

**DEVELOPING A PROCEDURE TO OPTIMISE CYCLE TIME IN A
MANUFACTURING PLANT**

Venter, J.P.

21439702

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Supervisor: J.A. Jordaan (Operations Management)

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Abstract

Productivity advances generated from 'lean manufacturing' are self-evident. Plants that adopt 'lean' are more capable of achieving shorter lead times, less waste in the system and higher quality levels.

The goal of this study was to ascertain which 'lean' tools and techniques are available for use. A matrix was constructed with a summation of the authors who agree that specific 'lean' tools will reduce cycle time.

It was found that reduced set-up time and waste elimination are most affected by the implementation of 'lean' tools and techniques.

An empirical study was conducted to confirm the results of the literature study. The respondents' knowledge on the 'lean' tools was also tested. It was found that respondents have a sound understanding of set-up time; they agree that it must be reduced in the plant. Pre-scientific evidence and the response from the empirical study confirm that there is a substantial amount of waste in the factory.

A current state value-stream map was drawn from a single welded part – Product X. The value-stream was analysed to reduce the cycle time in the process, with the focus on set-up time reduction and waste elimination. The future state value-stream map was drawn, displaying astonishing results.

A continuous improvement (*kaizen*) programme will help reduce the cycle time even further by making use of the other 'lean' tools discussed in this study. This programme forms part of the procedure to optimise cycle time.

Keywords: 5S housekeeping, Bottlenecks, Cycle time, Rework, Set-up time, Value-stream mapping, Waiting time and Waste.

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List of abbreviations and common terms used

SMED – Single Minute exchange of Dies

TPS – Toyota Production System

TQM – Total Quality Management

Japanese Translations

Genchi Genbutsu – Go and see

Hansei – relentless reflection

Heijunka box – Load levelling box

Jidoka – Autonomation

Kaizen – Continuous improvement

Muda – Waste

Mura – Production levels

Muri – Equipment

Nemawashi – Implement decisions rapidly

CHAPTER ONE

1.1 INTRODUCTION

This study is conducted at an agricultural manufacturing plant that manufactures a variety of agricultural equipment. For various reasons the company would like to stay anonymous.

The finished goods are used primarily for the cultivation of maize, wheat and sunflowers. They find further application in vineyards and also in the cultivation of potatoes, sorghum and beans. The organisation has two manufacturing factories. One is located in the Western Cape Province and the other in the North-West Province. The implementation of the procedure on optimising the cycle time will be done at the North-West factory drawing on some 180 to 200 permanent employees. The procedure will also be tested at the Western Cape factory.

To make ultimate use of machinery the factory runs a three-shift system operating 24 hours a day, seven days a week.

The locally-manufactured equipment is distributed country wide through a network of 30 branches. These branches are responsible for all the marketing of the equipment, the selling of required spare parts as well as the supplying to the local farming community with the best service and advice on the diverse agricultural equipment.

Some of these branches handle exports to African countries and other destinations. These exports do not represent the company's core market; rather they are only a small portion of the company's business.

Most of the parts are manufactured locally; only a few parts are imported or supplied by vendors. Plates, angle iron and pipes are among the most used raw material that is supplied by local steel mills and merchants.

The aim of this study is to create a procedure/framework to reduce the number of problems in the manufacturing process such as constraints, bottlenecks and inventory issues, in order to reduce the total cycle time of the product. In a highly competitive market it becomes critical that a plant manufacture its products as quickly as possible, with the minimum amount of money spent. (Rother, 2003:43). This procedure must be implemented in both plants in order to be more versatile, in keeping with the ever changing demand from customers.

1.2 BACKGROUND TO THE STUDY

This study will focus on “lean” manufacturing tools as to optimise cycle time in the North-West plant. The procedure to optimise cycle time will also be implemented in the Western Cape plant but special care should be taken as plants have different layouts and cultures. The main reason for the different cultures is that the two plants belonged to different shareholders before the merge in 1999/2000. There are diverse ethnic groups: there is a majority of coloured people in the Western Cape while there are mainly black people in the North-West.

With an empirical study done by Koufteros, Vonderembse and Doll, (1998:37) it was found that the greatest impact on reduction of cycle time or throughput time is achieved through re-engineering or faster set-up time, quality improvement (*kaizen*), preventative maintenance and pull production. This study will focus mainly on implementing and optimising of pull production and faster set-up time. Celley *et al.* (1986), Schonberger (1987), Im and Lee (1989), Gilbert (1990) and Huson and Nanda (1995) in White, Pearson and all the actions currently required when bringing a product through the main flows as essential to every product. Wilson, (1999:3) confirm that the implementation of just-in-time principles in a manufacturing plant will improve the performance in the following areas: lead times, inventory levels, quality levels, labour productivity, employee relations and manufacturing costs.

A study done by White *et al.* (1999:6), found that reduced set-up times is the most common and frequently implemented tool used in both small and large manufacturing plants. The most frequently cited improvement after implementation of just-in-time principles is that throughput time decreased. This was confirmed by Flynn (1995:1354).

Flynn (1995:1354) states that cycle time can be reduced by reducing reworking through Total Quality Management (TQM) practices.

The main objective of Koufteros *et al.* (1998:23) is to create pull production through several ‘lean’ tools: quality improvement, reduced set-up time, cellular manufacturing and employee involvement.

Sakakibara, Flynn, Schroeder and Morris, (1997:1255) concluded that just-in-time is an overall organisational phenomenon that is taking place worldwide.

The researcher will make use of visual screenings and pre-scientific evidence obtained in the factory to determine where certain problems exist in the plant. The screenings and evidence will also be used to determine which areas could be made more efficient and productive.

The focus will be on just one welding assembly (Product X) from the implement-department; nevertheless it will be possible to use the procedure throughout the factory. Pre-scientific evidence suggests the following problems in the process of manufacturing in this department: 1) Housekeeping; 2) Scheduling, 3) Inventory control; 4) Rework and 5) Bottlenecks.

1.2.1 Housekeeping

Up to now not much effort has been made to ensure a tidy workplace where everything has a place and everything is in its place.

A clean and more organized workplace will ensure a safer and more productive workplace which does not produce poor quality parts not delivered on time (Carreira, 2005:238).

1.2.2 Scheduling

It is currently quite difficult to schedule the implements owing to a number of reasons that will be discussed later. To be versatile one needs to have corrected scheduling in place so as to satisfy both branches and clients.

1.2.3 Inventory control

Goldratt (1992:60) defines inventory as all the money the system has invested in purchasing items which it intends to sell.

It was found that inventory control for production was not optimal. Some downstream processes were awaiting inventories from upstream processes because some parts were scrapped or needing reworking or because of bottlenecks in the process.

1.2.4 Bottlenecks

A bottleneck exists in the process when there is a lot of inventory in front of the machine or process waiting to be completed (Stevenson, 2009:197). During a walk through the plant a few bottlenecks were identified. To reduce the cycle time in the plant these bottlenecks should be addressed, as far as possible eliminating them.

1.2.5 Rework

It was found that a great deal of rework is being done on parts before they can be used. To scrap these parts is not an option, taking into account the relatively high price of steel worldwide. Thus it makes sense to rework the parts: the labour cost of reworking is far lower than the direct cost of the material. The downside is that some employees spend quite a great deal of time reworking the parts, whereas delivering high quality products should be the priority.

1.3 PROBLEM STATEMENT

According to Ballé (2005:203), for greatest efficiency, one should adopt the “lean manufacturing” practice. This process will be enlarged upon later.

The company, where the study is done, is currently using a kanban system and a ‘supermarket’ pull system for receiving raw materials on time. As a result of a lack of communication and for various other reasons it happens quite often that departments do not receive their parts when they need them most. This is also a reason why the plant is not as efficient as it could be.

Problems in the manufacturing process also cause on-time delivery problems; it is difficult to keep to the delivery schedule if there are constant supply-problems. The problems identified in Paragraph 1.2 will be discussed to a greater extent below. A procedure will be formulated to minimize these problems and to increase productivity with optimised cycle times.

Housekeeping: From a visual screening it was found that the workplace is cluttered with unnecessary items which take up space. Any unutilized space could be used to increase productivity. One idea is to create ‘supermarkets’ in the unutilized space. With ‘supermarkets’ a complete pull system could be created (Heizer & Render, 2008:589).

Scheduling: It is difficult to do an accurate scheduling of delivery times owing to erratic supplying of raw material from the various departments. With a more even flow of material it will be much easier to do proper scheduling and most importantly, to keep to the schedule.

Make-lists of the different implements will be created: these are bill of materials (BOM) for the complete implement. All the parts are sent to the next department, making it easier to collect the parts. (See Appendix A for an example of a make-list).

The make-list should be handed out a few days in advance thus ensuring that all parts are available by the time of production and assembling of the implements, or when welders await the parts. The aim is to reduce the number of days to a minimum from the day the packing list is handed out to the day that the plant ships the implement. Part of the make-list will contain a checklist, enabling quality control. The supervisor and the engineer should inspect the implement for any defects or poor paintwork before dispatching the implement.

Inventory control: To reduce the total cycle time the correct amount of inventory must be produced when needed (Jacobs *et al.*, 2009:548). It is vital that all raw materials are always available despite receiving empty promises from suppliers from time to time. Special care should be taken to ensure regular deliveries from suppliers.

From the researcher's visual screening it was clear that the implement production process is not running smoothly. The aim is to use an optimising procedure to eliminate possible problems, ensuring a smoother material flow throughout all departments with the resultant reduction of cycle time.

The agricultural sector is a sporadic industry with many fluctuations - the exchange rate, the price of crops such as maize, and other factors. It is necessary to deal with these fluctuations and in peak times to deliver the machinery timeously.

Rework: With further investigation it was found that a substantial number of parts need some kind of rework, whether pencil grinding of holes, re-bending of parts or re-machining. Reworking of parts consumes much available production time; this urgently needs to be addressed in order to reduce cycle time.

1.4 OBJECTIVES OF THE STUDY

1.4.1 Primary objective

The purpose of this study is to formulate a procedure for optimising the cycle time of the in-house products manufactured by the company. Several 'lean tools' which help reduce the cycle time will be studied. A questionnaire will be used to determine the opinions of the respondents. The outcomes of the questionnaire will be used to construct the procedure.

If feasible, this procedure will be employed by both company plants.

1.4.2 Secondary objectives

To achieve the above objective, the following secondary objectives will be pursued:

- 1) Use of current state and future state value-stream maps.
- 2) Suggestions for improvements will be made.
- 3) Obtaining opinions on application of 'lean tools and techniques' from the employees.
- 4) A suggested framework/procedure will be made available.
- 5) Suggestions for further studies will be made.

1.5 SCOPE OF THE STUDY

The study will take place at an agricultural manufacturing organisation in the North-West province. The employees of this factory will complete a questionnaire that will be analysed.

The study will present a procedure which aims to reduce cycle time in the manufacturing processes. There being two factories in the organisation, the researcher would like to use the procedure in every manufacturing department of both factories.

The researcher will bear in mind that seasonal fluctuations in the agricultural sector are encountered; these fluctuations must be correctly dealt with. Such fluctuations are a worldwide phenomenon. The maize price is determined by the amount of maize available worldwide as well as by weather patterns worldwide. The rand / dollar exchange rate also plays an important role in the local price of maize.

1.6 RESEARCH METHOD

1.6.1 Literature/theoretical study

There are a variety of frameworks, theories, techniques and best practices available in the literature for manufacturing process optimisation. This study will focus the most-used frameworks and techniques and best practices available so as to develop a procedure that the company can use within their organisation. A matrix will be conclude from the literature establishing best practices and the most common 'lean tools' applied in the industry; these practices can be followed by the company . The procedure to reduce cycle time will follow from the constructed matrix and value-stream maps.

1.6.2 Empirical study

This study made used of a convenience sampling method that is part of the non-probability group (Welman, Kruger and Mitchell, 2010:69). A questionnaire was compiled asking questions about certain 'lean tools'. This questionnaire was completed by all employees at various levels of the manufacturing process. This questionnaire consists of three sections namely:

- Demographic information
- Awareness of certain lean tools
- Perceptions of lean tools to be applied

The completed questionnaires were analysed by the Statistical Consultation Service of the North-West University. Descriptive statistics were used to measure the perception of the respondents with regard to which 'lean tools' should be applied. Arithmetic mean values were used to measure the central tendencies with standard deviations, thus drawing a scatter diagram of the data around the arithmetic mean values.

Interpretations were made from the 'effect sizes' (d-values) which indicate whether there is a practical significant difference between any of the demographic variables. The reliability of the awareness and application sections was assessed by calculating the Cronbach's Alpha coefficients of each section. A value of 0.7 and higher will be regarded as an acceptable level of reliability.

1.7 LIMITATIONS OF THE STUDY

The study is conducted at the plant in North-West. The procedure is only tested in this plant and should still be tailor-made for the other factory.

The target population is small thus giving only a small sample from which to draw accurate conclusions.

The information for this study is fairly readily available although for some sections such as the 5S housekeeping, there is little information available.

It is more difficult to create the 'lean' culture in an organisation that is not used to 'lean' manufacturing. The outcome of this study will be applicable for use in almost any organisation, however, every organisation should customize the application of 'lean' tools to specific situations and plant layout.

1.8 LAYOUT OF THE STUDY

1.8.1 Chapter 1: Scope of study

This chapter gives an overview of the study. The scope of the study is discussed in this chapter together with the objectives and the limitations of the study.

1.8.2 Chapter 2: Literature study

A comprehensive literature study of all possible manufacturing processes and tools available will be undertaken. The study will focus, by means of a matrix, on the best practices available from the literature. The matrix will show the most critical changes that need to take place, as well as the sequence of implementing the 'lean' processes or tools.

1.8.3 Chapter 3: Empirical study

An empirical study was performed at the North-Western manufacturing factory belonging to the company, in order to verify the need for optimising cycle time. The attached questionnaire was completed by all managers, engineers, charge hands (supervisors) and production team members at the plant who were directly involved with manufacturing.

This data was statistically analysed and interpreted by means of a representation of figures and tables. The conclusions from Chapter Three were compared with chapter two to develop a procedure for reducing the cycle time.

1.8.4 Chapter 4: Conclusion and proposals

The information and suggestions from the previous chapters were summarized in this chapter. Recommendations and conclusions were made as well as the formulation of the procedure to reduce the cycle time.

Suggestions for further studies were made and a review showed how the objectives would be achieved.

The most difficult part of the procedure is the implementation and the maintenance thereof in the factory. The implementation and maintaining of the suggested procedure offers an ideal topic for a future proposal.

2 CHAPTER TWO

2.1 INTRODUCTION

In this chapter a comprehensive literature study will be conducted to identify which available 'lean tools', techniques and principles will help to reduce the total cycle time of a specific product in a manufacturing plant. The same procedure can also be used throughout the rest of the factory and other similar manufacturing plants. The current state value-stream map will be drawn to identify all the waste in the manufacturing process of specific product labelled 'Product X'. The knowledge obtained from this chapter will be used to draw a future state map with a reduced cycle time. The future state map will be discussed in Chapter Four.

This chapter will explain what throughput time and cycle time are; thereafter, which 'lean' tools and techniques are available to reduce cycle time. Cycle time optimisation is a wide field with many different techniques that need to be implemented. It is possible to have single piece flow in certain plants. Where single piece flow is not possible alternative lean tools should be used with the minimum possible waste.

Because of the limitation of this document the study will make use of the 80/20 principle where 20% of the most used techniques and tools account for 80% reduction in the cycle time after implementation.

2.2 THROUGHPUT TIME

Heizer and Render (2008:644) defined throughput time as the measure (in units or time) that it takes to move an order from receipt to delivery.

Goldratt (1992:231) interpreted throughput time as the time a piece of material spends in the plant from the beginning to the end; this time can be divided into four elements: set-up time, process time, queue time and wait time.

Process time is the only value adding time for the material in the manufacturing plant. The process should be as short as possible (Jacobs, Chase and Aquilano, 2009:175). The rest of the study will focus on the reduction of cycle time which will lead to a reduced throughput time.

2.3 CYCLE TIME

Cycle time is the length of time the part spends being modified into a new, more valuable form which is the desired element (Goldratt, 1992:231).

Cycle time is the actual time it takes to perform a process step and is defined by Heizer and Render (2008:367) as the maximum time that a product is allowed at each workstation and is calculated using the following formula:

$$\text{Cycle time} = \frac{\text{Production time available per day}}{\text{Units required per day}}$$

Heizer and Render (2008:644) defined manufacturing cycle time as “the time that an order is in the shop”. With a shorter cycle time it is possible to use a smaller area of floor space which means that floor area is better utilized.

Cycle time can be reduced by 1) shop floor employee involvement 2) re-engineering set-ups 3) cellular manufacturing 4) quality improvement efforts 5) preventative maintenance 6) dependable suppliers and 7) pull production (Koufteros *et al.*, 1998:23-25).

Reduced cycle times are beneficial because they allow for placement of smaller orders; companies can respond more quickly to changes in the market demand; shorter delivery time being the result. (Verma and Boyer, 2010:499).

A matrix will be constructed placing all the authors of books and publishers of articles in the rows, with all the most used and discussed ‘lean’ manufacturing tools in the columns. The matrix will be completed as more and more information from the literature is obtained.

Table 2.1 – Example of matrix for lean tools v author/publisher

	Lean tool 1	Lean tool 2	Lean tool 3	Lean tool 4	Lean tool 5
Author 1					
Author 2					
Author 3					
Author 4					
Author 5					
Total					

2.4 LEAN MANUFACTURING (THE TOYOTA PRODUCTION SYSTEM)

According to Jacobs *et al.* (2009:403) the following aspects were evident in the Toyota Production system:

1. **Value** – Understanding the value of the work performed, by defining it as something that customers want to pay for.
2. **Value Chain** – Mapping the process steps throughout the supply chain by identifying the steps that add value, while striving to eliminate those that add waste.
3. **Pull** – Eliminating the primary source of waste – overproduction – by producing only what customers want, when they want it. This means starting production only when the customer ‘pulls’.
4. **Flow** – Removing other major sources of waste – bloated inventory and waiting – by ensuring that goods flow ceaselessly through the supply chain.
5. **Kaizen/continuous improvement** – Striving for the total elimination of waste through a succession of small, action-oriented events within the production process.

