighten. Straighten involves having order in the workplace and less congestion so that every activity can be performed freely with minimum time. After all unwanted items are moved, the next step is to organise the items that are needed in the best way possible. First of all, at the shipping docks tools and packaging materials should all have a well-defined and designated area for placement. This area should be within reach of the workers so that items are available when needed, and it should be outlined clearly by painting a rectangle around it. Items that have a designated storage place must be labeled with the name and a return address on the label so that they can be brought back to the proper place. The same thing applies to the blanking area as well. Tools must be placed in an area very close to the machine so that they can be transferred quickly whenever a changeover is needed. All tools must be labeled.

Sustain is the third element of 5S. It has to do with cleaning the working environment so as to sustain the improvement. Cleaning includes items such as machines, tools, rolls, jigs, fixtures, floors and walls. Dirt, oil and stains should be wiped off from machines. When touring the FM shipping area, the place looked cluttered and dusty. Cleaning should be carried out on a daily basis. By cleaning jigs and fixtures, sources of malfunctions such as broken covers or loose nuts can be uncovered and immediate action can be taken to fix these problems. Cleaning responsibilities should be assigned to different workers to

make cleaning a team effort. To prevent dirt from getting into tools, rolls, jigs and fixtures, simple actions such as covering around cords, legs of fixtures and tables can be done to make the removal of dirt easier.

The fourth element of 5S is Systematise. Systematise means continuous work on the previous three 5S pillars. Kaizen efforts in the workplace do not end if they have been implemented once or twice. Rather, it is a continuous improvement effort. Procedures should be set up to ensure that employees are working on Sort, Straighten and Shine. How can this be done at FM? A team of two people can be assigned to the shipping area and the Rocam area to conduct weekly audits to see if every 5S initiative is being followed. At the startup of a new initiative, it is always difficult to obtain results right away; so it is important to develop a checklist or assessment sheet to follow upon these initiatives. A 5S assessment sheet developed for all areas at FM is shown on Appendix D. This checklist sheet can be used to evaluate the current status of a 5S program at FM on a weekly basis and corrective actions and improvement can be taken accordingly.

The last element of 5S is Standardise. Standardise means to sustain and adhere to 5S standards. Managers should set standards and make everyone follow them. People should be held accountable at the shipping area and Rocam area for carrying out 5S actions. 5S does not promote adding extra people to the shop floor, but it requires that existing workers at each area carry out these tasks and make practicing 5S tools a habit. Also, in order to see the improvement, people at FM should be encouraged to take before and after photographs that recognise the difference and provide more motivation.

