

**The Application, Utilisation and level of value adding
of selected Lean Manufacturing Techniques Amongst
Assembly Manufacturing in Gauteng**

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To all the organisations that participated in this research, thank you for your willingness and effort.



EXECUTIVE SUMMARY

Any organisation's aim is to make profit. This phenomenon determines the survival and growth of each business activity. Organisations have to learn faster about new production techniques in order to become leaner and to enter new competitive environments as they experience lower reward potential in the existing environments. Organisations have to deliver faster to the markets, with product quality exceeding customers' expectations with regard to competitive price.

Lean manufacturing provides manufacturers with techniques to overcome these problems. The question arises which techniques to choose from the wide array of lean manufacturing techniques that are available.

The aim of this study was to determine which lean manufacturing techniques Gauteng manufacturers, specifically in the Johannesburg area, prefer to use. The value that these techniques contribute to the manufacturing process was measured in a percentage of productivity improvement, inventory reduction and operating cost reduction.

The research design was both qualitative and quantitative in nature and a structured questionnaire, applying the Likert scale, was used to gather the data.

Most of the manufacturers in the Johannesburg area indicated that the techniques had, to a large extent, led to improvement in their productivity. These manufacturers indicated the opposite of what the literature indicate, namely that the techniques only reduced inventory to a moderate extent. The manufacturers did not prefer the techniques recommend by the lean manufacture advocates, which are mainly Just in time (JIT), waste elimination and value-stream mapping. They preferred total preventative maintenance (TPM), cycle time and assembly line balancing.

In general a positive relationship was indicated between how frequently the techniques were used and the level of value it added, in terms of reduction in inventory levels, cost reduction and productivity improvement.

Conclusion drawn from this research is that Gauteng assembly manufacturers use these techniques to a limited extent, which is to their disadvantage. Of all the lean manufacturing techniques Single Minute of Dies (SMED) has indicated a 87.5% improvement in inventory reduction if it was used always and a 75% operating cost reduction was reported. It is therefore recommended that Gauteng assembly manufacturers should pursue the implementation of lean manufacturing techniques, to reduce inventory levels, improve productivity and reduce cost. This will ultimately reduce waste and lead to an increase in company profits.

The result suggested that further research can be conducted to verify industry's perception in terms of the reasons why they do not implement and use lean manufacturing techniques, especially JIT. The same research can be extended to other industries for example, logistics and procurement.

GLOSSARY

ABC Analysis: Dividing inventory into percentage categories based on customer demand and cost per unit, part complexity and lead time. “A” category products will be 80% of the customer demand and will have the highest cost per unit. “B” category products will be 20% of customer demand and will have the lowest cost per unit.

Assembly: An assembly line is a manufacturing process in which parts are added to a product in a sequential manner to create a finished product.

Assembly Line Balancing: This technique entails ensuring that each workstation spends the same amount of time on the task allocated to it; hence no workstation has to wait for the previous workstation to complete a task and the manufacturing process is continuous. The time it takes for each workstation to complete its task before handing it over to the next station in the cell is equal.

Cell Manufacturing: Brings together machines and people previously scattered into different sections or departments, either in a U-shape or straight line, to complete the process or product in one place.

Cycle Time: The maximum time for a product to be completed at all the workstations.

Continuous Flow: Allows the work to flow from one process to the next without inventory build-up before or after each process.

Just In Time (JIT): A process where supplies and components are pulled through the system to arrive where they are needed, when they are needed. On-time delivery when you need it, with no inventory or as little as possible and to eliminate waste (reduction of tasks that do not add value to the product (unnecessary movement and handling, rework etc).

Kanban: The Japanese word for card that has come to mean “signal”. A kanban system moves parts through production via a “pull” from a signal.

One-Piece Flow: Products are passed from operation to operation one piece at a time.

Poka Yoke: A mistake proofing device or procedure used to prevent defects from entering a work process.

Single Minute Exchange of Dies (SMED): A structured method for reducing changeover down time on equipment to less than 10 minutes. This refers to the reduction of changeover time from one product to the next by performing some of the set-up operation to before and after the actual set-up and using quick snap-in locking devices rather than bolt and nuts. This means shortening the actual set-up time to the minimum.

Statistical Process Control (SPC): The use of statistics and data gathering to monitor process output and to control the quality of the process.

Total Preventative Maintenance (TPM): All employees must carry out productive maintenance. TPM is maintenance management that recognises the importance of reliability, maintenance and economic efficiencies in the plant, allowing employees to be responsible for some of the maintenance tasks. Employees must take responsibility for their machines.