Liker (2004:37) summarizes the system of The Toyota Way in 14 principles. These principles can be organized into 4 sections: 1) Long-term philosophy 2) The right process will produce the right results 3) Add value to the organisation and 4) Continuous solving of root problems drives learning within the organisation.

The majority of the concepts discussed in this chapter are extracted from books and articles that focus on the ‘Toyota Production System’.

2.5 'LEAN' TOOLS

The main aim of 'lean' manufacturing is to process exactly what the next process needs when it needs it. With lean manufacturing the aim is to link all the processes from the final customer to raw material in the shortest lead time, with the highest quality at the lowest cost (Rother, 2003:43).

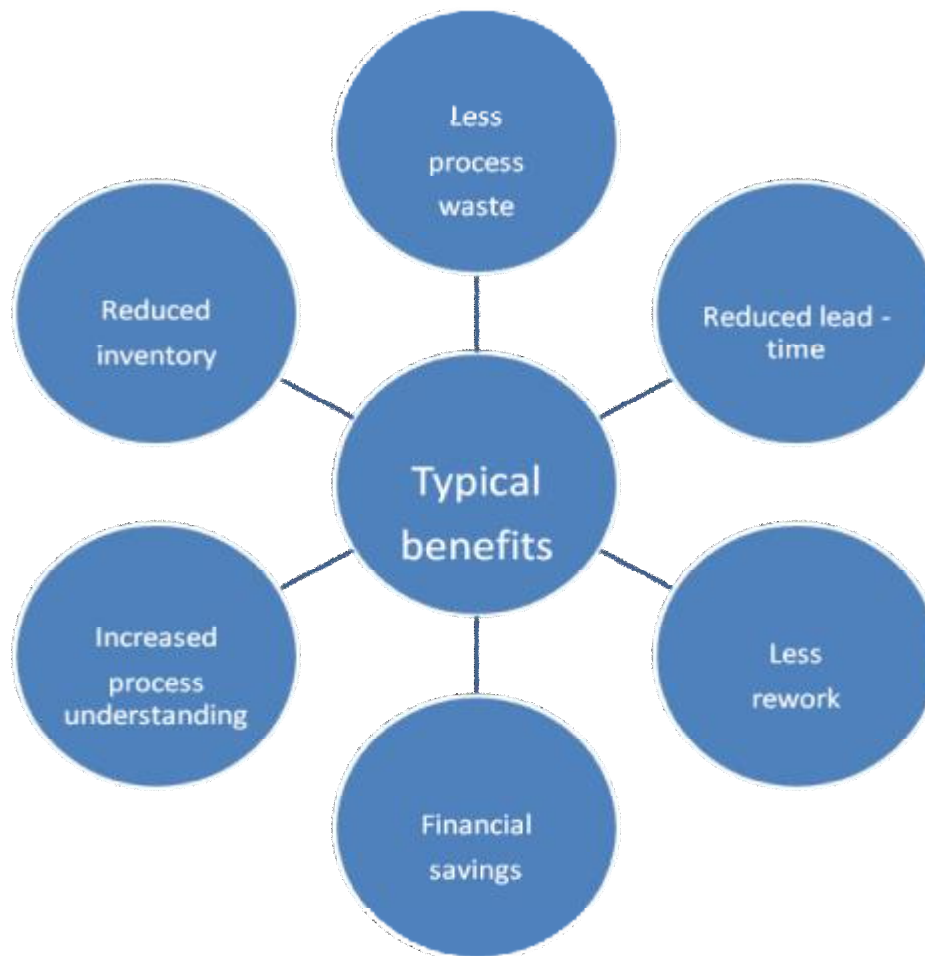
Not all of the aspects are applicable for the company's production line because the nature and the quantities manufactured differ greatly. Therefore a best fit for the concepts will be selected by designing a framework or procedure for the application of the best concepts in the production line.

The following topics will be discussed in the literature study: The 5S housekeeping tool 2) bottlenecks and 3) the characteristics of 'lean manufacturing'.

According to Melton (2005:663) there are several benefits of being 'lean'. The most important benefits as shown in figure 2.1 are:

- decreased lead times for customers
- less process waste
- reduced inventories for manufacturers
- improved knowledge management
- more robust processes (as measured by fewer errors and therefore less rework - one of the seven 'deadly' wastes).

Figure 2.1: The benefits of 'lean'



Source: Melton: (2005:663)

The 'lean' tools and techniques obtained from the literature are discussed below.

2.5.1 Reduced set-up time / Single minute exchange of dies (SMED)

The term 'set-up time' has been on the lips of many authors and publishers over a long time. 'Set-up time' is regarded as the time a part spends waiting for a resource, while the resource is preparing to work on the part (Goldratt, 1992:231).

According to Koufteros *et al.* (1998:23) the path to fast and flexible factories involves **set-up time reduction**, product-oriented layouts and quality improvements.

Reduction of set-up time is an important step towards reducing cycle time. According to Goldratt (1992:231), set-up time is one of the four elements of cycle time, therefore any reduction in set-up time will result in a reduction in cycle time.

Although set-up time is often necessary it should take the minimum time possible. One way is to make use of Shigeo Shingo's famous Single Minute Exchange of Dies (SMED) (Shingo, 1996:2).

Blackburn (1991) in Koufteros *et al.* (1998:21), identified set-up time reduction as an essential element for creating manufacturing systems that focus on cycle time thus achieving 'pull' production. Set-up time reduction is an important component of throughput time and is a determinant of shop floor responsiveness to sudden demand from clients. Smaller batch sizes are an outcome when set-up time is reduced or when cellular manufacturing is implemented (Koufteros *et al.* 1998:24). McLachlin (1997:287) advises that the next set-up needing to be done could be organized while the applicable machine is still running with the current batch. This will reduce machine waiting time.

2.5.2 The seven deadly wastes

There is much mention made in the literature about how to eliminate this enormously worrying problem which do not add value to the company (Hicks, 2007:236). Work processes need to be designed in such a way as to eliminate waste ('*muda*' in Japanese) through the process of continuous improvement (*kaizen*). The seven most common types of '*muda*', according to Liker (2004:28) and Rother (2003:63) are: 1) Defects in products 2) Overproduction of goods not needed 3) Waiting time 4) Unnecessary transportation of material and goods 5) Unnecessary movement of people 6) Unnecessary processing and 7) Inventory awaiting further processing.

George (2010:27) refers to the seven facets of waste using the acronym TIMWOOD:

Transportation
Inventory
Motion
Waiting
Overproduction
Over processing
Defects

Reducing the above facets of waste will decrease costs while simultaneously increasing speed of production (George, 2010:27). The seven 'deadly' wastes will be discussed in more detail below.

2.5.2.1 Unnecessary transporting of material and goods

In some case factories that were used to mass-production, thereafter changing to 'lean' manufacturing, still retain poor plant layout. Poor layout is one of the causes of unnecessary movement of goods or material (Aikens, 2011:173).

2.5.2.2 Inventories of goods awaiting further processing

A certain predetermined minimum amount of inventory is necessary for a smooth production flow, however, any additional inventory that is manufacturing which cannot be used immediately will result in unnecessary handling and storage. The extra inventory also increases the production lead time. (Verma, 2010:454).

2.5.2.3 Unnecessary movement of people

Aikens (2011:171) noted that employees may travel back and forth between operating areas or around the shop obtaining technical information or finding special tools elsewhere. As in the case of Paragraph 2.5.2.1 where a poor plant layout causes unnecessary movement of material or goods it also causes unnecessary movement of people.

2.5.2.4 Waiting by employees for process equipment to finish its work or on an upstream activity

Aikens (2011:173) claimed that waiting time may occur for to several reasons such as manufacturing-line imbalances, a shortage of material, machines that break down, quality problems and scheduling errors.

2.5.2.5 Over-production of goods not needed

Over-production (*Muda*) is the most significant source of waste. Over-production also lengthens lead times (Rother, 2003:43).

Excess inventory needs be stored, handled and counted. Inventory also gets damaged from time to time owing to unnecessary handling.

Any defects in the parts remain hidden in the excess inventory queues until the downstream eventually processes the parts, discovering the problem (Rother, 2003:42). In such a case, as discussed in Paragraph 1.2.5., the parts may need some rework.

These excess inventories and overly large batch sizes can cause unnecessarily long customer lead times (Nakamura, Sakakibara and Schroeder, 1998:232).

Rother (2004:44) gives the following seven guidelines with the understanding that one process produces only what the next process needs when it needs it.

- 1) Produce to your 'takt time' (The rate at which the plant sells the product to end user)
- 2) Develop continuous flow where possible
- 3) Use supermarkets to control over-production where continuous flow does not extend upstream
- 4) Schedule the work only at one production process/operation
- 5) Level the production mix
- 6) Level the production volume
- 7) Make every part every day/hour

A plant in which everyone is working all the time is very inefficient: excess manpower is needed to create excess inventory (Goldratt, 1992:84).

2.5.2.6 Unnecessary processing

Unnecessary processing means that any unnecessary process done on a job is regarded as redundant and increasing the cost price of the part (Aikens, 2011:171).

2.5.2.7 Defects in products – rework needing to be done

Parts or products that are not manufactured to specification need to be scrapped and are then wasted. Furthermore, the resources used to create these scrapped items are also wasted. It is sometimes possible to do rework on parts in order to save the cost of the material, but this may also be costly (Verma, 2010:454).

2.5.3 Total quality management

Schonberger (2007:406) suggested that the first as well as the last part in the batch need to be inspected to increase the quality of the products. Toyota takes this a step further with their methods of detecting defaults as they occur and by stopping the line. This put Toyota in the position to fix the problem immediately preventing defects being spread downstream (Liker, 2004:130).

2.5.4 Throughput time

Throughput is the rate at which the system generates money through sales and not production (Goldratt 1992:60). This links into the 'lean' philosophy of producing products when the customer 'pulls' for them (Melton, 2005:666).

Operational expense is all the money the system spends in order to turn inventory into throughput (Goldratt, 1992:60) and (Melton, 2005:666).

The goal is to increase throughput while simultaneously reducing both inventory and operating expense (Goldratt, 1992:67) and (Melton, 2005:666).

2.5.5 Batch size reduction

Reduction of batch sizes provides quality control of non-conformities plus a short track-back loop making it easy to trace the origin of a quality problem (Schonberger, 2007:406).

According to Johnson (2003:296) large reductions in batch sizes require conversions to cell manufacturing.

2.5.6 Super market pull

A 'pull' system is that in which a process signals to its predecessor that more material or parts are needed. The 'pull' system produces only the required material or parts once the material or parts are 'pulled' from the process. This system is necessary to reduce the waste caused by overproduction (Liker, 2004:107).

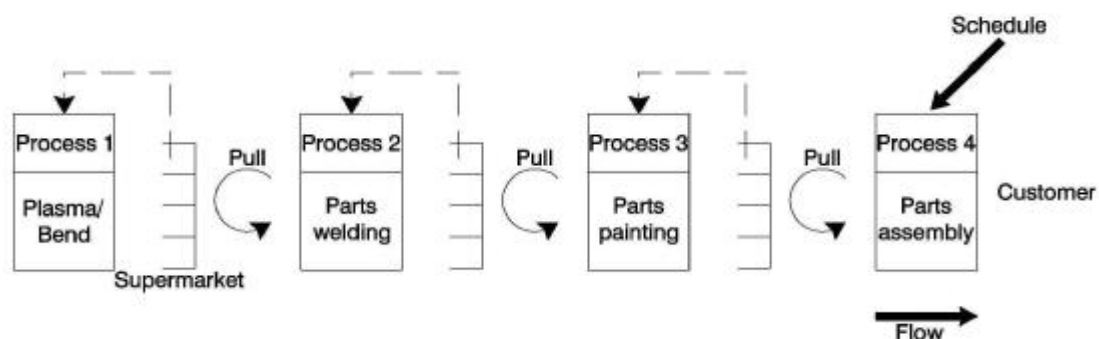
There are often sections in the value-stream where continuous flow is not possible and batching is necessary. Several reasons for this include the following:

- Processes operate at either very fast or slow cycle times which need to change over so as to serve multiple-product 'families'.
- Some processes are at a distance: shipping of one piece at a time is not feasible. Parts from suppliers fall into this category.
- Some processes have too much lead time or are too unrealistic to couple directly to other processes in a continuous flow.

According to Rother (2003:47) the supermarket should be located near the supplying process in order to help that process maintain a visual sense of customer usage and requirement. Before deciding to make use of a supermarket 'pull' system, continuous flow across as many process steps as possible should be introduced.

When using supermarket 'pull' systems it is necessary to schedule production at only one point in the value-stream. This point is called the **pacemaker process**. The way the pacemaker process is controlled determines the pace of production of all downstream processes. Material transfer from the pacemaker process downstream to finished goods needs to occur as a flow. There should be no supermarket 'pull' systems downstream of the pacemaker process, making the pacemaker process is the most downstream continuous flow process in the value-stream (Rother, 2003:49).

Figure 2.2: "The pacemaker process"

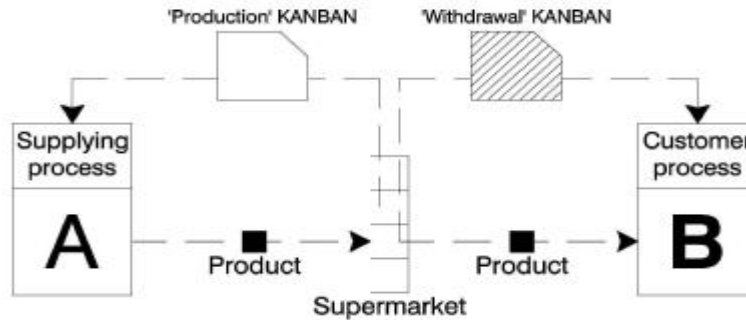


Source: Rother (2003:49)

2.5.7 Kanban

Supermarket-based 'pull' systems are used for linking production to their downstream customers (Figure 2.3).

Figure 2.3: 'Supermarket pull system'



Source: Rother (2003:46)

Customer process: The customer goes to the supermarket, withdrawing what is needed when needed.

Supplying process: The supplying process produces to replenish what was withdrawn.

The purpose of the above two processes is to control production at supplying process without trying to schedule and control production between flows.

Production kanban: The 'production' kanban triggers production of parts.

According to Rother (2003:47), the purpose of placing a 'pull' system between two processes is to give accurate production instructions to the upstream process without having either to predict downstream demand or to schedule the upstream process.

Withdrawal kanban: The 'withdrawal' kanban is a shopping list for the material handler to get and transfer parts. The downstream process will withdraw parts out of a supermarket. This withdrawal determines what the upstream process produces when and in which quantity. A kanban limits the length of queues and the time the it spends in the queue (Schonberger, 2007:408).

2.5.8 Wait time

Waiting time is the time the part waits, not for the resource, but for another part to which it must be assembled (Goldratt, 1992:231).

2.5.9 Cellular manufacturing

Continuous flow refers to the production of only one piece at a time, with each item passed immediately from one process step to the next without a delay or stagnation in between. Continuous flow therefore eliminates waste.

Continuous flow is the most efficient way production; there is endless scope for creativity in trying to achieve it (Rother, 2003:45).

2.5.10 Kaizen

The main principle for continuous improvement (*kaizen*) is to create a long-term vision by working on emerging challenges, continuous innovation, going directly to the source of the problem or issue (Liker, 2004:225).

The principles relating to respect for people are as follows:

1. **Respect for others** – Make every effort to understand one other, taking responsibility for one's actions, doing one's best to build mutual trust
2. **Teamwork** – Stimulate personal and professional growth; share the opportunities of development while maximizing individual and team performance.

Liker (2004:256) claims that the process of becoming a 'learning-organisation' involves criticizing every aspect of what one does. The general problem-solving techniques to determine the root cause of a problem include:

1. Initial problem perception
2. Clarifying of the problem
3. Locating area/point of cause
4. Investigating root cause by asking five times 'why?'
5. Countermeasures
6. Evaluation
7. Standardization

Another kaizen tool used by Toyota managers is 'go-and-see' (*genchi genbutsu*). Managers are expected to view the operations when a quality issue is encountered. Without experiencing the situation for themselves, managers will not have an understanding of how the issue can be improved. Liker (2004:225) suggested that managers use the following nine principles from Tadashi Yamashina as a guideline:

1. Always keep the final target in mind.
2. Clearly assign tasks to yourself and others.
3. Think and speak on verified and proven information and data.
4. Take full advantage of the wisdom and experiences of others to send, gather or discuss information.
5. Share information with others in a timely fashion.
6. Always report, inform and consult in a timely manner.
7. Analyse and understand shortcomings in your capabilities in a measurable way.
8. Relentlessly strive to conduct kaizen activities.
9. Think 'out of the box' or beyond common sense and standard rules.

By following these tools managers will be able to solve the encountered problem, putting a stop to it thus ensuring continuous improvements.

2.5.11 Value-stream mapping

Rother (2003:3) refers to a value-stream map as all the actions currently required when bringing a product through the main flows as essential to every product.

A value-stream perspective means working on the 'big picture', not just individual processes; improving the whole, not just optimising the parts (Rother, 2003:3) and (Melton, 2005:667). According to Melton (2005:667) one needs to improve the efficiency and effectiveness of the whole supply chain not just one part of it; one needs to operate the supply chain not the production unit.

Value-stream mapping is used to highlight sources of waste, eliminating them by implementation of a future-state value-stream. This can become a reality within a short period of time.