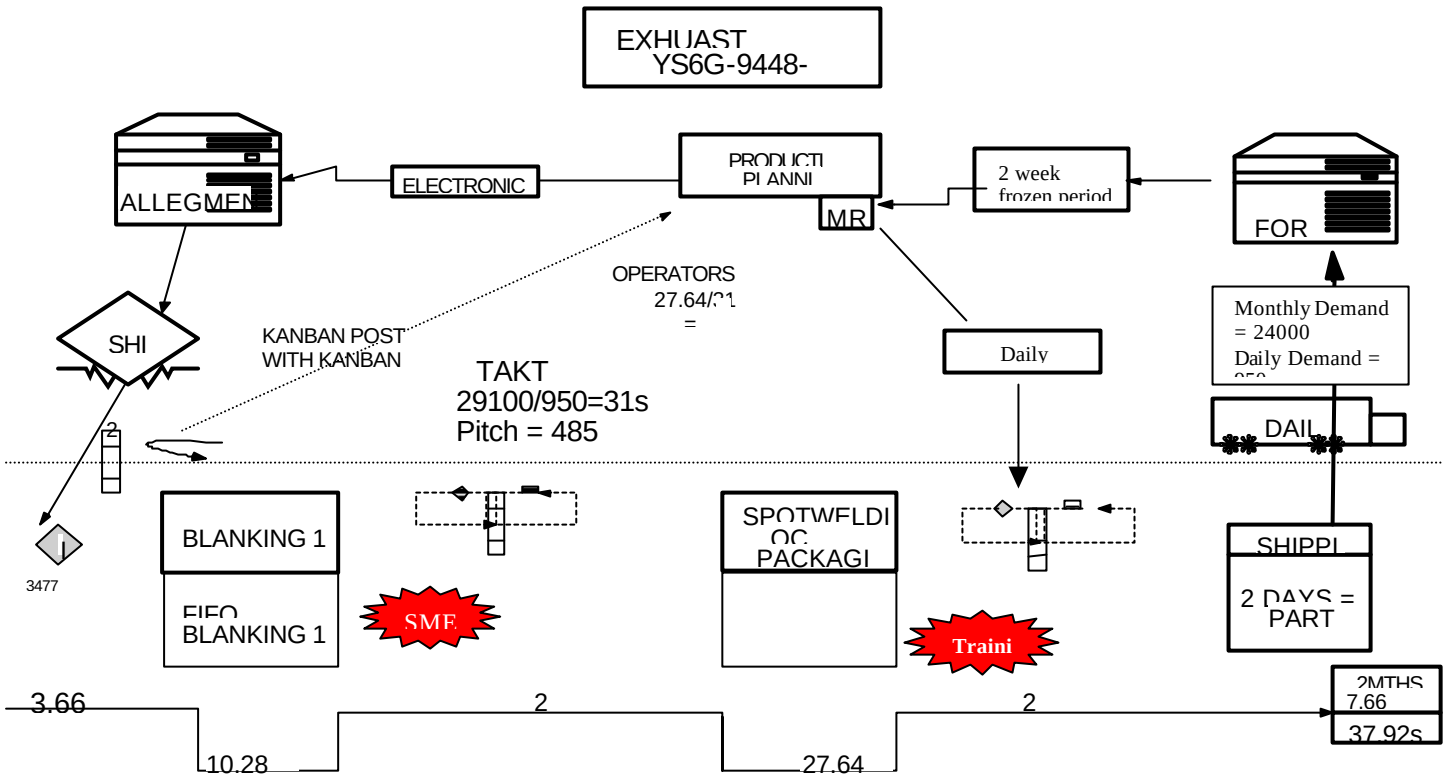

Figure 10: Future State Map.

5.9. Achieving the Future State Map

The future state map for exhaust manifold product is shown in figure 10. The results of the questions answered above are documented on the future state map. Also on the map, the proposed lean tools that where discussed are shown as kaizen bursts to highlight the improvement areas. Also shown are the supermarkets between each process. With the new improvements at FM the percentage of value added time (37.92 sec) to the non value added time (7.66 days) is 0.02% for the future state.

Note that the starting lead time in the current state map was 3.2 mths + 12.31 days. The future state map reveals that there's been an improvement of 1 month and 4.65 days in inventory. The value adding time on both the current state and future state is 37.92 seconds. The number of operators was reduced from 6 operators to 2 operators

Currently the Takt time for the process = 31 seconds (effective working time per shift/customer demand per shift, 29100/950). The pitch for the process equals 485 minutes (Takt in minutes x pack out quantity). From this you we conclude that:

Operators required = process time/Takt time.

- For Blanking 1 & 2

10.28/31 = 0.33, therefore you require 1 operator.

- For Spot-welding, inspection & packaging

27.64/31 = 0.89, therefore you require 1 operator.

This indicates that current labour force of 6 could be trimmed down. From the calculation it can be deducted that only 2 operators are adequate. One for Blanking and one for spot-welding, inspection and packaging.

Chapter 6

6. SUMMARY AND CONCLUSIONS

In this chapter, we summarize the key aspects of this research are summarized and conclusions are provided. The future possible directions of this research are addressed and are offered for the work.

6.1. Summary of the Research

In this research the use of lean manufacturing tools and techniques in the manufacturing industry are addressed and in particular the automotive component industry as represented by FM. In order to identify opportunities for implementation of lean methods value stream mapping was used as a tool. In particular, at FM it was used to identify various types of waste in the value stream of the company and to try and take steps to eliminate them.

The current state map was developed by mapping all the information and production flow at FM. All the data for the current state map was gathered on site (at FM); this included machine cycle times, inventory numbers, setup times, and information flow data such as how often customers placed orders. The map was studied and target areas for improvement were identified to eliminate the waste revealed by the current state map at FM. Procedures were then developed for adapting lean manufacturing techniques such as kanban pull systems, TPM, setup reduction, and 5S to help in reducing the wastes and developing a future state map.

6.2. Conclusions

The main goal of this dissertation was the use of value stream mapping to map the current and future state for FM and identify waste in a specific product line.

The main problem was addressed as he current state map for FM revealed a huge amount of waste represented by excessive inventory and large production lead-time. The link between the current state map and the unveiling of waste was very clear. The literature explained and demonstrated a universally applicable method to view the value stream and identify areas of large inventories, long lead-time and lack of pull systems used by FM to satisfy a typical customer. Value stream mapping is a valuable tool in any lean manufacturing effort and can unveil all the wastes in the entire value stream and not just portions of it. For those in the manufacturing industry who want to start the lean journey, it is the ideal starting point. Value stream mapping can systematically guide the manufacturing industries to see the waste in their value streams and identify the lean tools that best fit their environment.