Total Quality Management (TQM): The management of an entire organisation to ensure that the organisation excels in all aspects of production and services important to the customer. TQM stresses a commitment by management to a continuing company-wide drive towards excellence in processes through incremental improvements to satisfy the needs of customers.

Value-Stream Mapping: A value stream includes all the actions, both value-adding and non-value-adding, required from the input stage to the output stage for every product manufactured. It is the production flow from raw material to final product for consumption by the customer. The same concept is applicable to the design process, i.e. from the concept to the launch of the new product or service.

Waste Elimination: Whatever does not contribute to profit is waste. Every action that does not add value is waste: overproduction = waste, waiting time = waste, unnecessary transportation = waste, unnecessary inventory = waste, defects and rework = waste, excessive walking or reaching = waste.

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CHAPTER 1

BACKGROUND

This chapter provides background to the study. It starts with the overview of the fundamental aim of a manufacturing company, which is to make profit. This is followed by the problem statement, reasoning of the study, a short literature study, aim of the study, research design and data gathering methodology.

1.1 BACKGROUND AND RATIONALE

The aim of any organisation is to increase profit and add value to the business (Salvatore, 2001:11) and this is in line with the statement by Kachienga'a and Koekemoer (2002:1) that it becomes extremely challenging in South Africa to increase profit with the unstable rand and the low cost of imports.

Heizer and Render (2004:6) claim that when faced by global competition, the approach that numerous companies take is to try to improve their operations activities. Heizer and Render (2004:6) make use of a simple financial statement to demonstrate the contribution of improving operations management activities they postulate that the impact of reducing the production cost by 20% is far greater than either having a 50% increase in sales or a reduction of 50% in finance cost. The end result of increasing sales by 50% is a 71% increase in profit. A 50% reduction in finance cost will result in a 21% increase in profit. However, a 20% decrease in production cost will result in a net increase of 114% in profit. This indicates that companies must focus on the reduction of production costs to make profit and to survive low-cost imports.

Heizer and Render (1999:199) explain that when products and technology reach the mature stage of their lifecycle, companies should focus on the processes that reduce costs in order to maximize their profitability.

According to Halevi (1999:25) a company must change the manner in which it does business in order to compete successfully and remain competitive in the global market arena. Global markets impose new and greater demands on a business moving towards the global arena. This requires greater delivery speed to markets, product diversity, product quality, customer satisfaction and more competitive pricing

Where lean producers are committed to the continuous removal of activities that do not add value to the products, lean manufacturing techniques can provide methods that solve these problems (Heizer and Render, 2004: 596). Lean manufacturing can constitute a formidable weapon in the increasingly more competitive global markets (Soriano-Meier, & Forrester, (2002:104).

Traditional managers have accepted that a certain percentage of defective parts are standard and therefore they build up a safety stock inventory to safeguard them against inconsistent deliveries. *“Customary production techniques have limited goals”* (Heizer and Render, 1999:240). Lean producers use many different techniques to identify and eliminate product waste, such as JIT, TQM, value-stream mapping from suppliers to customer, zero defects, one-piece flow, continuous flow and kanban. Whichever technique is used, lean manufacturers are the key players in building a work culture that endorses continuous improvement. Womack, Jones and Roos (1990:7) recommend that these techniques be applied equally in any industry across the globe.

1.2 PROBLEM STATEMENT

Free market forces are the fluctuation of the rand, low-cost imports and technology and product depreciation (Chaharbaghi and Nugent, 1994). According to Halevi (1999: 25) this phenomenon determines the survival and growth of each business activity. Organisations have to learn faster about new production techniques in order to become leaner and to enter new competitive environments as they experience lower reward potential in the existing environments. Organisations have to deliver faster to the markets, with product quality exceeding customers' expectations with regard to competitive price.

Halevi (1999:26) further states that the manufacturing industry realises that it is going to be the survival of the fittest and that a change towards lean manufacturing is essential in the drive towards increased productivity in the global manufacturing arena. A dissonance exists between the processes/techniques proposed by the advocates of lean manufacturing and the real processes/techniques used by successful manufacturing firms already achieving lean manufacturing. He also states that more than 90 different lean manufacturing techniques are available.

The following question therefore requires more investigation: “Which lean manufacturing techniques/processes are utilised by manufacturing enterprises that have successfully evolved from the micro or local to the macro or global arena? ”In conjunction with this, it should be investigated why certain techniques/processes are chosen above others from the wide array of “lean manufacturing” techniques/processes available and also the extent to which techniques/processes contribute to increasing productivity, reducing inventory levels or reducing operating cost.