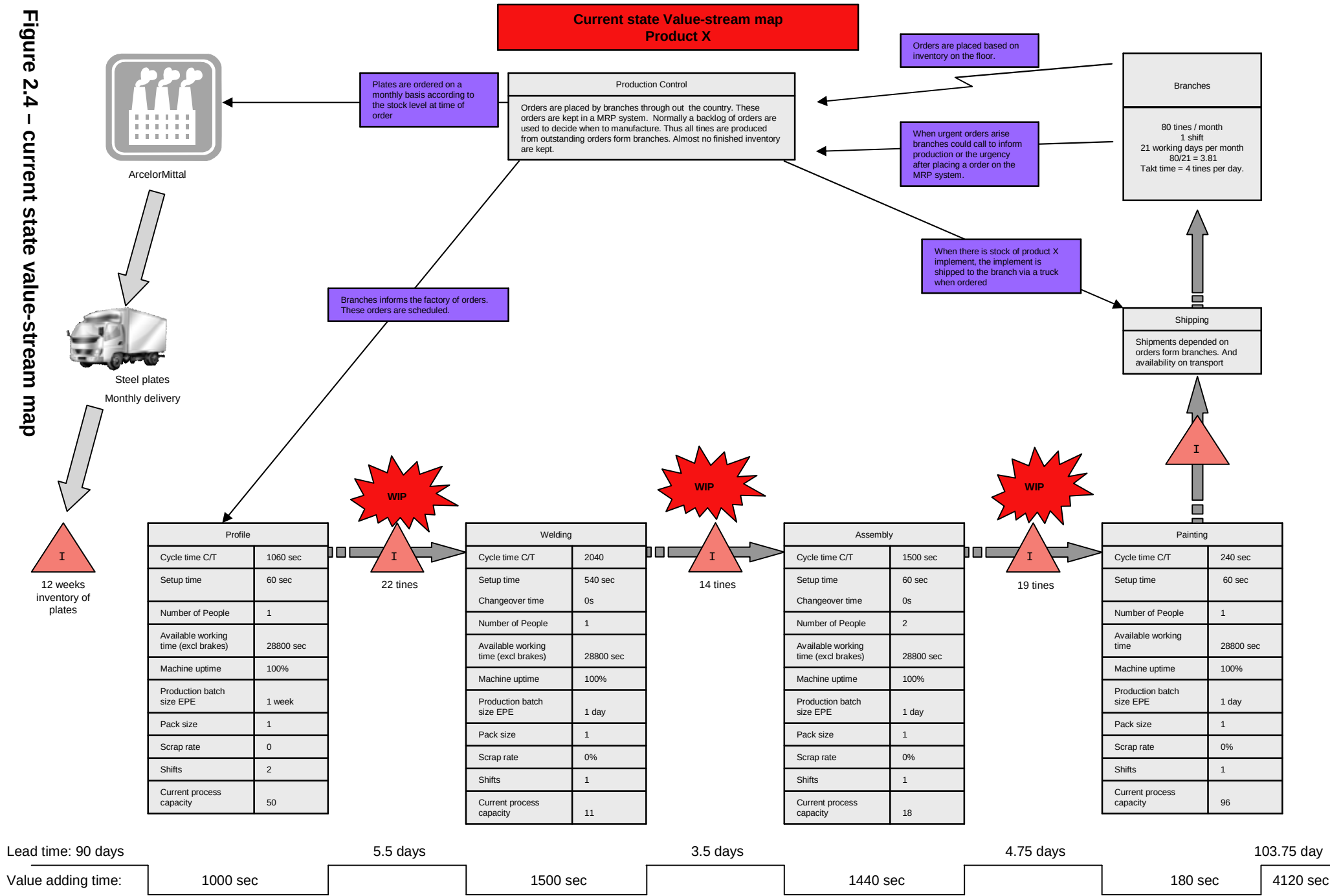
The aim is to build a chain of production where processes are linked to their customer(s) either by continuous flow or by 'pull'. It is necessary that every process as closely as possible produces only what its customers need when they need it (Rother, 2003:57).

In an existing facility with an existing product and process, some of the waste in a value-stream will be the result of the product's design, the existing processing machinery or the location of some activities. These features of the current state map cannot easily be changed, but the future state map should take these features as a given, seeking to remove all other sources of waste as quickly as possible.

The current state value-stream map for the manufacturing of Product X will be drawn from the information available in the literature. The future state value-stream map will be drawn after the literature study has been completed. The future state value-stream map will be discussed in Chapter Four as will the reasons for all the changes from the current state map.

A process chart is used to determine the time each step of a specific process consumes. It also indicates the activity that is taking place (Heizer, 2008:268).

Figure 2.4 – current state value-stream map



2.5.12 *Multifunctional teams*

Success is based on the team and not on the individual. Teams should consist of 4-5 people; there should be numerous management tiers. Liker (2004:198) concluded that the backbone of management's approach should be to train exceptional people and to build individual work groups (teams).

One needs to be determined to change: the correct attitude is necessary in changing the manufacturing facility to a 'lean' facility (Goldratt, 1992:150).

Without constant attention, all the 'lean' tools and principles will fade. Employees must be educated and trained, inculcating into them these principles. The principles will thus be retained; employees will be maintained in a learning environment, feeling part of a multifunctional team (Liker, 2006:258).

2.5.13 *Process time*

Process time is the time a part spends time at a process while adding value by changing the part in a more desirable form (Goldratt, 1992:262).

2.5.14 *Standardized work*

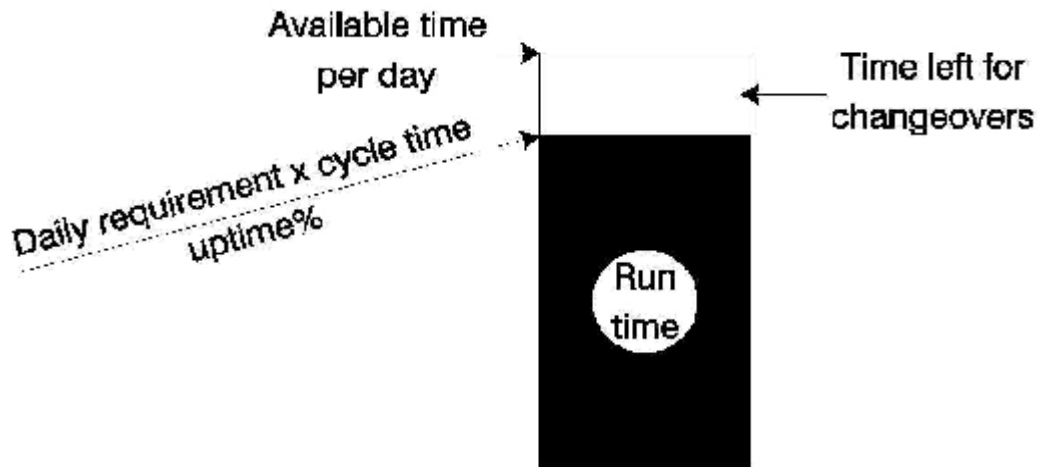
Standardized work is a way in itself to countermeasure quality problems (Liker, 2004:134).

Standardized tasks and processes are the foundation for continuous improvement and employee empowerment. Standardized tasks will be discussed later, in the fourth 'S' of the 5S program. Although Toyota has a bureaucratic system, the way in which it is implemented allows continuous improvement (*kaizen*) from the people affected by that system. Employees are empowered to aid in the growth and improvement of the company. (Liker, 2004:143).

According to Taiichi Ohno in Liker (2004:140), the standard work sheets and the information contained therein are important elements of the Toyota Production System to increase efficiency while preventing defective work.

Initial batch sizes at the fabrication processes are determined by how much time the operator has left in the day to make changeovers (figure 4) (Rother, 2003:53).

Figure 2.5: Run time



Source: Rother (2003:54)

2.5.15 *Poka-yoke*

Poka-yoke refers to mistake-proofing, error-proofing or foolproofing. Poka-yoke is a creative device that makes it almost impossible for operators to make an error (Liker, 2004:133).

Each Poka-yoke device should have its own standard form that addresses and summarizes the problem and the action to be taken in the event of a poka-yoke method breaking down (Liker, 2004:134).

2.5.16 *Heijunka box*

The more one levels the product mix at the pacemaker process (takt time) the more one is able to respond to a variety of customer requirements with a short lead time while holding a minimum finished goods inventory. This allows for a particular supermarket to be smaller; the reward is the elimination of large amounts of waste in the value-stream (Rother, 2003:50).

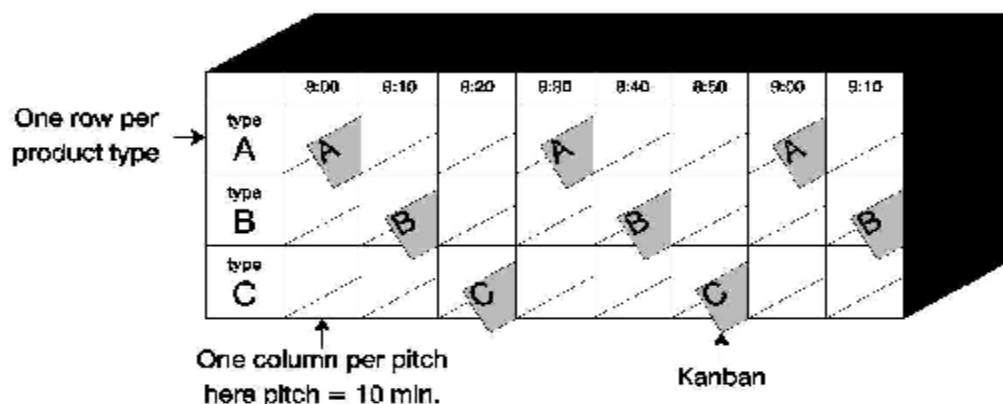
According to Rother (2003:51) many companies release large batches of inventory onto their shop floor processes which causes the following problems:

- There is no sense of 'takt' time and no 'pull' to which the value-stream can response.
- The volume of work performed typically occurs unevenly over time with peaks and valleys; this causes an extra burden on machines, people and supermarkets.
- The situation becomes difficult to monitor: "Are we behind or ahead?"
- With large amount of work released onto the shop floor, each process in the value-stream can shuffle orders. This increases lead time and the need to expedite orders.
- Responding to changes in customer requirements becomes very complicated, which can often be seen in very complex information flows in current-state drawings.

Rother (2003:51) advised that, by establishing a consistent or level production pace, a predictable production flow is created, which by its nature advises of problems, enabling the speedy taking of corrective action.

The consistent increment of work is called the pitch. Calculation of the pitch is often based on the container quantity. Thus, when the 'takt' time of a part is 30 seconds with the container size of 10 pieces, the pitch will be 5 minutes. That means that every 5 minutes a finished pitch quantity is taken away; the pacemaker process is instructed to produce one container (Rother, 2003:51).

Figure 2.6: Heijunka (load levelling) box



Source: Rother (2003:52)

Level out the workload (*heijunka*) working like the tortoise, not like the hare. This principle helps to achieve the goal of minimizing waste (*muda*), avoiding overburdening people or the equipment (*muri*) and avoiding the creation of uneven production levels (*mura*) (Liker, 2004:114).

By running smaller batches of parts in the upstream fabrication processes and by shortening changeover times, those processes will respond more quickly to changing downstream needs. The upside is that the upstream processes require even less inventory held in their supermarkets. The aim is to manufacture, for high-running parts, at least every part every day (Rother, 2003:54).

2.5.17 *Bottlenecks*

According to Goldratt (1992:139) flow, rather than capacity, should be balanced.

To increase the capacity of the whole plant one needs only to increase the capacity of the bottleneck (Goldratt, 1992:152). This also aligns with 'lean' 'pull' production: production is inhibited by the lack of customer 'pull'. The customer may either be any downstream process or the end user (Melton, 2005:667).

Goldratt (1992:159) warns that the time at a bottleneck must not be wasted; every minute wasted at the bottleneck is a minute wasted on throughput of the entire plant. The bottlenecks should not have any idle time during breaks. A bottleneck should not process any defects from upstream processes. Ensure that bottlenecks work only on what will contribute to throughput *on the day*.

Goldratt (1992:230) also suggests that batch sizes should be cut in half at non-bottleneck, these processes having extra capacity. Bottlenecks also dictate inventory as well as throughput.

According to Goldratt (1992:301) the following five steps should be followed in managing bottlenecks:

Step 1: Identify bottlenecks in the system.

Step 2: Decide how to exploit the bottlenecks.

Step 3: Subordinate everything else to the above decision.

Step 4: Eliminate the bottlenecks within the system.

Step 5: If, in a previous step, the bottleneck has been broken, return to step 1.

2.5.18 *The “5S” housekeeping tool*

Work efficiency begins with good housekeeping (Aikens, 2011:171). Proper housekeeping will help to identify and eliminate waste in the plant.

5S is a set of housekeeping techniques originating from Toyota. This study considers the tool the most important of all concepts because most problems of lack of productivity can be ascribed to a disorganized and cluttered workplace. Cluttered workspaces hide defects and their causes (Schonberger, 2007:406).

The 5S steps are used to make all work spaces efficient and productive. The programme helps people to share workstations, to reduce time looking for needed tools and to improve the work environment (Liker, 2004:150).

The 5 Japanese terms for 5S are: 1) *Seiri*, 2) *Seiton*, 3) *Seiso*, 4) *Seiketsu* and 5) *Shitsuke*.

Seiri (*Sort and eliminate*) – According to Ballé (2005:122) this technique requires both choice and commitment. When sorting a work station many unnecessary items may be found. Sometimes employees use ‘special’ tools in the manufacturing process. On examining this equipment one may find that the process or design could be improved so as to eliminate the use of ‘special tools’.

Seiton (*Straighten/Stabilize*) – After sorting the workplace one needs to create a set place for all necessary tools and equipment. The aim of *seiton* is to organize tools and parts for the greatest ease of use; this is not costly to implement (Ballé, 2005:122).

Aikens (2011:172) described *seiton* as an efficient workstation that has a place for everything with everything kept in the right place. People need to find something when they need it, so as not to waste valuable time. *Seiton* will also eliminate unnecessary movement of employees, as discussed in section 2.2.2.5.

Seiso (*Scrub/Shine/Sweep*) – *Seiso* means to clean parts and to inspect for cracks, anticipating future failures. It is important to do the maintenance in time, especially in quiet times, so as to be ready when the machines need to withstand heavy strain (Ballé, 2005:123).

Aikens (2011:172) described *seiso* as the act to maintain cleanliness and tidiness. He also suggests that one of the employees of each department sign off a daily check sheet in order to keep the workplace in a clean and orderly way.

Seiketsu (Standardize) – *Seiketsu* means to maintain the first three S's by introducing standardized clean-up sheets for the operators. The result is that the operators are more committed: they take responsibility for their workstations (Ballé, 2005:124).

Aikens (2011:172) suggests that 5S disciplines like the first three discussed should become a company-wide standard, ensuring that the areas are kept this way.

Shitsuke (Sustain) – *Shitsuke* is about discipline, ensuring that the 5S discipline is both sustainable and maintained every day no matter the circumstances (Ballé, 2005:125).

Aikens (2011:173) noted that *shitsuke* is the 'kaizen' discipline of the 5S housekeeping disciplines. This means that the cleanliness and orderliness of the workplace should continuously be improved. It is easy to clean spills; but the aim of this step is to determine the reason for the spill.

2.5.19 'Six Sigma' as a tool for reducing waste

The term 'six sigma' has several meanings. Statistically, 'six sigma' means that opportunities for creating a defect in a process are no more than 3.4 units per million (Stevenson, 2009:429).

'Six Sigma' is a powerful tool with which significantly to improve quality while to reducing waste at a given company. 'Six Sigma' empowers every employee to make drastic improvements in the company's performance (Jacobs *et al.*, 2009:404).

'Lean/six sigma' is an approach to process improvements that integrates 'lean' and statistical tools to reduce variation in achieving speed and quality (Stevenson, 2009:430).

Heizer (2008:199) explained a five-step process improvement model, using the acronym DMAIC, as follows:

Define the problem

Measure key aspects of the current process

Analyse the data to investigate and verify cause-and-effect relationships

Improve by modifying or redesigning processes and procedures

Control the new process to maintain performance levels

2.5.20 *Takt time*

Takt time means the synchronized production pace to the pace of sales (Rother, 2003:44). Stevenson (2009: 702) defines takt time as: “the required cycle time to match customer demand for the final product”.

Takt time is calculated to divide the total customer units per day through the available working time per day and is usually expressed in seconds.

According to Rother (2003:44) takt time takes in how often one part or product should be produced, based on the rate of sales to meet customer demand. Takt time is also used to synchronize the pace of production with the pace of sales, particularly at the ‘pacemaker process’.

To produce to takt time sounds simple, nevertheless it requires concentrated effort to:

- provide quick response to problems in takt
- eliminate the causes of unplanned downtime
- eliminate changeover time in downstream assembly-type processes.

2.5.21 *Queue time*

Queue time is the time which the part spends in line for a resource while the resource is busy working on something else ahead of it (Goldratt, 1992:231).