The measure of success of value stream mapping in this research was address on how one could eliminate the wastes identified by the current state map and come up with the first version of a future state map. This was done by answering a set of structured questions, so as to develop the future state map. Again, these questions could almost all be applied to any continuous environment. The results indicate that FM should integrate the customer into their production system according to the customer takt time, and can then try to practice kanban pull systems production leveling, and paced withdrawal wherever possible in order to achieve potential improvement in the value stream.

The findings of this research demonstrated potential gains in different areas at FM. It is worth mentioning that there could also be some limitations and potential barriers to implementing the different lean tools addressed in this research. These vary from issues like the workers might resist changes to their current work environment; a simple reason for this is the statement “this is the way we always do business.” Another barrier might be in reducing the number of maintenance workers for the proposed TPM program. Again, the union contracts might not allow for getting rid of or reducing the number of maintenance workers.

Additional limitations of value stream mapping that where encountered during this research is listed below:

- Lacks any worthwhile economic measure for “value” (ex. profit, throughput, operating costs, inventory expenses).
- Lacks the spatial structure of the facility layout layout, and how that impacts inter-operation material handling delays, the sequence in which batches enter machine queues, container sizes, trip frequencies between operations, etc.
- Fails to consider the allocations and utilization of an important resource – factory floorspace – for WIP storage, production support, material handling aisles, etc.
- Fails to show the impact on WIP, order throughput and operating expenses of in-efficient material flows in the facility ex. backtracking, criss-cross flows, non-sequential flow, large inter-operation travel distances, etc.
- Lacks the capability, due to the manual process of creation, for rapid development and evaluation of multiple “what if” analyses required to prioritize different alternatives for improving a Current State Map when time and/or budget constraints exist.

In conclusion, the primary focus of this research was how value stream mapping can used as a tool to identify waste in an organisation, with a focus on automotive components. It was shown that value stream mapping is an ideal tool to expose the waste in a value stream and to identify tools for improvement. It was also illustrated by the help of lean manufacturing tools can greatly reduce wastes identified by the current state map. The development of the future state map is not the end of a set of value stream activities. It should be stressed that the value stream should be revisited until the future becomes the present. The

idea is to keep the cycle going because if sources of waste are reduced during cycle, other wastes are uncovered in the next cycle.

6.3. Future Possible Research

The value stream mapping in this work was conducted by focussing on the exhaust manifold family at FM. So a natural extension of this work is to map other product families in the value stream. It is speculated that by mapping other product families, FM can further expose other types of wastes in the value stream. It is also important to investigate how the synchronization of the pull systems for different product families could be best accomplished.

Having mapped a single firm's value stream, another possible extension of this work would be to extend the current state map to integrate the suppliers and major customers. By doing this a full integration of the entire supply chain for FM could be achieved. Even though FM owns its own raw materials, there were huge amounts of raw material at the facility indicating that if the suppliers are integrated into the mapping activities better coordination can be accomplished.

As far as customer integration goes, FM should focus on one of its major customers and try to include it in the current map. Although, the mapping activities developed in this work are from the customers' perspective, the inclusion of the customers' value stream in the current state map would mean full customer integration.