1.3 LITERATURE SURVEY



Lean manufacturing imply many things, but inventory is a highly visible measurable phenomenon as Schonberger (2004:20) states: *“know how to operate with little (inventory) and you’re lean, hold lots (of inventory) and you’re fat”*. One of the measures of a company using lean manufacturing is a low inventory. This means that an enterprise with a large inventory in the form of products in the process of manufacturing, or an enterprise that stores a lot of finished goods in a warehouse, has a large amount of money committed in the form of work-in-progress (WIP). Consequently the word “fat” is used to describe such an enterprise.

When a company does the opposite, it is considered “lean” and the business makes use of lean manufacturing as described by Schonberger (2004:20). The mission of lean producers is to work towards perfection through continuous learning, creativity and teamwork, and to continuously dispel non-value-adding activities (Heizer and Render, 1999:239).

Slack, Chambers and Johnston (2001:482) describe lean manufacturing techniques under the heading of “JIT” (Just In Time). JIT aims to meet a demand instantaneously, with perfect quality and almost no waste. JIT is a disciplined approach to improving overall productivity and eliminating waste. It provides for cost-effective production and delivery of only the necessary quantity of parts at the right quality, at the right time and place, while using a minimum amount of facilities, equipment, materials and human resources. JIT is dependent on the balance between the supplier’s flexibility and the user’s flexibility. It is accomplished through the application of elements that require total employee involvement and teamwork. “A key philosophy of JIT is simplification” (Slack et al., 2001: 482).

Feld (2001:4) identifies five primary elements to present the various facets required to support a solid lean manufacturing programme, namely manufacturing flow, organisation, process control, metrics and logistics. For each of these elements there are at least six tools for an organisation to become and promote lean manufacturing

Bicheno (2000:8) describes lean manufacturing as “a philosophy, not a system or a technique. It is about simplicity, flow, visibility, partnership and value.” He highlights five lean principles from Whomack and Jones for the elimination of waste:

- Specify value from the point of view of the customer.
- Identify the value stream.
- Make value flow.
- Pull at the customer’s rate of demand and seek perfection through continual improvement.
- Seek perfection through continual improvement.

1.4 AIMS OF THE STUDY

- To determine which of the lean manufacturing techniques Gauteng, or more specifically Johannesburg assembly manufacturers preferred.
- To rank the most frequently used techniques from “most used” to “least used”.
- To determine in percentage the well-being of the manufacturing process with regard to the value being added to productivity, inventory reduction, reduction in operating cost and inventory control.
- To construct a matrix illustrating the contribution in terms of value added by the various techniques, from high to low.

1.5 RESEARCH METHODOLOGY

The research design was both quantitative and qualitative in nature. The data was gathered by means of a structured questionnaire using an ordinal scale from “not at all” to “always”. An introductory letter accompanied the questionnaire to explain the research and to confirm the confidentiality of the information. The questionnaires were e-mailed after telephonic confirmation of participation in the research. The questionnaire consisted of three sections. Section one requested information about the respondent, section two information about the manufacturer and section three covered the different techniques, the frequency of usage of the techniques and the value the techniques add to the business. The research included an empirical phase to gather data from actual manufacturing sites in Gauteng (in the Johannesburg area) where lean manufacturing techniques are utilised. Underpinning the study is the literature review on lean manufacturing techniques in assembly cells and their place in the running of a production assembly. The comparative data gathered from the questionnaire has been analysed using a matrix/typology of the actual techniques used. The questionnaire design was based on the analyses and observations of the literature review and with the assistance of STATKON at the University of Johannesburg. The validity and the reliability of the questionnaire were tested. STATKON assisted with the actual processing of the data into cross tabulation and statistics.

A literature survey was conducted on lean manufacturing and lean manufacturing techniques with specific emphasis on the following techniques: ABC product analysis, assembly line balancing, cell manufacturing, continuous flow, cycle time, JIT, one-piece flow, product-quantity (PQ) analysis, Poka Yoke, single minute exchange of dies, takt time, TPM, TQM, value-stream mapping and elimination of waste. These techniques are applicable to assembly manufacturing.

The value added to the enterprise was measured in terms of inventory reduction, productivity improvement, operation cost reduction and improvement to inventory control. The results were expressed in percentages.