2.6 MATRIX CONSTRUCTED FROM LITERATURE

Table 2.2: Matrix various cycle time reduction techniques and authors/publishers

	SMED (2.5.1.)	7 Wastes/ waste elimination (including rework) (2.5.2.)	Total quality management (2.5.3)	Cycle time/throughput time (2.5.4)	Batch size reduction (2.5.5)	Supermarket pull (2.5.6)	Kanban (2.5.7)	Wait time (2.5.8)	Cellular manufacturing (2.5.9)	Lean Manufacturing (2.5)	Kaizen (2.5.10)	Value stream mapping (2.5.11)	Multifunctional teams (2.5.12)	Process time (2.5.13)	Standardize work (2.5.14)	Poke Yoke (2.5.15)	Heijunka box (2.5.16)	Bottlenecks (2.5.17)	5S Housekeeping (2.5.18)	Six Sigma (2.5.19)	Takt time (2.5.20)	Queue time (2.5.21)
Ahlstrom, 1998	•	•				•	•				•		•									
Allahverdi, 2008	•			•				•						•								
Bicheno <i>et al.</i> 2001	•	•	•	•	•	•	•	•		•		•										
Buscher, 2007		•	•		•			•														
Calvallini, 2008	•	•	•	•	•	•				•		•		•	•					•	•	
Cardenas-Barron, 2009	•	•	•		•																	
Carlier <i>et al.</i> 2010								•						•				•				
Chiu, 2008	•	•			•																	
Cuatrecasa <i>et al.</i> 2011	•	•		•		•		•				•		•				•			•	
Dimopoulos, 2000	•	•	•	•		•	•	•	•					•								
Flynn <i>et al.</i> 1995		•	•	•																		
Flynn <i>et al.</i> 1999					•																	
Forza, 1996	•	•	•			•				•	•											
Goldratt, 1992	•						•	•						•				•				•
Herron, 2008	•	•	•		•		•		•		•				•	•			•			
Hicks, 2007	•	•								•	•	•							•	•		
Hines, 1997		•	•			•	•	•			•	•				•						
Johnson, 2003	•	•		•	•			•	•					•		•						•
Khorshidian <i>et al.</i> 2011	•							•						•								
Koufteros <i>et al.</i> 1998	•	•				•			•		•		•									
Leachman <i>et al.</i> 2002				•																		
Lee <i>et al.</i> 1999		•	•					•		•												
Liker, 2004	•	•	•	•	•	•	•		•	•	•	•	•		•	•	•			•	•	
Liker, 2006	•	•	•	•	•	•	•	•		•	•	•	•		•	•	•			•	•	
Liu <i>et al.</i> 2009	•				•				•													
McLachlin, 1996	•	•	•	•	•	•	•		•	•			•	•	•		•					
Melton, 2005	•	•	•	•		•	•	•	•	•	•	•	•			•		•	•			•
Nakamura <i>et al.</i> 1998	•	•	•	•	•	•	•	•	•	•			•									
Nave, 2002		•	•	•		•					•	•					•			•		
Rivera, 2007	•		•		•	•	•	•	•	•		•					•		•			
Rother, 2003						•			•						•		•				•	
Sakakibara <i>et al.</i> 1997	•	•	•	•	•	•	•															
Samaddar, 2008	•							•														•
Sarker <i>et al.</i> 2008	•	•	•	•	•			•						•								
Schonberger, 2007	•	•	•	•	•		•		•	•	•		•			•		•				
Shah, 2003		•	•	•	•	•	•		•	•			•				•					
Sharma, 2008	•			•																		
Shingo, 1996	•																					
Trybus, 2005	•			•	•	•					•				•				•	•		

2.7 CONCLUSION

A comprehensive literature study was done in search of the most used 'lean' tools and techniques for reducing the cycle time in a manufacturing plant. Most of the available 'lean' tools were discussed, although there are a few less critical tools not mentioned.

A matrix was constructed from the literature showing the various 'lean' tools and the number of authors and publishers who mentioned the 'lean' tools and techniques.

Set-up time reduction and the elimination of waste are two tools most mentioned.

From visual screenings in the factory, it was concluded that these are a priority.

The plant will benefit by a 5S housekeeping program. The literature proves that much waste is buried under disorganized and cluttered work areas.

At first an empirical study as described in Chapter Three will be conducted, to determine that the information obtained from the literature corresponds with the needs for shorter cycle times in the company.

With the knowledge obtained from the literature, it will be now possible to draw a future state value-stream map. The value-stream map will be shown and discussed in Chapter Four.

3 CHAPTER THREE

3.1 INTRODUCTION

A matrix of the various 'lean' tools and other much-used tools was constructed, based on the literature study in Chapter Two. In this chapter an empirical study is conducted by all the employees in the manufacturing plant. The aim of this study was to demonstrate that the company needs to implement these same most-used 'lean' tools. Although the company culture may vary from factory to factory some 'lean' tools will certainly make a huge difference in reducing cycle time.

In this chapter the questionnaire that was provided will be discussed. Results will be interpreted as statistical analysis. The researcher will first discuss all the frequencies obtained, explaining the relevant objectives.

All the arithmetical mean values will be discussed as also the meaningful standard deviation values. Thirdly, the questions asked in the questionnaire were grouped and tested via a Cronbach's Alpha test to determine whether the constructs are reliable. Lastly the study will test for correlations and comparisons between groups of demographic data and data of the 'lean' tools that need to be changed. The study will also test for correlations between the employees' experience of the 'lean' tools and their desire to implement these 'lean' tools.

The questionnaire was divided into three parts. The first part asked the following demographic details of the employee: Age, Race, Years of service, Factory of employment, Working department, Job description and Highest educational level.

The second part asked the employees whether they were familiar with the 'lean' principle terms; thirdly, employees were asked their opinion regarding which tools needed to be implemented in the plant.

The findings of the analysis will be discussed after the data is processed. A conclusion to this chapter will then be given.

3.2 GATHERING OF DATA

3.2.1 Target population

The target population was drawn from two factories in the company, the southern factory being smaller than the northern factory. The employees of the southern factory are not well aware of the various 'lean' tools available, this making it difficult to complete the questionnaire with them. It was then decided to make the northern factory the sole participant in the study.

The population of the factory is between 160 and 180 employees, while the total number of the study population is 115 respondents all directly involved in manufacturing. The balance of the population is needed to do the administration, sales, store-work and transport, these activities are not directly involved in manufacturing.

The majority of the sample has little school education if any, therefore it was decided to complete the form in groups of 15 - 20 employees at a time and to aid them in completing the form. Owing to this strategy the total response rate was 100%.

Because the study made use of a convenience sampling method, the respondents were selected from the same manufacturing plant and the population had either of three different job descriptions: Production team member, Charge hand/foreman and Manager/Engineer.

3.2.2 Data collection

The company has two manufacturing factories. The questionnaire was completed only at the northern factory because it has the larger population of the two, and the better knowledge of 'lean' manufacturing.

The data was collected by handing out questionnaires to all the respondents. The charge hands/foremen and managers/engineers groups had attended 'lean' awareness programmes in the past. They completed the questionnaire unaided, being literate and familiar with all the terms used in the questionnaire. In the case of the production team members the researcher assisted them by reading all the questions and by explaining of all the terms used in the questionnaire.

The data was captured on a spread sheet and analysed by the Statistical Consultation Service of the North-West University using the SPSS programme.

3.2.3 Questionnaire used in the study

The questionnaire (Appendix B) consists of three sections: the first asked all the demographic questions; the second tested the employees' awareness of all the 'lean' tools; the third section asked which 'lean' tools should be implemented/applied.

Demographic section:

To obtain demographics from the employees that took part in the questionnaire, the study requested the following information. The **age** of the employees was required in order to correlate the age with the desire for 'lean' tools to be implemented.

The age groups of the respondents was unknown therefore they provided this information. After the analysis, the results were grouped thus: 17 – 29; 30 – 39; 40 – 49 and 50 – onwards.

The reason for requiring the **race** to be indicated, was to determine whether there is different opinions from different ethnical groups and that employees with English and Afrikaans as second and third language have a different perspective of the knowledge and which lean tools should be implemented. Afrikaans is the language most spoken in the company.

Number of years of service was asked for the employees to determine whether the knowledge of 'lean' manufacturing tools increases as the employee's service increases at the manufacturing plant.

The number of years of service of the respondents was unknown, therefore this was asked of them. After the analysis the results were grouped thus: 0 – 4; 5 – 9; 10 -14 and 15 – onwards.

The questionnaire also asked the **location of the factory** where the employee was working. Initially, it was decided that both the factories in the Northern Province and the Southern Province would complete the questionnaire. It was later decided that it would be better to concentrate on the Northern Province factory because this factory has the largest manufacturing facility. Were both factories used, the data would have to differ drastically because the Southern province factory has not implemented many 'lean' principles. The Northern Province factory has far more employees than does its southern counterpart. It may be useful to use the data obtained in this study to implement the same 'lean' principles at the Southern Province factory.

The **department** was asked where the employee was working. Assembly, Sheet metal and Welding are the three departments where the majority of parts are

manufactured; they are also the ones, judging by a visual screening, that need the most attention.

The **job description** was requested because employees directly involved in manufacturing varied from charge hand / foreman to engineer / manager.

The last demographic question required the employee to supply the **highest education level** passed. This indicates to what extent the employee is educated and how easy it will be for him to learn the 'lean' principles.

There was not a request for gender because all those employed in manufacturing are male.

Awareness section:

The second part of the questionnaire tested the awareness of the following 'lean' manufacturing tools: Set-up time reduction, Waste reduction, Cycle time reduction, 5S Housekeeping, Total Quality Management (TQM), Value-stream mapping, Six Sigma, Cellular manufacturing and bottleneck reduction.

The reason for testing awareness of the above variables was to establish whether a procedure to optimise cycle time should include a major training intervention or whether it should entail simple applications of already-known 'lean' tools and techniques.

It will be established whether there is a correlation between the awareness of the 'lean' tools and respondents' perceptions of which 'lean' tools need to be implemented.

A four-point Likert scale was used where 1 = Very weak; 2 = Weak; 3 = Good and 4 = Very good.

Application section:

The third section of the questionnaire deals with the question, "Which 'lean' tools should be implemented?" In this section the opinions of the respondents on the ease of application of these 'lean' tools was tested.

As discussed in Chapter One, the purpose of establishing the opinions of the respondents is that these respondents play a vital role in implementation of the 'lean' tools, hence their 'buy-in' into these 'lean' tools and techniques is of crucial importance.

Some of the more complex constructs were tested through more than one question in the questionnaire, for the purpose of triangulation.

A four-point Likert scale was used where 1 = Strongly agree; 2 = Agree; 3 = Disagree and 4 = Strongly disagree.

It was later found that an inverse scale would have worked better. The values were recalculated and interpreted with a Likert scale where 1 = Strongly disagree; 2 = Disagree; 3 = Agree and 4 = Strongly agree

3.3 ASSESSMENT OF THE CONSTRUCTS MEASURED IN THE STUDY

3.3.1 The variables used in the study

The following variables, with a brief description from Chapter Two, were measured in the second and third section of the questionnaire:

- **Set-up time reduction:** Set-up time is regarded as the time taken to set a machine for a new job. Cycle time varies from simple machine settings to large tool changes that can take several hours. The shorter the set-up time the shorter the waiting time of the machine, making throughput time shorter.
- **Waste elimination:** Waste includes all the actions in the manufacturing process that do not add value to the product that is manufactured. For instance, the manufacturer cannot charge the customer extra money for the unnecessary transporting of goods from one point to another in the plant. The seven most 'deadly' wastes are known as:
 - o unnecessary transporting of material or goods from one department to another.
 - o inventories awaiting further processing
 - o unnecessary movement of people:
 - o waiting time by employees:
 - o overproduction of goods not needed rather than of goods more urgently required.
 - o unnecessary processing of materials or goods:
 - o defects in products that result in reworking of parts needed; sometimes resulting in scrapping the parts.

- **'Lean' principles:** All the principles and techniques discussed in Chapter Two are regarded as 'lean' tools. The 'lean' tools help an organisation to be more efficient in a competitive world by a speedier delivery in response to customer demand.
- **Cycle time:** The cycle time is the time it takes to perform the task in the plant. The aim of this study is to reduce the cycle time.
- **5S housekeeping:** This is the Japanese programme that cleans and organizes the workplace, maintaining the current state of the workplace until further improvement. The 5S tool helps remove waste from the system.
- **Quality management:** Quality management is important because customers expect the best quality products at the best price. A company cannot be sustained unless it delivers a good quality product to its customers.
- **Value-stream mapping:** These are tools that draw a current state map as well as a future state map illustrating all the value-adding processes as well as the waste in the system.
- **Six Sigma:** Six Sigma is a tool which reduces variation in the system while increasing quality.
- **Cellular manufacturing:** This is a process where single piece flow is possible. The total waste in a cellular manufacturing environment is very limited.
- **Bottlenecks:** A bottleneck is a process where parts flow at the slowest pace compared with the rest of the supply chain. A bottleneck can easily be identified by the huge amount of inventory at that work station.

3.3.2 Arithmetic mean and standard deviation

The arithmetic mean, also referred to as the mean, is the most common measure of central tendency. The mean is the only measure in which all values play an equal role (Levine, Stephan, Krehbiel and Berenson, 2008:97). The formula for the mean is as follows:

$$\bar{X} = \frac{\text{Sum of the values}}{\text{Number of values}}$$

Standard deviation is a measure of variation and is denoted by the letter S. Variance (S^2) and standard deviation are two commonly-used measures of variation that take into account how all the values in the data are scattered around the mean (Levine *et al.*, 2008:106). The formula for the variance (S^2) and standard deviation (S) is as follows:

$$S^2 = \frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + \dots + (X_n - \bar{X})^2}{n - 1}$$

Thus:

$$S = \sqrt{S^2} = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n - 1}}$$

3.3.3 Reliability

The questionnaire used in this study is new and tailor-made for this study, therefore the reliability of this questionnaire should be tested before the results are analysed. Reliability means that the measure of a questionnaire should consistently reflect the construct that it is measuring. This means that respondents should obtain the same score on a questionnaire should they complete the questionnaire at two different points in time (Field, 2009:673). Cronbach's alpha coefficient will be used in this study to test for reliability.

Reliability with Cronbach's alpha coefficient

The Cronbach's alpha, α , is a value equal to the equivalent of the average correlation coefficient values of the combinations when a set of data is split in every possible way. The Cronbach's alpha is the most common measure of scale reliability (Field, 2009:674).

The Cronbach's alpha is calculated as follows:

$$\alpha = \frac{N^2 \overline{Cov}}{\sum s_{item}^2 \sum Cov_{item}}$$

Where:

α = Cronbach's alpha coefficient

N = total number of items

Cov = average covariance

$\sum s^2$ = sum of variance

$\sum Cov$ = sum of covariance

Field (2009:675) maintained that a value for α above 0.7 indicates that the data is reliable.

The Cronbach's Alpha value determines whether there is a correlation between the questions (Welman, 2010:147). A value above 0.7 indicates that the construct is reliable.

Table 3.1 – Cronbach's Alpha Value

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
.805	.818	30

The reliability of the questions in section three of the questionnaire was tested. The value of 0,805 in Table 3.1 indicates that all the questions tested whether 'lean' tools would result in reducing cycle time.

Table 3.2 – Cronbach's Alpha Value if variable is deleted

Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item Total Correlation	Cronbach's Alpha if Item Deleted
Do you think you can reduce set-up times?	64.74	62.677	.483	.791
Do you need to do rework on parts already manufactured?	64.58	65.285	.235	.804
Do you make more than two days' worth of parts in each batch?	64.50	60.734	.557	.787
Do you have waiting time for a machine?	64.75	65.582	.211	.805
Do you do unnecessary transporting of parts?	64.30	65.124	.316	.799
Do you have unnecessary movement of people?	64.38	66.820	.143	.808
Do you do unnecessary processing of parts?	64.26	67.690	.125	.807
Do inventories have waiting times for further processing?	64.73	64.607	.397	.796
Are you dependent on a kanban system in your department?	64.94	64.414	.467	.794
Do you have the need to be part of a multifunctional team?	65.05	65.010	.340	.798
Do you think we could reduce batch sizes?	64.43	67.184	.157	.806
Do you make use of a supermarket pull system?	64.98	63.721	.587	.790
Do you do regular improvements of production?	64.74	66.019	.303	.800
Do you think you can increase the number of products manufactured per day?	64.99	64.620	.428	.795
Does your department need regular organizing (weekly)?	64.95	67.542	.171	.804
Do you organize your workstation every day?	64.89	67.949	.112	.807
Does your department need regular cleaning (weekly)?	65.13	65.630	.452	.796
Do you clean your workstation every day?	64.71	66.385	.236	.802
Do you have control of the quality of parts you manufacture?	65.14	67.994	.142	.805
Do you want to work in a manufacturing cell?	64.76	66.766	.195	.804
Do you make the same parts every day?	64.50	68.101	.057	.812
Do you have a need for more safeguards in your process to prevent errors?	64.93	65.260	.351	.798
Is there a bottleneck in your process?	64.81	64.914	.367	.797
Do you think we could reduce bottlenecks in the process?	64.89	64.025	.553	.791
Do you wait for parts from other departments?	64.90	66.041	.239	.803
Can you reduce the process time of the products you manufacture?	64.73	64.202	.461	.794
Do you think Six-Sigma quality will add value to our process?	64.83	64.501	.468	.794
Do you have a need for a value-stream map in your department?	64.53	65.366	.377	.797
Do you think we should implement 'lean' principles?	65.00	66.380	.418	.798
Do you experience regular bottlenecks?	64.99	65.000	.367	.797

Table 3.2 shows that Cronbach's alpha will remain about 0.8 with the deletion of any question. This confirms that the questionnaire is reliable.

3.3.4 Demographic information

The demographic variables are depicted in the following tables and graphs to illustrate the demographic data of the respondents. Important information will be pointed out as they appear.

3.3.4.1 Age

Age is part of the demographic section establishing if there is a correlation between the age of the respondent and the awareness of the 'lean' tools and techniques. Older workers may be more aware of the 'lean' tools because of their knowledge obtained over the years.

Table 3.3 – Frequencies of age groups in demographic section.