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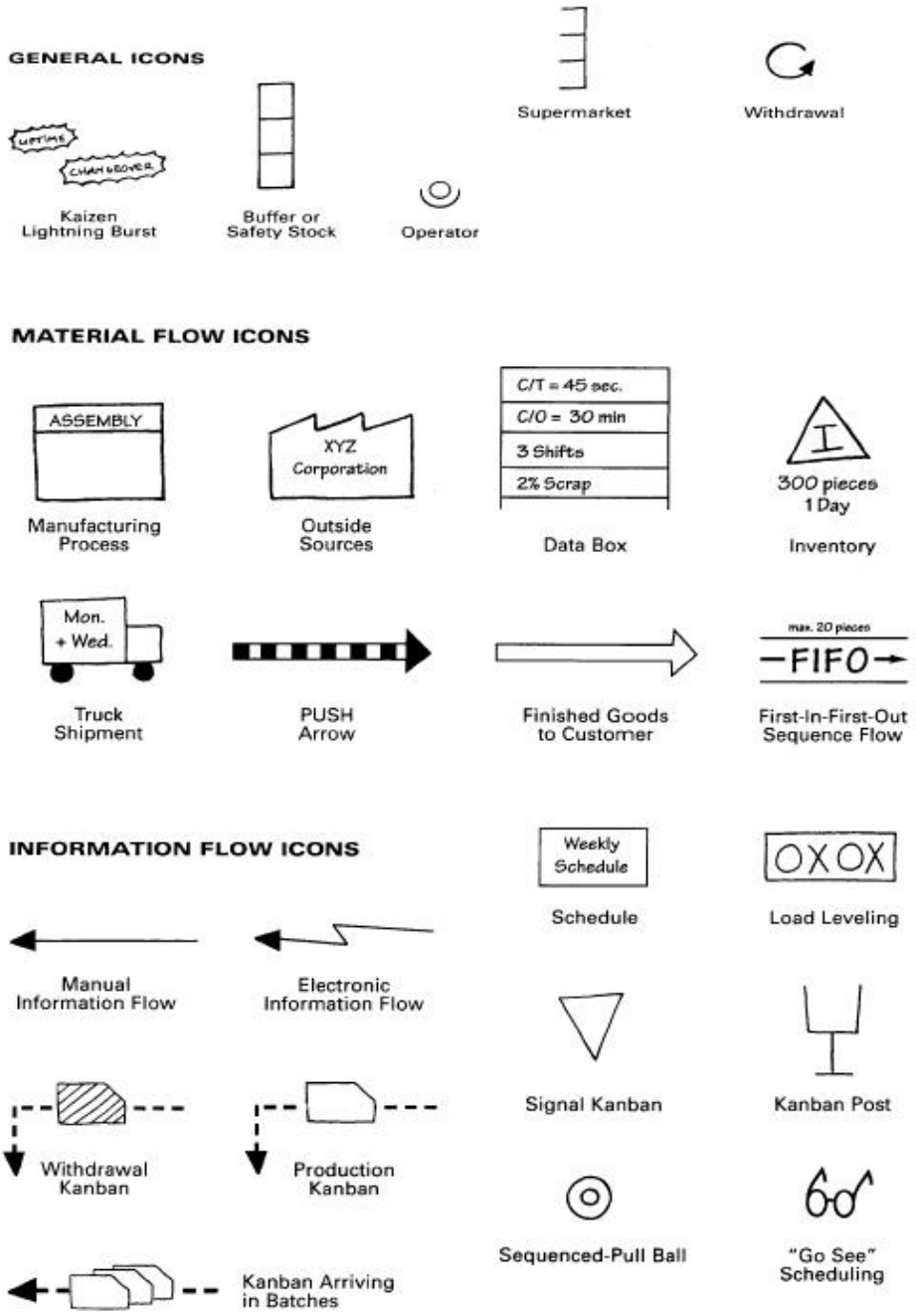
Appendix A

Value Stream Mapping Icons



Source: (Rother & Shook,1999)

Appendix B

Value Stream Implementation Plan

Revised Date:	24/11/2003
Facility Manager:	JC de Villiers
Lean Manager:	PJ Fry

Lean Manufacturing: Roll out Plan

Product Family	Exhaust Manifold YN2G-9N454-AC

NO.	Focus Areas	Objectives	Goals (Measurable)	Monthly Schedule 1	2	3	4	5	6	7	8	9	10	11	12	Resp.	Related Individual & Dept.	Review Schedule: Reviewer	Review Schedule: Date
1	5S (Housekeeping)	5S Training	Monthly 5S Audits in Manufacturing & Office Block													Completed		B.Barnes	19-May-03
2	Value Stream Mapping (VSM)	VSM Training	1. Executive Training 2. Office Training 3. Factory Training													D. van Rossum PJF/JS PJF/JS	Ind. Eng. Ind. Eng.		
2a	VSM (Exhaust Manifold)	Loop 1: (Blanking) 1. Create 1pc flow by Combining Blanking 2. Implement visual guides for supermarket 3. Reduce Setup Times (SMED) 4. Determine the required no. of operators	Loop 1: 1. Kanban pull system between blanking and spotwelding 2. Visual aid 3. Setup time reduction >= 25% 4. Takt time calculation													TL & VSM Team	Rocam	JS	16-May-04
		Loop2: (Spotwelding) 1. Provide training 2. Implement visual guides for supermarket 3. Determine the required no. of operators.	Loop2: 1. Waste Training 2. Kanban pull system between blanking and spotwelding 3. Tatk Time calculation													TL & VSM Team	Rocam	JS	Jun - Jul
		Loop 3: (Supplier) 1. Reduce Inventory on Raw Material	Loop 3: Leadtime reduction.													AN	Logistics	JS	Aug - Oct
3	SMED	SMED workshop 1. Rocam/Arvin 2. CHG/MRM 3. Softs/Cork	SMED workshop 1. Setup time reduction (Tarket = single figures) Mechanical/Hydraulic presses 2. Blanking/closing presses 3. TG42, splitting, THP													TL MP RU	Rocam CHG Softs/Cork	JS	Aug - Sep
4	Preventative Maintenance	Operators/Maintenance Training	TPM implementing maintenance schedules.																