The sites chosen for the research were mainly assembly-manufacturing companies in the Johannesburg area (Gauteng Province). Gauteng was selected on the basis of information provided by Statistics South Africa (2004) according to which 43% of manufacturers in South Africa were situated in Gauteng at the time of the census in 1996. Gauteng manufacturers further contribute 40% of the South African production output.

1.6 BENEFICIARIES

Companies that contributed to the study were existing and new businesses with assembly lines that could benefit from the research as it will confirm whether the industry is using the techniques and to what extent the techniques contributed to business profitability. In addition, technological institutions and operational research consultants could also benefit as their recommendations on and designs for continuous improvements to the manufacturing process/tools/techniques are actually used by the industry manufacturer who seeks to add real value in tougher markets. Academic institutions in the field of operations management can convey the outcome of this research to their students who are ready to enter employment.

1.7 LAYOUT OF THE STUDY

Chapter 1: Background

This chapter covers the background, the rationale behind the research, the problem statement and the objectives of the research.

Chapter 2: Literature Review

The literature review will cover theory on lean manufacturing recommended by the lean manufacturing advocates, the techniques they prefer and the simplification of the techniques. It will provide an in-depth description of the tools/techniques and their application and finally discuss the value the techniques can add to an enterprise.

Chapter 3: Research Design and Methodology

The research design will be presented, as well as the associated research methods used to accomplish the study.

Chapter 4: Data Presentation and Analysis

Findings based on the data will be presented. The findings were used to develop a matrix of the lean manufacturing techniques actually used by some manufacturers in the Johannesburg area.

Chapter 5: Discussions and Conclusions

Conclusions will be drawn and discussed.

1.8 CONCLUSION

From the background it is obvious that companies can benefit from lean manufacturing to compete globally. Choosing the correct techniques can be confusing because advocates of lean manufacturing have different opinions on the techniques to be used. The research objective was to clarify the techniques used by manufacturers in the Johannesburg area and the value these techniques add to the manufacturer.

CHAPTER 2

LITERATURE REVIEW

This chapter illustrates the background and history of lean manufacturing and then the different lean advocates' reasoning behind lean manufacturing and the preferred techniques. In conclusion an explanation of a few selected techniques with relevance to assembly manufacturing follows.

2.1 BACKGROUND ON LEAN MANUFACTURING

Womack, et al. (1990) were the first to use the phrase "lean manufacturing" in their book *'The machine that changed the world'* that explained the pioneering work of Eiji Toyoda and Taiichi Ohono at the Toyota Motor Company in Japan. The famous quote used to describe the lean production is "*uses less of everything, half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the inventory on site, results in many fewer defects and produces a greater and ever growing variety of products*" (Womack et al., 1990:13).

Lean manufacturing must be viewed as a tactically formidable weapon in a more and more competitive market (Soriano-Meier and Forrester, 2002). Although lean manufacturing can be mastered by anyone, it takes 10 years of practice under expert guidance (Womack et al., 1990:243). It is important to take note that lean manufacturing can only be achieved over time and cannot be used to solve short-term competitive problems (Soriano-Meier and Forrester, 2002). It took Toyota 20 years to develop their production system (Womack et al., 1990:243).

The transformation to lean manufacturing requires careful strategy as lean manufacturing brings considerable changes to corporate culture, visible support from top management and patience. The considerable changes to corporate culture may be the reason why so many lean manufacturing implementations fail. The failures are the

reason why so many managers view lean manufacturing just as another fad or buzzword (Parks, 2002). The fact is that lean manufacturing is not a fad or buzzword, it works for Toyota. Womack and Jones (1994) use Chrysler and Sony as examples in the development of the lean concept. According to Conner (2001:1) the concept worked for many others - from a 10-person manufacturer to larger manufacturers.

Leanness of a business or lean manufacturing involves lean development, lean procurement, lean distribution and lean enterprise (Karlsson and Åhlström, 1996). In lean manufacturing alone there are different views on the tools to be used to make a manufacturer lean.

2.2 DIFFERENT VIEWS ON LEAN MANUFACTURING

This section explains the various lean manufacturing advocates' viewpoints on lean manufacturing and describes the different techniques each prefers. From these techniques various techniques concerning assembly manufacturing and were selected the advantages and value each tool might have added to a business.

Adendorff and De Wit (1997:16) explain that lean manufacturing is sometimes used incorrectly as a synonym for JIT (just in time). JIT results in lean production. "Lean" is in fact less of everything, for example human effort and manufacturing space. Lean production methods need less inventory and have fewer defects than the competition, with a greater variety of products.