Age groups	Frequency	Valid per cent	Cumulative per cent
17-29	27	23.7	23.7
30-39	31	27.2	50.9
40-49	30	26.3	77.2
50 -	26	22.8	100.0
Total	114	100.0	
Missing System	1		
Total	115		

Figure 3.1 – Age groups

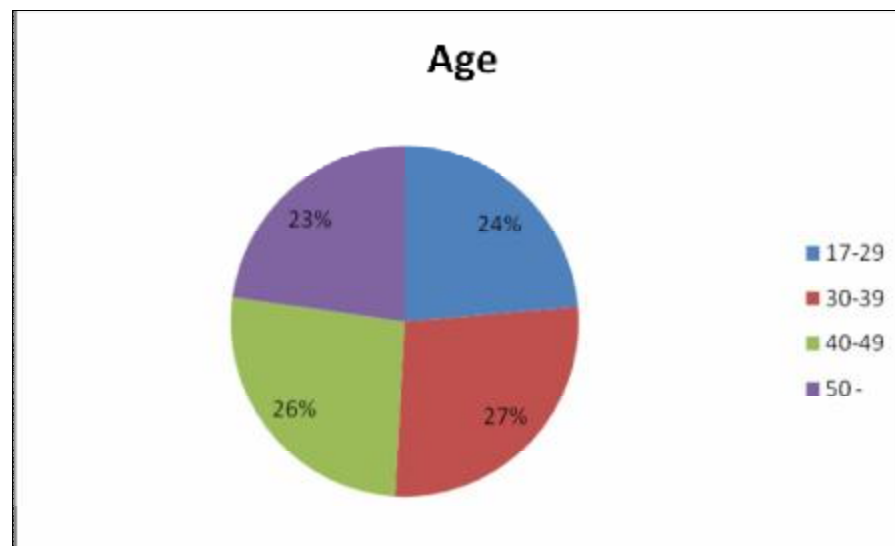


Table 3.4 – Descriptive statistics of demographic section

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Age	114	17	62	39.49	11.509

Four age groups comprising similar numbers illustrate that the factory has an even spread of employees of all different ages, giving more accurate results than with an uneven spread.

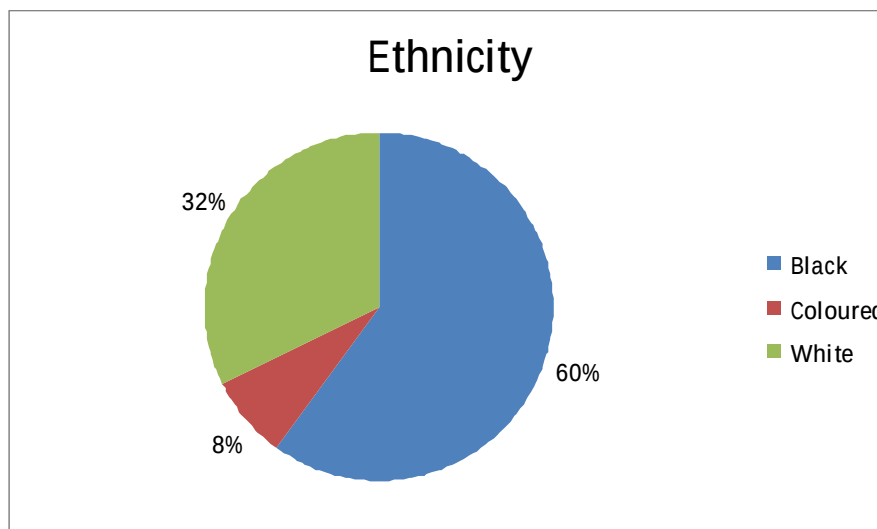
3.3.4.2 Ethnicity

The data for race is gathered to establish whether there are differences between the race groups in their awareness of 'lean' tools. Many African employees have neither English nor Afrikaans as a mother tongue. This must be remembered when the 'lean' tools and techniques are implemented.

Table 3.5 – Frequencies of ethnic groups in demographic section.

Ethnicity	Frequency	Valid per cent	Cumulative per cent
Black	69	60.0	60.0
Coloured	9	7.8	67.8
White	37	32.2	100.0
Total	115	100.0	

Figure 3.2 – Ethnicity race groups



The majority of the respondents were black Africans; some respondents were coloured, while the rest were white. There were no other race groups involved in the manufacturing.

3.3.4.3 Years of service

Years of service are studied to determine whether awareness of the 'lean' principles increased commensurately with years of service.

Table 3.6 – Frequencies of duration of service groups in demographic section.

	Frequency	Valid per cent	Cumulative per cent
0– 4	50	44.2	44.2
5 – 9	27	23.9	68.1
10 -14	13	11.5	79.6
15 -	23	20.4	100.0
Total	113	100.0	
Missing System	2		
Total	115		

Figure 3.3 – Years of service

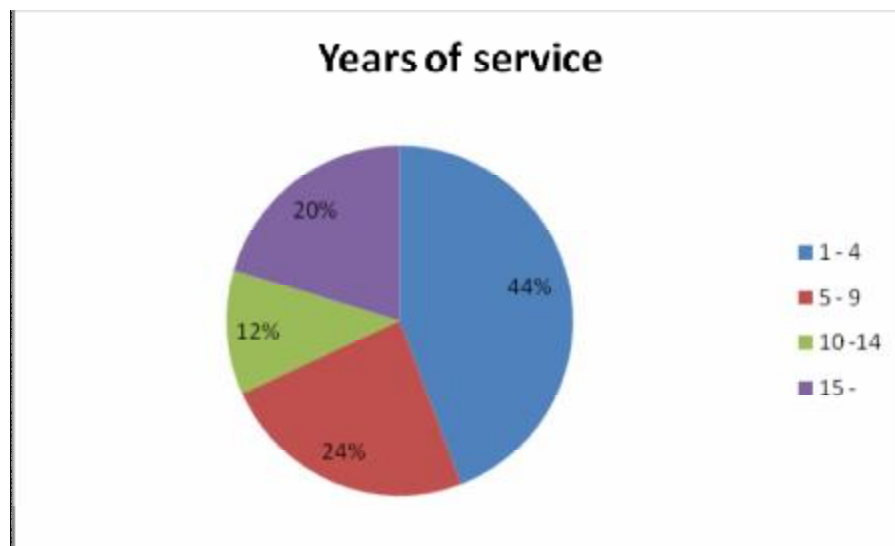


Table 3.7 – Descriptive statistics of demographic section

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Years of service	113	1	31	8.32	7.027

A large percentage (44%) of the respondents has fewer than five years of service at the company, while only 32% have more than 10 years of service. Newer respondents may have obtained some 'lean' principles from previous employers, while older respondents with longer service records may be unfamiliar with the 'lean' principles.

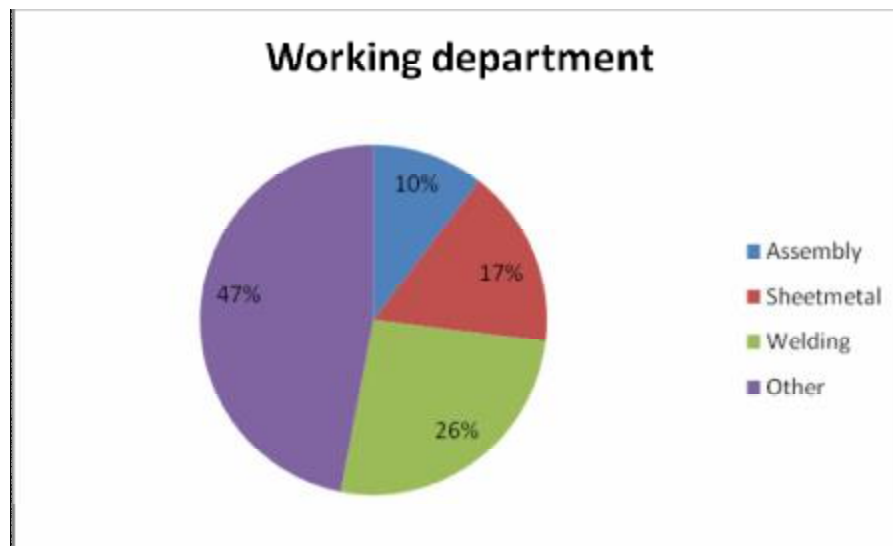
3.3.4.4 Department

The working department data were also obtained in order to see differences of awareness and application. Different departments may have differing opinions

Table 3.8 – Frequencies of departmental groups in demographic section.

Working department	Frequency	Valid per cent	Cumulative per cent
Assembly	12	10.4	10.4
Sheet metal	19	16.5	27.0
Welding	30	26.1	53.0
Other	54	47.0	100.0
Total	115	100.0	

Figure 3.4 – Working department



47% of the respondents are part of the other group such as machining, galvanizing or painting. More grouping options would have given a clearer picture of the the correlations of the different departments.

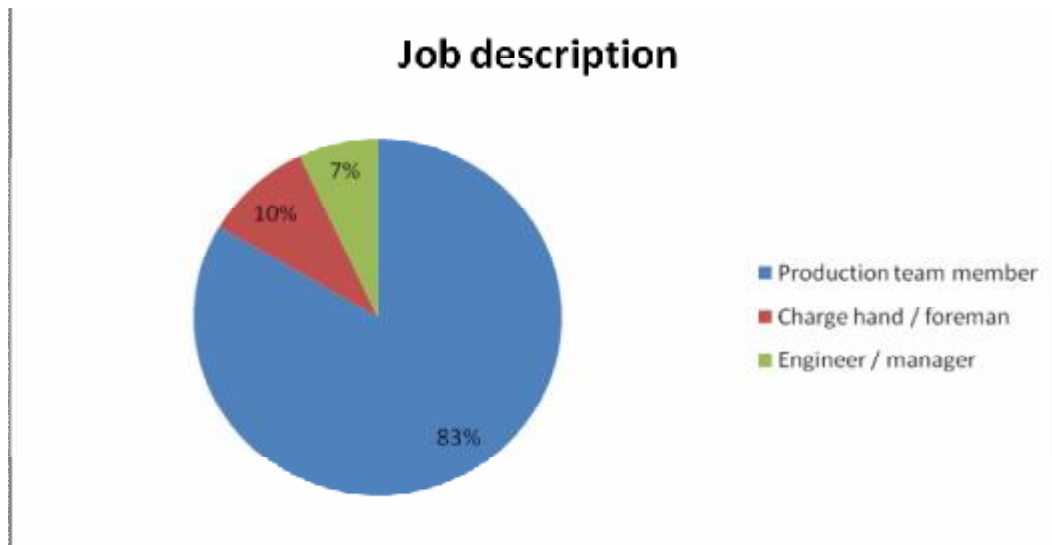
3.3.4.5 Job description

There are several job levels in the manufacturing plant. The various job descriptions are tested to establish the opinions held by employees at various job levels. Certain levels had already received 'lean' education. This would allow for differences of opinion on the application and awareness of the 'lean' tools and techniques.

Table 3.9 – Frequency of job description groups in demographic groups

Job description	Frequency	Valid per cent	Cumulative per cent
Production team member	96	83.5	83.5
Charge hand / foreman	11	9.6	93.0
Engineer / manager	8	7.0	100.0
Total	115	100.0	

Figure 3.5 – Job description



83% of the respondents were production team members while the rest were either engineers or managers or at least a charge hand or foreman. It is important to know the job description of the respondent, in order to establish whether there is a difference of opinion between management and the respondent on the floor.

The production team members are all employees that are not part of some kind of supervisory or management position.

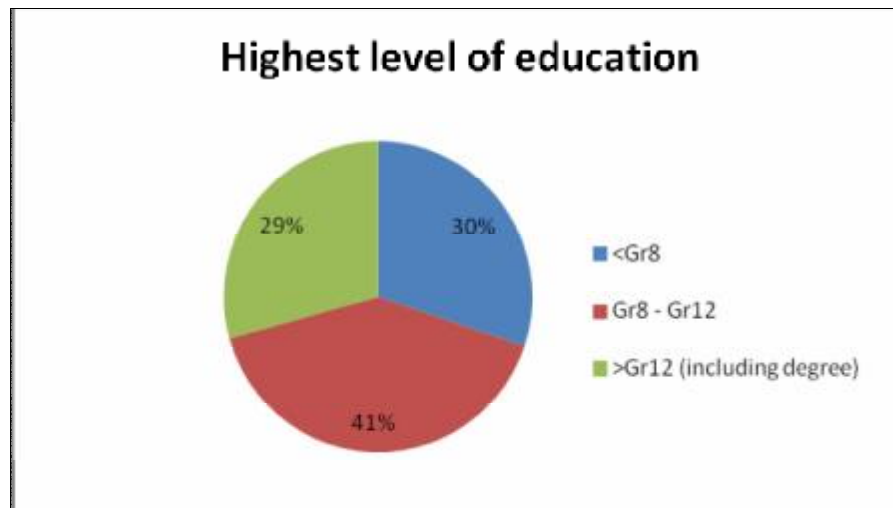
3.3.4.6 Highest education

To establish an understanding of 'lean' manufacturing tools and techniques, it is crucial to know the education level of the respondents; the highest education level was required by the questionnaire.

Table 3.10 – Frequency of education groups in demographic groups

Highest education	Frequency	Valid per cent	Cumulative per cent
<Gr8	37	32.2	32.2
Gr8 - Gr12	50	43.5	75.7
>G12 (including degree)	36	24.4	100.0
Total	115	100.0	

Figure 3.6 – Highest level of education



Almost a third (32%) of the total respondents had either no school education or only primary school education (Figure 3.6). All of these respondents are production team members. This must be kept in mind when educating them further on 'lean' principles. The implementation and teaching of the 'lean' principles should be done somewhat slower than it would normally be done.

The majority of the 24% with further education is either part of the charge hand/foreman or manager/engineer group. Only a small part of the production members have any qualifications after grade 12. Included in the group with an education above grade 12 are the managers and engineers with degrees.

3.3.5 Awareness

The awareness section tested the respondents' knowledge on a few 'lean' tools and techniques obtained from Chapter Two. Table 3.11 will give the descriptive statistics from the analysis. Only the highest and lowest mean value will be discussed; also any other variable that displays remarkable results.

Table 3.11 – Descriptive statistics of Awareness section

Variable	Mean	Standard Deviation
Set-up times	3.10	.737
Waste in the factory	2.62	.854
Lean principles	3.01	.613
Cycle time	3.01	.760
5S Housekeeping	3.08	.651
Quality management	3.07	.732
Value-stream mapping	1.91	1.077
Six Sigma	2.91	.762
Cellular manufacturing	2.51	.836
Bottlenecks	2.53	.910

A mean value of 1 indicates 'Very weak' while 4 indicates 'Very good'. It is seen that value-stream mapping has the lowest mean value. This indicates that the respondent has very little knowledge of the topic. Value-stream mapping also has the highest standard deviation. Thus implying that there are more respondents that know absolutely nothing on the topic and others that are more informed.

Set-up time reduction has the highest mean value, showing that respondents are familiar with set-up times. This is a positive indication of set-up time's being the most-used 'lean' tool in reducing cycle time of the manufacturing process. This was mentioned in Chapter Two. Once respondents have good knowledge in this field, it becomes easier to reduce set-up times.

3.3.6 Application

Table 3.12 shows the average values given by descriptive statistics. A mean value of 2.79 indicates that the respondent's overall opinion is closer to an "agree" than a "disagree". The standard deviation is fairly small, meaning that they agree more or less on all the variables.

Table 3.12 – Descriptive statistics of average application section

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Standard Deviation
Average Application	114	2.03	3.7	2.7908	.28646

Table 3.13 shows all the variables from the application questions below.

Table 3.13 – Descriptive statistics of Application section

Question	Variable	Mean	Standard Deviation
2.1	Do you think you can reduce set-up times?	2.86	.815
2.2	Do you need to do rework on parts already manufactured?	2.63	.914
2.3	Do you make more than two days' worth of parts in each batch?	2.62	.886
2.4	Do you have waiting time for a machine?	2.87	.885
2.5	Do you do unnecessary transporting of parts?	2.40	.759
2.6	Do you have unnecessary movement of people?	2.49	.865
2.7	Do you do unnecessary processing of parts?	2.31	.723
2.8	Do inventories have waiting times for further processing?	2.71	.703
2.9	Are you dependent on a kanban system in your department?	2.96	.690
2.10	Do you have the need to be part of a multifunctional team?	3.01	.738
2.11	Do you think we could reduce batch sizes?	2.48	.733
2.12	Do you make use of a supermarket pull system?	3.07	.623
2.13	Do you do regular improvements of production?	2.71	.680
2.14	Do you think you can increase the number of products manufactured per day?	3.00	.671
2.15	Does your department need regular organizing (weekly)?	2.99	.605
2.16	Do you organize your workstation every day?	2.86	.658
2.17	Does your department need regular cleaning (weekly)?	3.16	.527
2.18	Do you clean your workstation every day?	2.72	.706
2.19	Do you have control of the quality of parts you manufacture?	3.09	.558
2.20	Do you want to work in a manufacturing cell?	2.78	.713
2.21	Do you make the same parts every day?	2.43	.822
2.22	Do you have a need for more safeguards in your process to prevent errors?	2.88	.707
2.23	Is there a bottleneck in your process?	2.80	.719
2.24	Do you think we could reduce bottlenecks in the process?	2.88	.651
2.25	Do you wait for parts from other departments?	2.86	.769
2.26	Can you reduce the process time of the products you manufacture?	2.76	.669
2.27	Do you think Six-Sigma quality will add value to our process?	2.86	.596
2.28	Do you have a need for a value-stream map in your department?	2.58	.623
2.29	Do you think we should implement 'lean' principles?	2.96	.499
2.30	Do you experience regular bottlenecks?	2.90	.752

The highest mean value of 3.16 is found at question 2.17. The question asked the respondent whether he cleaned his workplace weekly. The next question, with a mean of 2.72, asked whether the respondent cleaned his workplace daily. The lower mean value indicates that the respondent is most likely to clean his workspace weekly rather than daily. This illustrates the need for the implementation of a 5S programme. This was also confirmed on a visual screening by the researcher. The standard deviation of Question 2.17 is fairly low, indicating that the respondents agree that they do regular cleaning in their work areas.

The lowest mean value from Table 3.10 is from Question 2.7 – Waste reduction – unnecessary processing on parts. This means that unnecessary processing is the smallest form of waste in the manufacturing plant. The standard deviation is quite high, indicating that some respondents do not feel that they perform unnecessary processing while others strongly agree that unnecessary processing occurs.