Appendix C

Informal Questionnaire

Questions for consideration analysing the Current State:

- How do you tell how you are doing?
- How do you tell if you are ahead or behind for today, this week, this month?
- How does work get to and from you?
  - Information: Orders?
    Set-Ups?
  - Materials: Pack Out Quantity / Container Size?
    Who Brings?
    Who takes away?
    When and how do they know?
- How do you know what to do next?
- Do you get interrupted to run "Hot" jobs?
  - While job is running?
  - Between jobs?
  - How often?
- How do the machines / operations run?
  - Reliability - Uptime %?
  - Quality - Scrap / Rework %?
  - Set-Up time?
  - Limitations – part number that must be run or can not be run on certain machines?
  - Batch / Run size?
  - Cycle time?
  - # of Shifts / Day?
  - # of Work Hours / Shift?

General questions for consideration:

- How frequently does the entire family of parts sequence through the operation?
- How does the process technology being used compare to the competition?
- How does the process technology being used compare to the "state-of-the-art"?
- Are actions / projects in process to upgrade the technology being used?
- Given the current state, where would the trigger point need to be for production in order to be able to achieve the lead-time the customer wants?

Appendix D

5s Checklist and Assessment

Score Card

Inspection for
the Week of _____ **Area/Team** _____

Scoring Key		
	Level fully achieved and maintained	5 points
	Partial achievement; some improvement required	2 - 4 points
	Very little or no achievement	0 - 1 points

5S Principle	Score Higher is Better	Comments
Sort		
Remove all items not needed or required to perform the intended production function.	0 1 2 3 4 5	
Disposition of all red tagged items should occur within 60 days of removal. (See red tag log book)	0 1 2 3 4 5	
Set in Order		
Every work area is clearly defined and labeled.	0 1 2 3 4 5	
Every item in the facility should have a specific area where it resides that is outlined and clearly labeled.	0 1 2 3 4 5	
All items are in there designated area unless being used by the operator to manufacture product.	0 1 2 3 4 5	
Aisles and walkways are clearly delineated and can be identified at a glance; lines are straight with no chipped or soiled paint.	0 1 2 3 4 5	
Walls, signs and boards must contain current information arranged in a straight and neat manner. Torn or soiled material must be replaced or removed.	0 1 2 3 4 5	
Clearly defined limits for raw materials and WIP are established for each production area and these limits may not be exceeded.	0 1 2 3 4 5	
Fire hoses, extinguishers, and other emergency equipment are unobstructed and stored in a prominent easy-to-locate manner. Stop switches and breakers are clearly marked or color coded for visibility.	0 1 2 3 4 5	
Shine		
All floors are clean of debris, oil, and dirt. Cleaning of floors is done routinely - daily at a minimum.	0 1 2 3 4 5	
Machines and equipment are kept clean by routine daily care and inspections; glass (windows) and work surfaces are kept clean and polished.	0 1 2 3 4 5	
All machines and equipment should be painted. There should be no place in the facility less than 2 meters high that is not painted.	0 1 2 3 4 5	
The storage of boxes, containers and packed materials should be neat. Stacked items should not be crooked or in danger of toppling over.	0 1 2 3 4 5	
Equipment leaks (oil, grease, water…ect) should be addressed and eliminated.	0 1 2 3 4 5	
Standardized Clean-up		
Detailed work instructions should be posted in each area. This should include a 5S map of the area.	0 1 2 3 4 5	
A 5S schedule should be posted detailing who is responsible for cleaning, what they should clean and when they should clean.	0 1 2 3 4 5	
A check list should be filled out each shift to ensure that assigned task are being completed.	0 1 2 3 4 5	
Sustain		
All safety and environmental processes and procedures should be followed at all times.	0 1 2 3 4 5	
A disciplined system of control and maintenance to assure that each of the above items is maintained at the highest level possible should be visible. It is everyone's responsibility to maintain the system.	0 1 2 3 4 5	
Audits should be preformed at least twice monthly. Previous scores should be posted. Corrective actions or plans for corrective actions from each audit should be documented before the next audit begins.	0 1 2 3 4 5	
Audit Score	**/ 100**	