Contrary to this Bicheno (2000:8) describes lean manufacturing as a philosophy, not as a system or a technique. Essentially, it is about simplicity, flow, visibility, partnership and value. Lean must be applied throughout the process - from the supply chain to distribution. Bicheno uses five lean principles to eliminate waste and they are described as follows: Specify value from the point of view of the customer, then identify the value stream - this means to evaluate the processes to manufacture the products. He then suggests mapping the physical flow of raw material and work-in-progress as it goes through all the manufacturing processes. Then map the information flow (instructions to

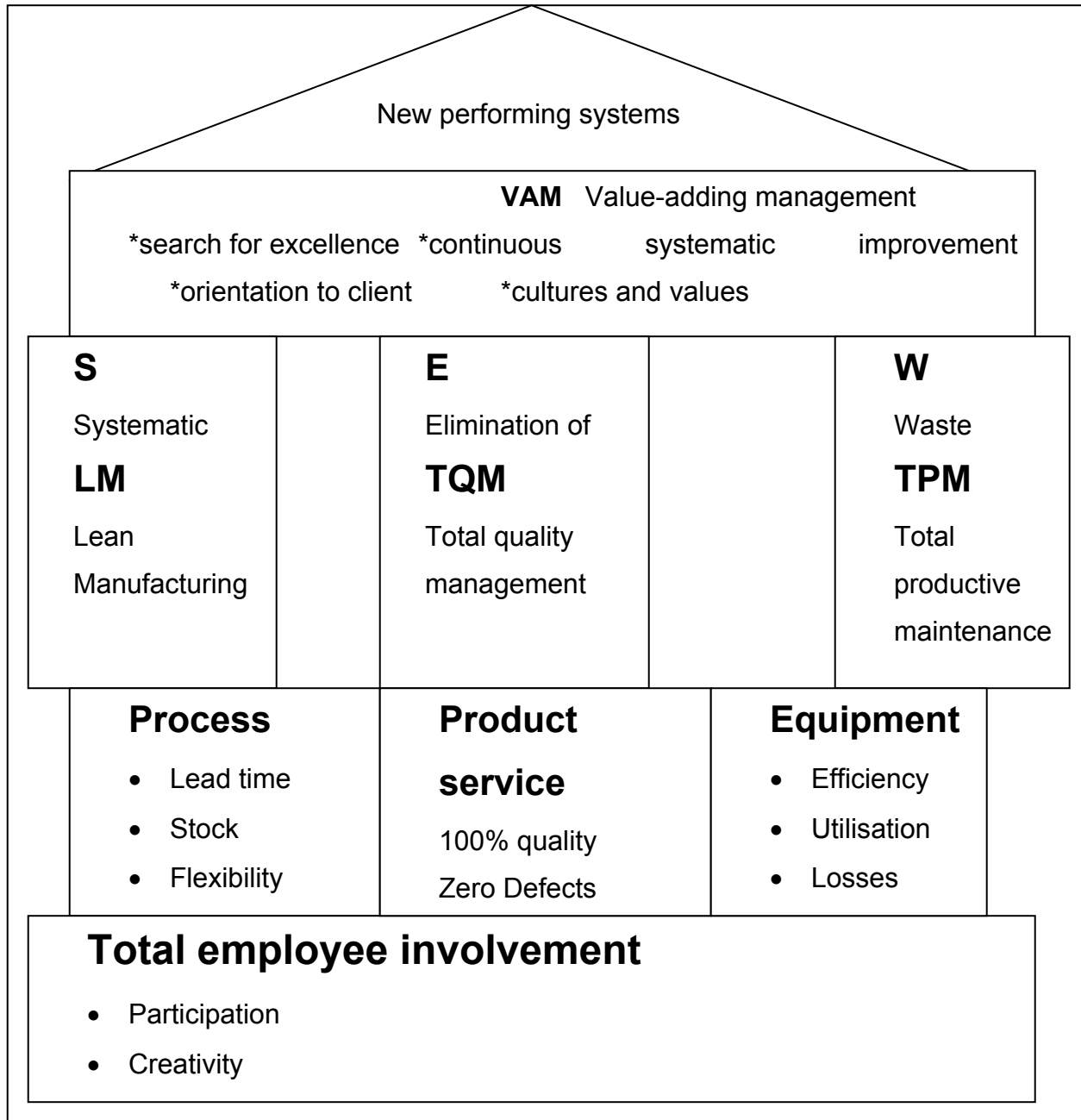
the shop floor about what and when to produce). Mapping of information flow includes purchase orders and customer orders that are essential to manufacturing. Each of these processes includes value-adding and non-value-adding activities. The purpose of the process recommended by Bicheno is to develop the value-adding activities and to get rid of the non-value-adding activities and thereafter to make value flow by using one-piece flow and removing bottlenecks that prevent flow from taking place. According to Bicheno it is crucial to pull at the customer's rate of demand by using the kanban technique. Lastly, seek perfection through continual improvement.