The average application variables are sorted by applicable awareness variables. Mean awareness variables and mean application variables will be plotted against each other by the use of a radar diagram. This will shows any outliers.

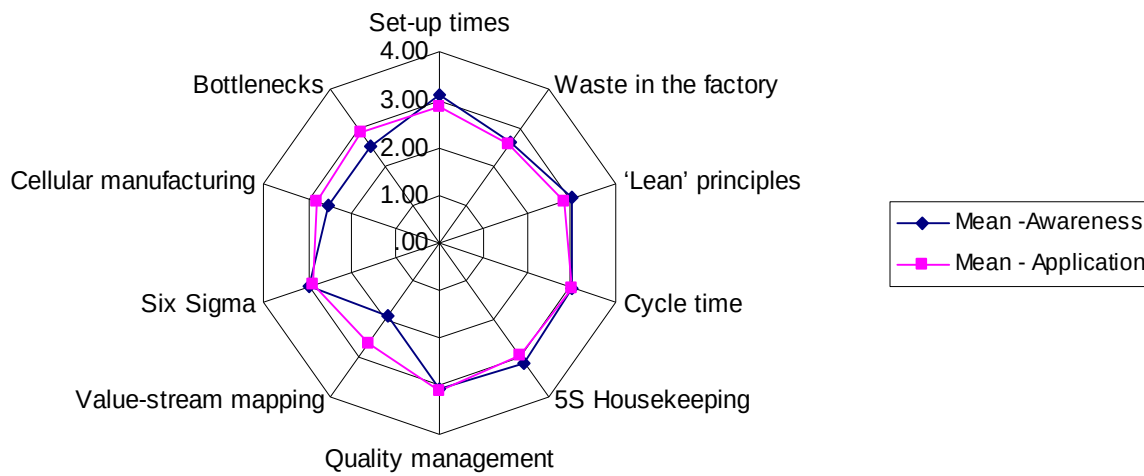
Section 2 (Awareness) tested for 10 variables. The 30 questions from section 3 (Application) were divided into the appropriate variables from section 2. The mean application values were calculated from these variables.

Table 3.14 – Constructs with mean values on Awareness and Application

Construct variable	Awareness mean	Awareness Standard deviation	Application mean	Application Standard deviation
Set-up times	3.10	0.737	2.86	0.815
Waste in the factory	2.62	0.854	2.58	0.819
'Lean' principles	3.01	0.613	2.81	0.693
Cycle time	3.01	0.760	3.00	0.671
5S Housekeeping	3.08	0.651	2.93	0.624
Quality management	3.07	0.732	3.09	0.558
Value-stream mapping	1.91	0.737	2.58	0.623
Six-Sigma	2.91	0.854	2.86	0.596
Cellular manufacturing	2.51	0.613	2.78	0.713
Bottlenecks	2.53	0.760	2.86	0.707

Figure 3.7 – Radar diagram with mean values of Awareness and Application

Mean - Awareness v Mean - Application on radar diagram



It is seen from Figure 3.7 that the respondents are aware of almost all the constructs that were tested, however, their awareness on waste in the factory, bottlenecks, cellular manufacturing and value-stream mapping was slight.

Although all the mean values are around three, the respondents' opinion on the application of waste, value-stream mapping, bottlenecks, Six Sigma and cellular manufacturing were the least definite.

From pre-scientific evidence it was found that there is fairly large quantity of waste in the manufacturing process. Because the awareness of waste is remarkably low, it is obvious that respondents are not under the impression that there is waste in the plant; consequently it cannot be reduced.

The application of set-up time is quite high and this corresponds with the conclusions of Chapter Two that set-up times should be reduced.

The awareness of value-stream mapping is the lowest; while the feedback on application is also low. Value-stream mapping is a tool mainly used by managers in eliminating waste. Should all the respondents be more aware of value-stream mapping and waste, they could assist managers in eliminating waste and drawing future state value-stream maps.

Respondents are well aware of quality management, feeling that quality should improve. This offers scope for further study - quality management could be complex and intensive. This also confirms the literature study stating that Total Quality Management is one of the most-used 'lean' tools in reducing cycle time.

The overall opinion of the respondents is lower for the application of these tools although it was determined that cycle time could be reduced drastically. It may be difficult to convince the respondents to change their current way of doing their job. The respondent will have a high resistance to change and that must be borne in mind when the new 'lean' tools and techniques are implemented.

3.3.7 Frequency distribution diagrams

Frequency distribution diagrams were drawn of all the variables in the application section. The variables worthy of remark will be discussed below.

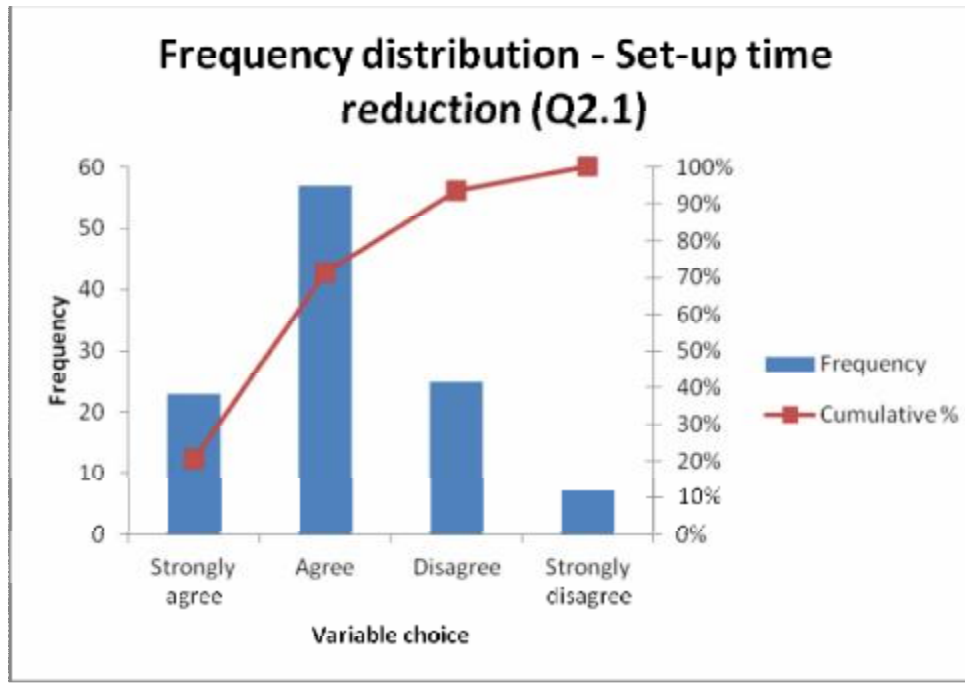
3.3.7.1 Set-up time reduction

Set-up time reduction as expressed in Chapter Two, is regarded as the most important cycle time reduction tool. The table and figure below will indicate the response to this aspect of the questionnaire.

Table 3.15 – Set-up time reduction (Q2.1)

	<i>Frequency</i>	<i>Percentage</i>	<i>Cumulative %</i>
Strongly agree	23	20.54%	20.54%
Agree	57	50.89%	71.43%
Disagree	25	22.32%	93.75%
Strongly disagree	7	6.25%	100.00%
Missings	3		

Figure 3.8 – Frequency distribution of Set-up time



71.4% of the population feels that it is possible to reduce set-up times in the plant. This confirms that the manufacturing plant agrees with the literature that reduced set-up time is an important tool in reducing cycle time. A speedier set-up time allows for reduction in batch sizes, which also reduces cycle time.

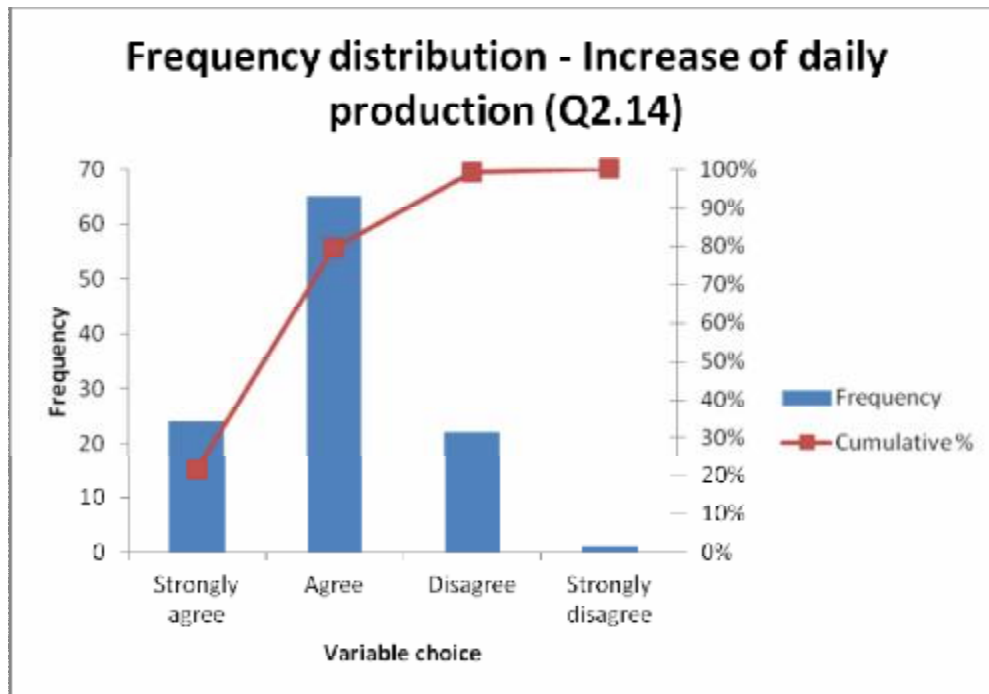
3.3.7.2 Production increase/Cycle-time reduction

Cycle-time reduction will result in an increase in productivity. Production increase was tested with Question 2.14; the result is shown below.

Table 3.16 – Increase daily production (Q2.14)

	<i>Frequency</i>	<i>Percentage</i>	<i>Cumulative %</i>
Strongly agree	24	21.43%	21.43%
Agree	65	58.04%	79.46%
Disagree	22	19.64%	99.11%
Strongly disagree	1	0.89%	100.00%
Missings	3		

Figure 3.9 – Frequency distribution of production increase (Cycle time reduction)



79.46% of the respondents agreed that they can increase their daily production in some way or another. The aim of the study is to reduce cycle time. Almost 80% of the respondents agree that this is possible. It is only possible by implementing the 'lean' tools and techniques discussed in Chapter Two.

It was not asked why they responded positively to this question but the it was assumes that this is because the total amount of waste is reduced in the process.

3.3.7.3 5S Housekeeping

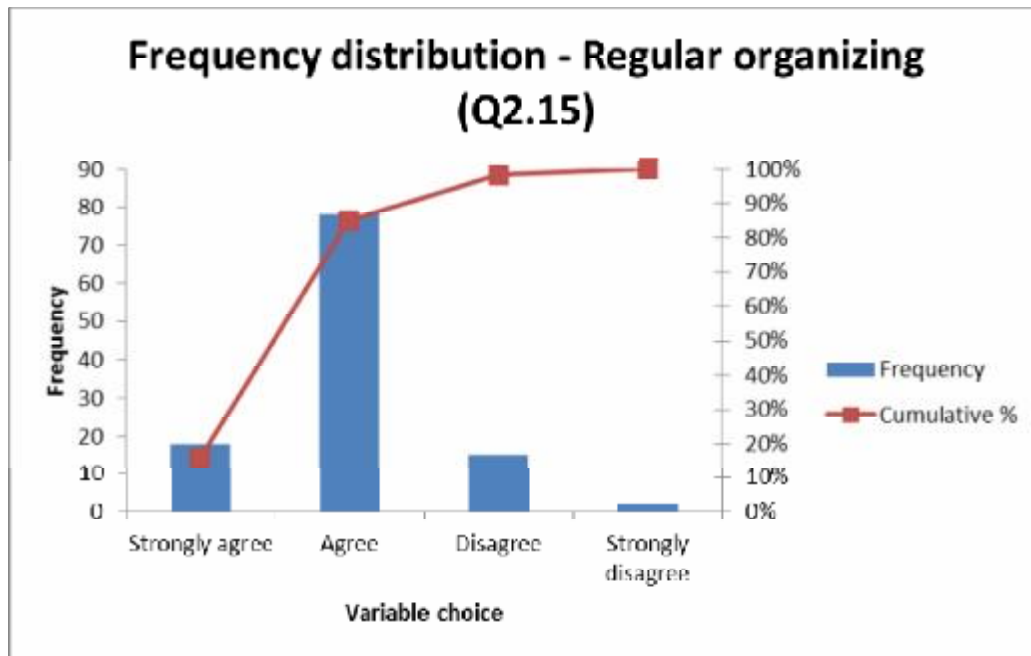
5S Housekeeping is regarded as a highly effective tool in organizing the workplace, maintaining it in that state. The response to regular organizing and regular cleaning will be analysed.

Regular organizing:

Table 3.17 – Regular organizing (Q2.15)

	Frequency	Percentage	Cumulative %
Strongly agree	18	15.93%	15.93%
Agree	78	69.03%	84.96%
Disagree	15	13.27%	98.23%
Strongly disagree	2	1.77%	100.00%
Missings	2		

Figure 3.10 – Frequency distribution of Regular organizing (5S Housekeeping)



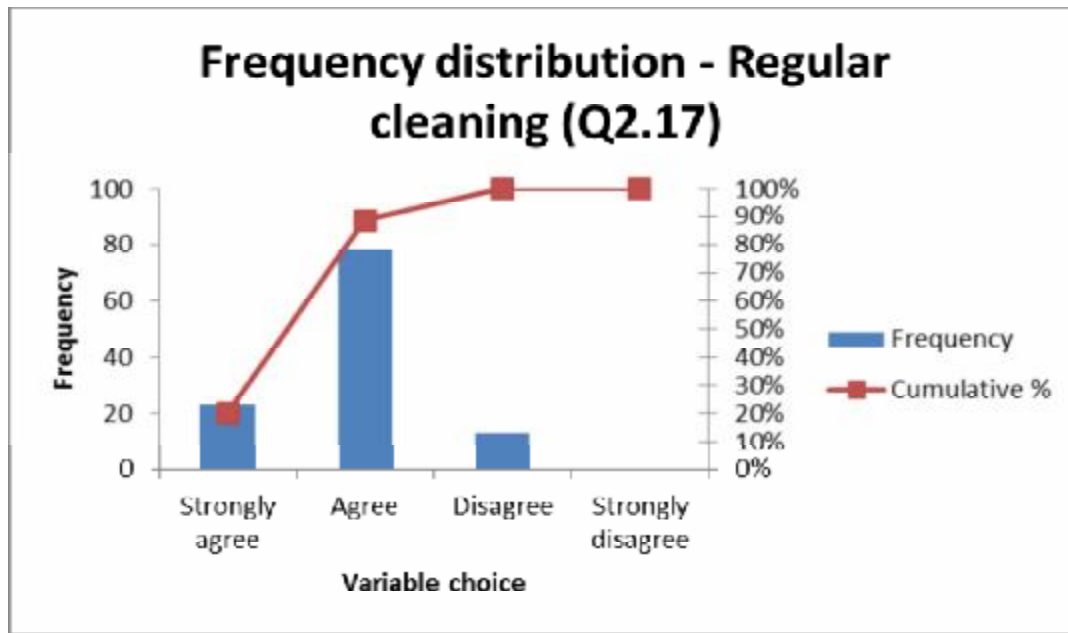
85% of the respondents agreed that their department needed a weekly organizing. Respondents are used to the weekly routine organizing of the department. They might well be willing to organize it daily, so maintaining or improving the state of the department.

Regular cleaning:

Table 3.18 – Regular cleaning (Q2.17)

	<i>Frequency</i>	<i>Percentage</i>	<i>Cumulative %</i>
Strongly agree	23	20.18%	20.18%
Agree	78	68.42%	88.60%
Disagree	13	11.40%	100.00%
Strongly disagree	0	0.00%	100.00%
Missings	1		

Figure 3.11 – Frequency distribution of Regular cleaning (5S Housekeeping)



A massive 95% of respondents need to clean their workstation on a weekly basis. The respondents are used to the weekly routine of cleaning their departments; they might well clean it daily to maintain or improve the state of the department. Thus it is necessary to implement 5S principles within the plant.

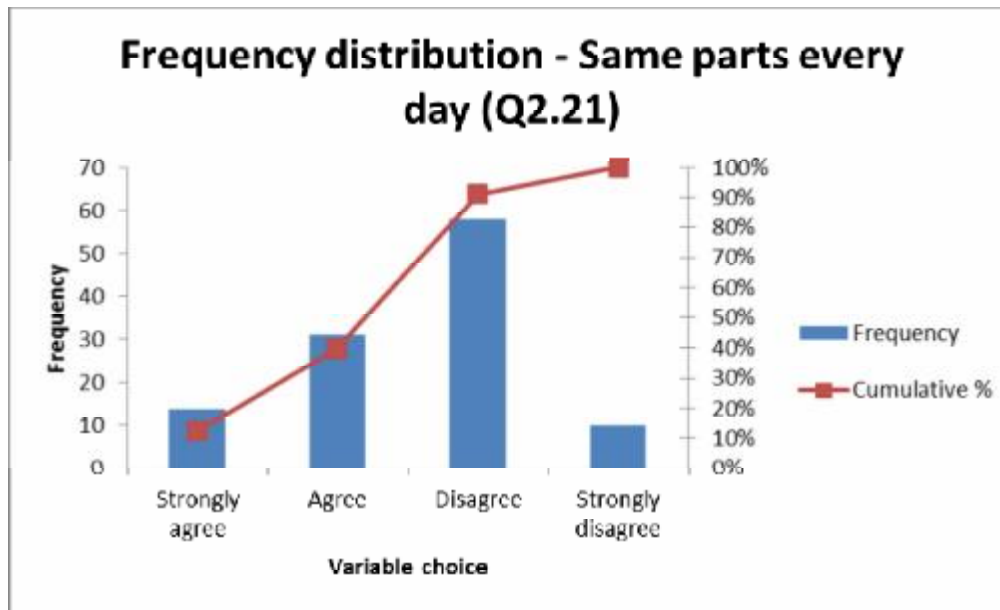
3.3.7.4 Work levelling

Work levelling or *Heijunka* is a way of levelling the workload by manufacturing every part every day. This will reduce system fatigue, ensuring a constant 'pull' of parts throughout the value chain.

Table 3.19 – Same parts every day (Q2.21)

	Frequency	Percentage	Cumulative %
Strongly agree	14	12.39%	12.39%
Agree	31	27.43%	39.82%
Disagree	58	51.33%	91.15%
Strongly disagree	10	8.85%	100.00%
Missings	2		

Figure 3.12 – Frequency distribution of the Same parts every day (*Heijunka*)



A mere 40% of the respondents make the same parts every day. This confirms the need to reduce set-up time in order to reduce cycle times. With a speedier set-up time it will be possible to change more frequently from one batch of parts to another.

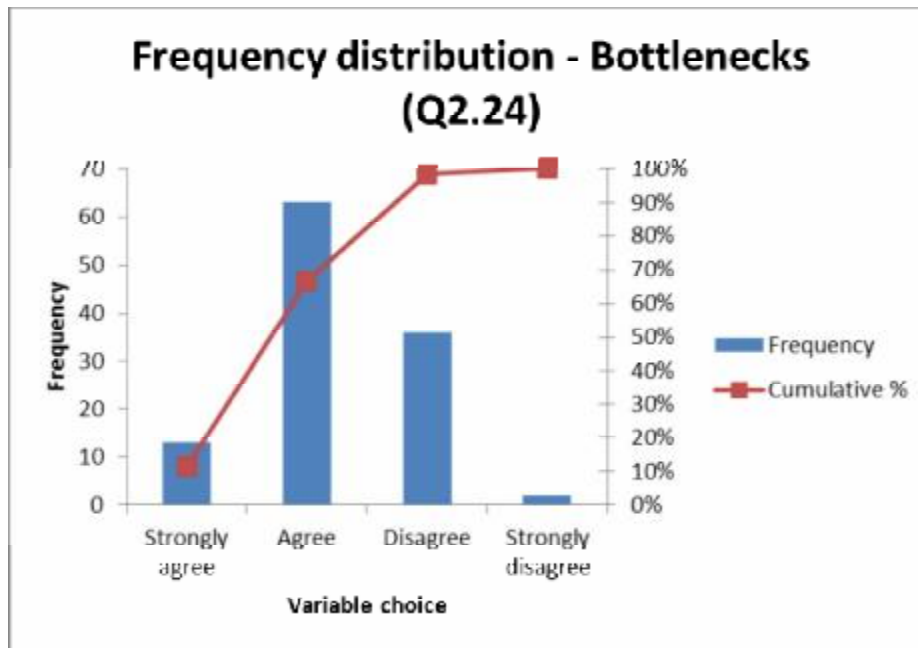
3.3.7.5 Bottlenecks

A bottleneck prohibits a process from running smoothly, having a direct influence on cycle time.

Table 3.20 – Bottlenecks (Q2.24)

	<i>Frequency</i>	<i>Percentage</i>	<i>Cumulative %</i>
Strongly agree	13	11.40%	11.40%
Agree	63	55.26%	66.67%
Disagree	36	31.58%	98.25%
Strongly disagree	2	1.75%	100.00%
Missings	1		

Figure 3.13 – Frequency distribution of the Bottlenecks



Three quarters (67%) of the population agreed that bottlenecks should be reduced. A reduction or elimination of bottlenecks will result in a quicker cycle time.

3.3.8 Correlations

3.3.8.1 Spearman's rho (ρ)

Spearman's correlation coefficient (Spearman's rho (ρ)) is a non-parametric statistic which can be used when the data have violated parametric assumptions such as non-normally distributed data. Spearman's test works by first ranking all the data and then by applying Pearson's equation to rank the data (Field, 2009:180).

According to Levine *et al.*, (2008: 128), the coefficient of correlation (ρ) is used to measure the relative strength of a linear relationship between two numerical variables. The value of ρ ranges from -1 for a perfect negative correlation to $+1$ for a perfect positive correlation. A ρ -value of 0 means that there is no correlation between the two variables.

The guidance values are as follows:

$\rho \sim 0.1$ – Small correlation. No practical significant correlation

$\rho \sim 0.3$ – Medium correlation. Visible practical correlation

$\rho \sim 0.5$ – Good correlation. Practical significant correlation

Levine *et al.* (2008:334) describes the level of significance as the size of the sample that can be rejected which still gives significant critical values. A level of significance of 0.05 indicates the size of rejection of 5% which is divided into two tails of 2,5% on either side of the distribution table.

Table 3.21 – Correlations between demographics and average application

		Average application
Age	Correlation Coefficient (ρ)	-0.187
	p-value (if random sample is assumed)	0.048
Years of service	Correlation Coefficient (ρ)	-0.095
	p-value (if random sample is assumed)	0.317
Highest education	Correlation Coefficient (ρ)	0.243
	p-value (if random sample is assumed)	0.009

Age: There is a small to medium negative correlation between the age of the respondents and the application of the 'lean' tool system. The negative correlation means that younger responders are keener to implement 'lean' tools which may be because they have less resistance to change.

Years of service: There is a small negative correlation between the years of service of the respondents and the application of the 'lean' tool system.

Highest education: There is a medium correlation between highest education of the respondents and the application of the lean tools. It is concluded that the higher the education level the keener the respondents are to apply the 'lean' tools and techniques.

Table 3.22 – Descriptive statistics of average application variables

	Mean	Standard Deviation
Average Awareness (Q1)	2.7635	.41571
Average Waste	2.4095	.48273
Average 5S Housekeeping	2.0417	.43665
Average Bottlenecks	2.1345	.56394
Average Lean principles	2.1883	.31594

Table 3.22 shows that the average mean value for the awareness questions is 2.76. This indicates that the respondents are on average slightly more aware of the 'lean' tools.

3.3.8.2 Correlations – Average Awareness v Average Application

Table 3.23 – Correlation between average awareness and average application

Correlations		
		Average Application (Q2)
Average Awareness (Q1)	Correlation Coefficient	0.260
	p-value (if random sample is assumed)	.005

There is a medium correlation between the average awareness of the 'lean' tools and the respondents' average opinion that the lean tools should be applied. This means that when the awareness of the lean tools is increased, the opinion of their application will also improve.

3.3.8.3 Correlations – Cycle time v Production Increase

Table 3.24 – Correlation between production increase and awareness

		Production increase (Q2.14)
Cycle time reduction (Q1.4)	Correlation Coefficient	0.212
	p-value (if random sample is assumed)	.027

Table 3.24 illustrates that there is a small to medium correlation between the knowledge and awareness of cycle time and the need for reducing the cycle times. This means that when the awareness of the cycle time is increased the opinion of its application will also improve.

3.3.8.4 Correlations – 5S Housekeeping v Average 5S Housekeeping

Table 3.25 – Correlation between 5S housekeeping awareness and application

		Application 5S Housekeeping (Q2.15 – Q2.18)
Awareness 5S Housekeeping (Q1.5)	Correlation Coefficient	0.373
	p-value (if random sample is assumed)	0.000

There is a medium to large correlation between the knowledge and awareness and the need to implement 5S housekeeping. This means that when the awareness of the 5S housekeeping tool is heightened, its application will receive concomitant approval.

3.3.8.5 Correlations – Bottlenecks v Average Bottlenecks

Table 3.26 – Correlations between bottlenecks and awareness

		Average bottlenecks (Q2.23, 2.24, 2.30)
Bottlenecks (Q1.10)	Correlation Coefficient	0.298
	p-value (if random sample is assumed)	0.001

Table 3.26 shows that there is a medium correlation between the knowledge and awareness of the respondents and whether bottlenecks should be reduced or eliminated.

3.3.8.6 ANOVAs

ANOVA stands for the analysis of variance and is regarded as a robust test. ANOVA is used independently in situations when one wants to compare several means.

Effect size: ~0.2 – Slight effect, no practical significant difference.
 ~0.5 – Medium effect, visible practical difference.
 ~0.8 – Great effect, practical significant difference.

Significance: $p < 0.05$ – Statistically significant difference
(Field, 2009:389)

Table 3.27 – Effect size, Ethnicity and average application

	N	Mean	Standard Deviation	p-value	Effect size	
					1 with	2 with
Black	69	2.7462	.25860	0.074		
Coloured	9	2.7767	.22930		0.12	
White	36	2.8799	.33296		0.40	0.31
Total	114	2.7908	.28646			

From Table 3.27 it is evident that there is a slight to medium effect between the Caucasian respondents and other race groups. This implies that Caucasian respondents feel marginally stronger than other race groups that 'lean' tools should be implemented.

Table 3.28 – Effect size – Department and average application

	N	Mean	Standard Deviation	p-value	Effect size		
					1 with	2 with	3 with
Assembly	12	2.8620	.28535	.416			
Sheet metal	18	2.7466	.15048		0.40		
Welding	31	2.7368	.29238		0.43	0.03	
Other	53	2.8213	.31598		0.13	0.24	0.27
Total	114	2.7908	.28646				

The mean values of the various departments are almost the same: this indicates that these departments feel the same about the 'lean' tools and techniques.

There is a medium effect between Assembly, Sheet metal and Welding which indicates that they mostly agree on the application of the 'lean' tools and techniques.

Table 3.29 – Effect size - Job description and average application

	N	Mean	Standard Deviation	p-value	Effect size	
					1 with	2 with
Production team member	96	2.7454	.24194	.00014		
Charge hand / foreman	10	2.9602	.30886		0.70	
Manager / Engineer	8	3.1236	.46035		0.82	0.35
Total	114	2.7908	.28646			

The manager and engineering group has the highest mean value for application. It is known that they have already had 'lean' education. Their opinion is more trustworthy because they are more familiar with the 'lean' tools and techniques.

It may be more difficult to convince the production team members: they may be resistant to any changes in the manufacturing process.

3.4 SUMMARY

A comprehensive empirical study was conducted, including three sections: demographic, awareness and application. It was proven that the questionnaire was reliable.

Several tables and graphs were given to illustrate the data and results from the statistical analyses. These tables and graphs were used in drawing conclusions from the empirical study.

The empirical study also confirmed that set-up time should be reduced. This displays the opportunity to make employees more aware of the seven 'deadly' wastes that are found in manufacturing plant.

About 80% of the respondents agreed that cycle time can be reduced in the manufacturing plant. This will be achieved by implementing the 'lean' tools and techniques discussed in Chapter Two.

Most of the employees confirm that there are bottlenecks in their process. This topic requires attention in order to reduce the cycle time in the plant.

The respondents also confirmed that they are well aware of most of the 'lean' tools and principles. Their opinion is positive: 'lean' tools and techniques can be implemented.

The results obtained in chapters two and three can now be used in developing a procedure for optimising cycle time in the manufacturing plant.

4 CHAPTER FOUR

4.1 INTRODUCTION

A thorough literature study was conducted on the available 'lean' tools and techniques to reduce the total cycle time of products manufactured. From Table 2.2 it was concluded that certain lean tools and techniques are easy to implement and will make a huge impact on the reduction of cycle times. From the empirical study done in Chapter Three it was found that respondents feel more or less the same that the specific 'lean' tools and techniques should be implemented.

In this chapter recommendations and conclusions for the reduction in cycle time will be offered. The reduction in cycle time will be confirmed by drawing future state value-stream map by implementing the knowledge obtained from the discussed 'lean' tools and techniques.

Suggestions for further studies on the topic of reduction of cycle times are also discussed in this chapter.

4.2 DISCUSSION OF RESULTS

Several results were obtained from Chapter Two and Three. The results were positive which means that cycle time can be reduced fairly easily. The results showing the biggest reduction in cycle time are discussed below:

- It was found from Table 2.2 that set-up time reduction is the most propounded 'lean' tool in the literature for **reducing cycle time**. The empirical study confirmed that the respondents feel fairly strongly that set-up times can be reduced.
- It was found from pre-scientific evidence and from the response from the empirical study that there is a substantial amount of **waste** in the plant needing to be eliminated.
- The empirical study confirms that the plant is untidy. This situation can be rectified by the well-known **5S housekeeping** tool which organizes and cleans the plant, ensuring that orderliness is maintained.
- There are a substantial number of **bottlenecks** which should be eliminated; this will result in a faster cycle time.

4.3 CONCLUSIONS

Value-stream mapping includes all the actions currently required when bringing a product through the main flows as is essential to every product. It was found from the empirical study that respondents are unaware of value-stream mapping (Table 3.7). The future state value-stream map is designed by setting up a current state value-stream map, using the 'lean' manufacturing tools and techniques to draw the future state values-stream map. The current state map shows all the waste and non-value adding steps in the process. By eliminating these non-value adding steps it will be possible to reduce the cycle time of Product X.

A process chart shows all the process steps in sequence and the type of process needed for the step. The process chart focuses on one process in the value-stream map at a time. The time line on the right-hand side indicates the time of the process and the total time taken, included the last step performed.

The value adding step is very noticeable in the process chart and is the step which would be the easiest to improve.

It is not always possible to reduce all the waste in the process, but as much waste as possible should be eliminated.

Process charts are shown below demonstrating the improvement of the cycle time by means of set-up time reduction and waste elimination.

Table 4.1 – Process chart – Current state

Step#	Step description	Current state					Time taken (s)	Total time (s)
		Operation	Transportation	Inspection	Delay	Storage		
1	Hot weld on frog to jig	○	→	□	D	✓	40	40
2	Place gusset in line	○	→	□	D	✓	20	60
3	Place the bush in line slot	○	→	□	D	✓	20	80
4	Place line in jig	○	→	□	D	✓	40	120
5	Insert pin through jig and bush	○	→	□	D	✓	25	145
6	Tack weld on frog to line	○	→	□	D	✓	30	175
7	Tack gusset to bush	○	→	□	D	✓	30	205
8	Tack bush and gusset to line	○	→	□	D	✓	30	235
9	Remove bolts from weld on frog	○	←	□	D	✓	25	260
10	Remove pin from line bush	○	←	□	D	✓	30	290
11	Remove line from jig	○	←	□	D	✓	60	350
12	Hot line to work bench	○	→	□	D	✓	90	440
13	Place bolt through line bush	○	→	□	D	✓	60	500
14	Insert braces on each side of line bush	○	→	□	D	✓	60	560
15	Tighten bolt through line bush	○	→	□	D	✓	60	620
16	Place line ear jig in position on line	○	→	□	D	✓	60	680
17	Attach left line ear to line ear jig	○	→	□	D	✓	40	720
18	Attach right line ear to line ear jig	○	→	□	D	✓	40	760
19	Insert bolt through left line ear, left braces, jig, right brace and right ear	○	→	□	D	✓	60	820
20	Tack ears to line	○	→	□	D	✓	40	860
21	Remove bolt from line bush	○	→	□	D	✓	40	900
22	Remove bolt from braces and line ear jig	○	→	□	D	✓	60	960
23	Remove braces and jig	○	→	□	D	✓	40	1000
24	Unscrew line from work bench	○	→	□	D	✓	40	1040
25	Place line on work bench (left side on top)	○	→	□	D	✓	40	1080
26	Weld weld on frog	○	→	□	D	✓	120	1200
27	Weld left line ear	○	→	□	D	✓	120	1320
28	Weld left bush and gusset	○	→	□	D	✓	180	1500
29	Turn line around	○	→	□	D	✓	60	1560
30	Weld weld on frog	○	→	□	D	✓	120	1680
31	Weld right line ear	○	→	□	D	✓	120	1800
32	Weld bush and gusset	○	→	□	D	✓	180	1980
33	Remove line from work bench	○	→	□	D	✓	60	2040
Total cycle time (min)								34
Value adding time = Operational time / Total time (1485/2040) = 73%								
○ = Operation → = Transportation □ = Inspection D = Delay ✓ = Storage								

Table 4.2 – Process chart – Future state (with reduced set-up time)

Future state (reduced set-up time)							Time taken (s)	Total time (s)
Step#	Step description							
1	Bot weld on frog to jig	○	⇒	□	○	▽	40	40
2	Place gusset in time slot	○	⇒	□	○	▽	20	60
3	Place time bush in time	○	⇒	□	○	▽	20	80
4	Place time in jig	○	⇒	□	○	▽	40	120
5	Insert pin through jig and bush	○	⇒	□	○	▽	25	145
6	Place time ear jig in position on time	○	⇒	□	○	▽	40	185
7	Attach left time ear to time ear jig	○	⇒	□	○	▽	40	225
8	Attach right time ear to time ear jig	○	⇒	□	○	▽	40	265
9	Insert bolt through left time ear, jig and right ear and tighten	○	⇒	□	○	▽	60	325
10	Tack ears to time	○	⇒	□	○	▽	40	365
11	Tack weld on frog to time	○	⇒	□	○	▽	30	395
12	Tack gusset to bush	○	⇒	□	○	▽	30	425
13	Tack bush and gusset to time	○	⇒	□	○	▽	30	455
14	Remove bolts from weld on frog	○	⇒	□	○	▽	25	480
15	Remove pin from time bush	○	⇒	□	○	▽	30	510
16	Remove time from jig	○	⇒	□	○	▽	60	570
17	Place time on work bench (left side on top)	○	⇒	□	○	▽	40	610
18	Weld weld on frog	○	⇒	□	○	▽	120	730
19	Weld left time ear	○	⇒	□	○	▽	120	850
20	Weld left bush and gusset	○	⇒	□	○	▽	180	1030
21	Turn time around	○	⇒	□	○	▽	60	1090
22	Weld weld on frog	○	⇒	□	○	▽	120	1210
23	Weld right time ear	○	⇒	□	○	▽	120	1330
24	Weld bush and gusset	○	⇒	□	○	▽	180	1510
25	Remove time from work bench	○	⇒	□	○	▽	60	1570
Total cycle time (min)								26
Value adding time – Operational time / Total time (1295 / 1570) – 82%								
○ = Operation ⇒ = Transportation □ = Inspection D = Delay ▽ = Storage								

A jig was designed to build and weld Product X with a reduced set-up time. The cycle time was reduced from 34 min to 26 min concomitantly with the reduction of set-up time for the jig. The value-adding time increased from 73% to 82%.