Scodanibbio (2005) describes lean manufacturing under the heading of value-adding management (VAM) (see Figure 2.2.1:). The foundation is total employee involvement. All staff, from management to the worker on the shop floor, must be involved and participate. There are three pillars carrying VAM, namely lean manufacturing, total quality management (TQM) and total productive maintenance (TPM).

Lean manufacturing consists of lead-time reduction, stock reduction and flexibility of the plant to meet customers' needs. Productivity is the ability to produce efficiently with better utilisation. With the three pillars in place, the aim should be to systematically reduce waste (SEW) and orientate the business towards the client. Change of the culture and values of the business will create a new performing system that will result in value for the customers - this is called value-adding management. The lean process cannot function if there is not a "zero defects" system in place and this may be particularly true in a one-piece flow process. If the first operations pick up a quality problem, the whole process line downstream comes to a halt. The same results are experienced if a machine or tool, relative to the completion of a specific process, brakes down - therefore TPM is important for the lean manufacturer.

Scodanibbio (2005) recommends techniques such as continuous flow, one-piece flow, cell manufacturing, pull production, process mapping (arrow mapping), quick changeover, P-Q analysis (categorising products in groups of product quantity produced and numbers of process lines), systematic reduction of waste, value-stream mapping, JIT and kanban to be used in the lean manufacturing process.

Figure 2.2.1: Carlo Scodanibbio's Lean Manufacturing View



Source: Adapted from Scodanibbio, C. (2005) Next generation lean manufacturing. [On-line]