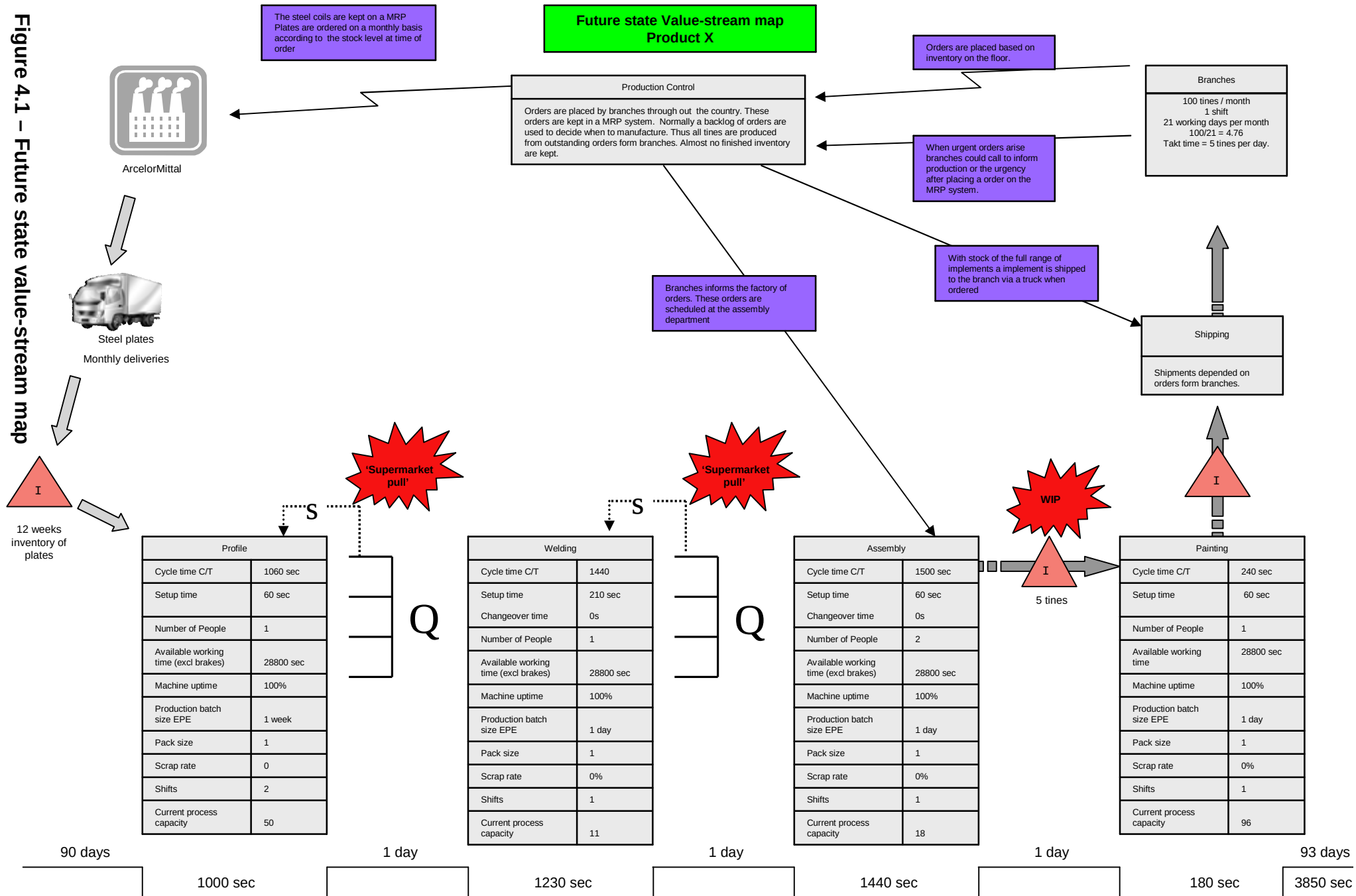
Table 4.3 – Process chart – Future state (with reduced set-up time and waste elimination)

Future state (Reduced set-up time and waste elimination)							Time later (s)	Total time (s)
Step:#	Stepdescription							
1	Bolt weldon frog to jig	○	→	□	D	▽	32	32
2	Place gusset in tine slot	○	→	□	D	▽	20	52
3	Place tine bush in tine	○	→	□	D	▽	20	72
4	Place tine in jig	○	→	□	D	▽	32	104
5	Insert pin through jig and bush	○	→	□	D	▽	20	124
6	Place tine ear jig in position on tine	○	→	□	D	▽	32	156
7	Attach left tine ear to the ear jig	○	→	□	D	▽	32	188
8	Attach right tine ear to tine ear jig	○	→	□	D	▽	32	220
9	Insert bolt through left tine ear, jig and right ear and tighten	○	→	□	D	▽	40	260
10	Tack ears to tine	○	→	□	D	▽	40	300
11	Tack weldon frog to tine	○	→	□	D	▽	30	330
12	Tack gusset to bush	○	→	□	D	▽	30	360
13	Tack bush and gusset to tine	○	→	□	D	▽	30	390
14	Remove bolts from weldon frog	○	→	□	D	▽	20	410
15	Remove pin from tine bush	○	→	□	D	▽	30	440
16	Remove tine from jig	○	→	□	D	▽	40	480
17	Place tine on work bench (left side on top)	○	→	□	D	▽	40	520
18	Weld weldon frog	○	→	□	D	▽	120	640
19	Weld left tine ear	○	→	□	D	▽	120	760
20	Weld left bush and gusset	○	→	□	D	▽	180	940
21	Turntine around	○	→	□	D	▽	40	980
22	Weld weldon frog	○	→	□	D	▽	120	1100
23	Weld right tine ear	○	→	□	D	▽	120	1220
24	Weld bush and gusset	○	→	□	D	▽	180	1400
25	Remove tine from work bench	○	→	□	D	▽	40	1440
Total cycle time (min):								24
Value adding time = Operational time / Total time (1230 / 1440) = 85%								
○ = Operation → = Transportation □ = Inspection D = Delay ▽ = Storage								

The process charts shows only the process steps of the welding of the Product X. This welding process is only one of the processes in the values-stream map. Thus an improvement in the welding process will result in Table 4.1 – 4.3 this is the process chart showing the process steps of the welding of the Product X. This welding process is only one of the processes in the values-stream map. An improvement in the welding process will result in the reduction of the cycle time.

The cycle time will be reduced by another two minutes because waste would be eliminated from the process, while the work will be done with more ease. The eliminated waste from this process includes rework done, unnecessary processing and unnecessary movement of parts and people. The value-adding time also increased from 82% to 85%.

Figure 4.1 – Future state value-stream map



Only the welding process was optimised in the future state value-stream map. A new jig was developed to reduce the set-up time of Product X and to eliminate waste in the process.

The total value adding time was reduced from 4 120 seconds to 3 850 seconds resulting in a 7% reduction in cycle time.

The lead time was reduced from 103.75 days to 93 day which results in a 11.5 reduction in lead time.

The cycle time and lead time can be reduced even further by implementing the rest of the 'lean' tools to all the departments.

The production flow was uneven in the past which resulted in the production of Product X only on certain days of the month. An yearly average of 80 Product X were manufacture per month.

The work flow was levelled in the future state value-stream map and the production was increased by 25% spare capacity from the employees. The excess production is used to build buffer stock for the braches to pull once they received an order.

With a practical proof that cycle time could be reduced together with the conclusions from the literature and the empirical study a procedure can now be developed.

4.4 A PROCEDURE TO OPTIMISE CYCLE TIME

The procedure to optimise cycle time is demonstrated below. The data obtained from the literature and empirical study was used to develop this procedure with the aim to implement the 'lean' tools that is the easiest.

Figure 4.2 – Proposed procedure to optimise cycle time

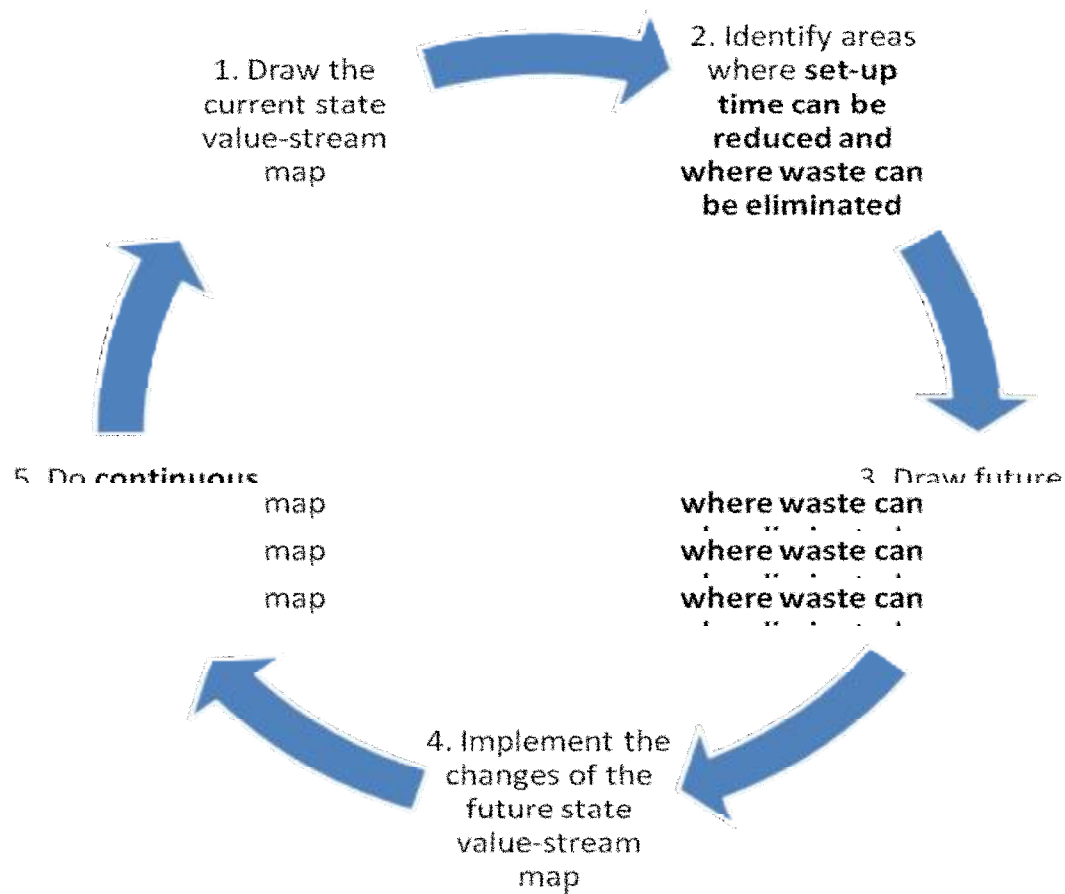


Figure 4.1 shows the procedure to achieve shorter cycle times in a manufacturing plant. The first step is to draw a current state value-stream map of the products manufactured. Secondly, the current state map must be analysed to spot the waste in the process as well as the area where set-up time can be reduced.

When the analysis is complete the future state value-stream map can be drawn up. After completion, the changes should be made altering the process to the new state. Since this state will not be to an optimum the first time, it is necessary to continue improving the process (*kaizen process*). This will ensure an optimum cycle time at all times.

4.5 RECOMMENDATIONS

A few recommendations arising from the literature study, will be made. It seems from the literature and empirical study that these five 'lean' tools are the easiest tools to implement when reducing cycle time:

- Focus to reduce set-up time throughout the plant. Once set-up times are reduced batch sizes can be reduced.
- Organize and clean the plant with the help of a 5S housekeeping programme. The 5S programme will bring waste to the surface.
- Identify and eliminate the waste in the process with the aid of current and future state values-stream maps.
- Concentrate on *kaizen* constantly to improve cycle time through continuous improving of the processes.
- Increased usage of 'supermarket pull system' which secures the availability of parts for downstream processes.

4.6 ACHIEVEMENT OF OBJECTIVES

4.6.1 *Primary objectives*

The primary objective was achieved: a procedure was formulated to reduce the cycle time of the process.

4.6.2 *Secondary objectives*

The study met the secondary objectives in several ways. Firstly, by becoming familiar with value-stream maps thus learning to recognize the waste in the process. Secondly, suggestions for improvements were made. Thirdly, empirical testing was undertaken to obtain the opinion of all the employees involved in manufacturing. Fourthly, a suggested framework/procedure was offered.

4.7 SUGGESTIONS FOR FURTHER RESEARCH

The scope of this study was very limited. Everything could not be covered in this mini-dissertation owing to the prescribed restriction. This gives the opportunity for several other studies that could follow from the below- mentioned:

- Certain 'lean' tools and techniques were not discussed in this study owing to certain limitations. Some of these are Brainstorming, 5 Why's and the Six Honest Servants – What, Why, When, How, Where, Who.
- Kaizen is the term used by the Japanese meaning continuous improvement. The study focused on only a few of the 'lean' tools and techniques. It is possible to reduce the cycle time even further by implementing other 'lean' tools and techniques applicable to various situations.
- The respondents felt that quality could be improved. This is a complex study, giving scope for further studies on quality improvement.
- Much effort was made in order to study the various 'lean' tools and even more effort was needed implement these tools. A study on how to sustain the 'lean' environment in manufacturing will be a challenging one. At all costs, the old habits, which die hard, must be totally eradicated.

4.8 SUMMARY

Conclusions were drawn from other chapters.

The procedure was discussed in this section mentioning which tools should be used. Recommendations were also made on how to reduce the set-up time, the organizing and cleaning of the department, the identification and elimination of waste in the plant and the implementing of a 'supermarket pull' system

It was seen that both the primary and secondary objectives of the study were fulfilled. The chapter ends with suggestions of topics for further studies relating to this one.

The field of 'lean' manufacturing is wide and complex, and an ongoing process. Any company will reap the benefits once they start to implement 'lean' tools and techniques.

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6 Appendix A

IMPLEMENT MAKELIST

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List contents:

- 1 Assy, weldment, tine, Product X

Machining

- 1 ☐ Bush, main, Product X, $\varnothing 25,5 \times \varnothing 40 \times 150$
- 1 ☐ Weldon frog, Product x, 60 x 60 x 327 EN8

Store

- 1 ☐ Nipple, ghries, 45°

Sheetmetal

- 2 ☐ Bracket, spring, tine, Product X, 10 mm
- 1 ☐ Gusset, Product X, 16 mm
- 1 ☐ Tine, Product X, 25 mm plate

Checklist

- 1 ☐ Check nipple is ghriesed
- 1 ☐ Paint work is good

Checked by: (Name)

Capacity

Signature:

Date:

Notes:

Engineer: (Name):

Signature:

Date:

Notes:

7 Appendix B

Demographic

Your age				
Your ethnical race	Black	Colored	White	Other
Amount of years service at the company				
At which factory are you employed?	Northwest		Western Cape	
Department	Assembly	Sheetmetal	Welding	Other
What is your job description	Production teammember		Charge hand / Foreman	Manager / Engineer
Your highest education level	< Gr 8	Gr 8 - Gr 12	> Gr 12	Degree

Awareness section

How is your knowledge on the following:		Very weak	Weak	Good	Very good
1.1	Setup times (2.1)				
1.2	Waste in the factory (2.2 - 2.8)				
1.3	Lean principles				
1.4	Cycle time (2.14)				
1.5	5S house keeping (2.15 - 2.18)				
1.6	Quality management (2.19)				
1.7	Value stream mapping (2.28)				
1.8	Six sigma (2.27)				
1.9	Cellular manufacturing (2.20)				
1.10	Bottlenecks (2.23, 2.24, 2.30)				

Application section

		Strongly agree	Agree	Disagree	Strongly Disagree
2.1	Do you think you can reduce set-up times?				
2.2	Do you need to do rework on parts already manufactured?				
2.3	Do you make more than two days' worth of parts in each batch?				
2.4	Do you have waiting time for a machine?				
2.5	Do you do unnecessary transporting of parts?				

2.6	Do you have unnecessary movement of people?				
2.7	Do you do unnecessary processing of parts?				
2.8	Do inventories have waiting times for further processing?				
2.9	Are you dependent on a kanban system in your department?				
2.10	Do you have the need to be part of a multifunctional team?				
2.11	Do you think we could reduce batch sizes?				
2.12	Do you make use of a supermarket pull system?				
2.13	Do you do regular improvements of production?				
2.14	Do you think you can increase the number of products manufactured per day?				
2.15	Does your department need regular organizing (weekly)?				
2.16	Do you organize your workstation every day?				
2.17	Does your department need regular cleaning (weekly)?				
2.18	Do you clean your workstation every day?				
2.19	Do you have control of the quality of parts you manufacture?				
2.20	Do you want to work in a manufacturing cell?				
2.21	Do you make the same parts every day?				
2.22	Do you have a need for more safeguards in your process to prevent errors?				
2.23	Is there a bottleneck in your process?				
2.24	Do you think we could reduce bottlenecks in the process?				
2.25	Do you wait for parts from other departments?				
2.26	Can you reduce the process time of the products you manufacture?				
2.27	Do you think Six-Sigma quality will add value to our process?				
2.28	Do you have a need for a value-stream map in your department?				
2.29	Do you think we should implement 'lean' principles?				
2.30	Do you experience regular bottlenecks?				