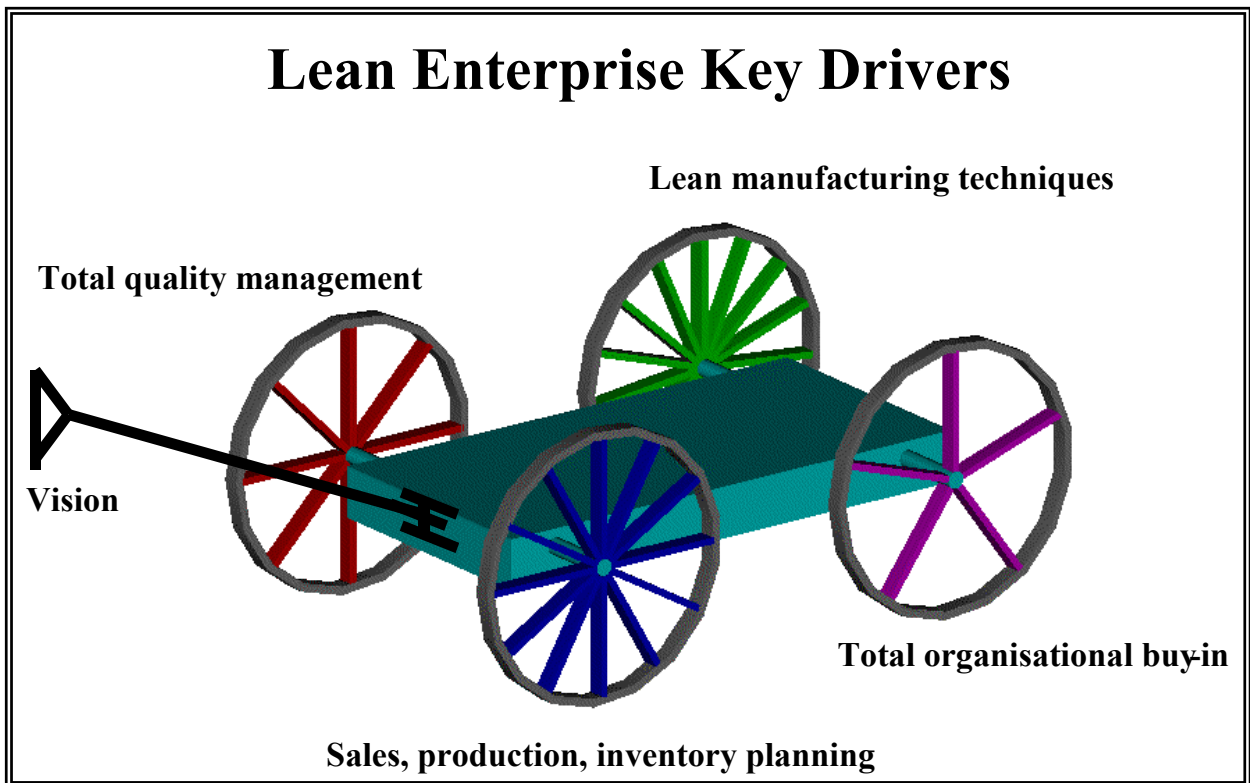
Internet: <http://www.scodanibbio.com/>

Where Scodanibbio (2005) uses a building with pillars to describe his lean manufacturing philosophy, Conner (2001:15) uses a wagon with wheels to describe the ideal lean enterprise (see Figure 2.2.2). Each wheel represents a critical part of the

business. The wheels are used as a visual measurement tool known as a Radar chart. The steering tool is the vision of the company. The wheels represent the following:

- Sales, production and inventory management.
- Total organisation buy-in.
- Total quality management
- Lean manufacturing techniques.

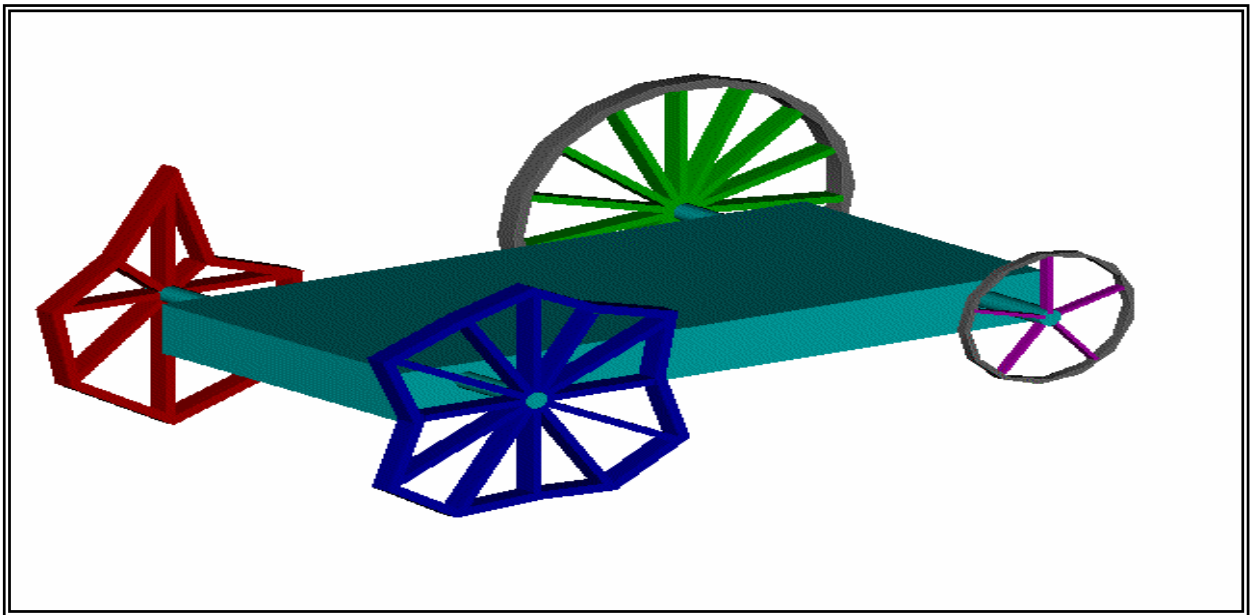
Figure 2.2.2: Lean Enterprise Key Drivers



Source: Adapted from Conner, G. (2001:1) Lean manufacturing for the small shop Dearborn, Michigan: Society of Manufacturing Engineers.

Each wheel has a number of spokes or key indicators that are the goals that can be measured on a level from one to ten. Ten is at the outer diameter and represents perfection. Zero is at the center and represents failure. When all the spokes (goals) reach a level of ten, the wheel is a perfect circle. Figure 2.2.3 shows uneven wheels that represent a non-lean wagon or enterprise.

Figure 2.2.3: Non-Lean Enterprise

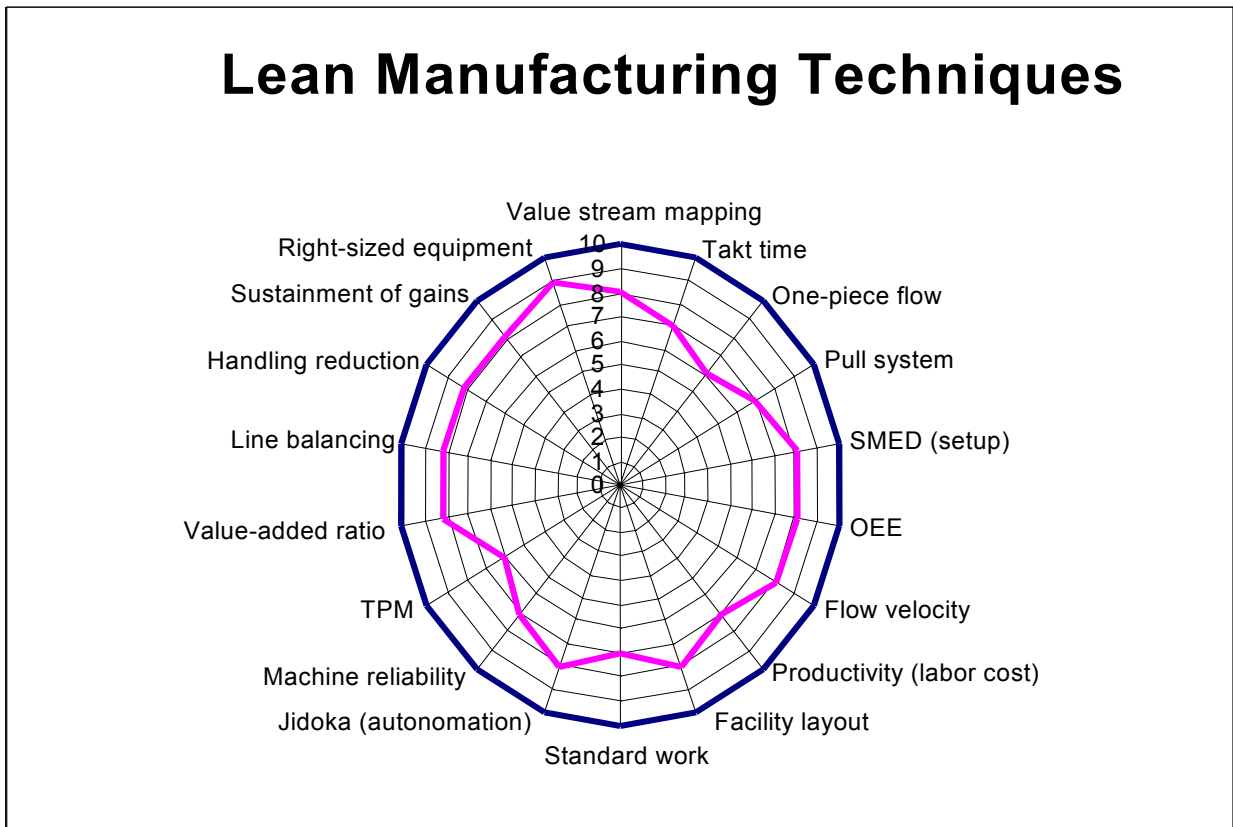


Source: Adapted from Conner, G. (2001:1) Lean manufacturing for the small shop Dearborn, Michigan: Society of Manufacturing Engineers.

As this is a short dissertation only one wheel will be explained, namely lean manufacturing techniques, even though, according to the author, the wagon (enterprise) can only function if the steering (company vision) is in place and all the wheels are completely round.

Conner selected a company and illustrated all their lean manufacturing techniques on a lean manufacturing radar chart (see Figure 2.2.4 below). The techniques used for the purposes of this research, namely value-stream mapping, tack time, single minute exchange of dies, total productive maintenance and line balancing are also included in this radar chart. It is clear that there is a big pool of tools to be used and, as the Conner (2001:22) explains, each enterprise has to select the tools suitable for their needs.

Figure 2.2.4: Lean Manufacturing Techniques



Source: Adapted from Conner, G. (2001:1) Lean manufacturing for the small shop Dearborn, Michigan: Society of Manufacturing Engineers.

Feld (2001:4) identifies five primary elements to present the various facets required to support a solid lean manufacturing programme:

- Manufacturing flow: Addresses the physical changes that ensures production flow without inventory build-up.
- The organisation: Focuses on identifying employees' responsibilities and duties. The crucial part is training in the new ways of working and communication.
- Process control: Focuses on the monitoring, controlling and stabilising methods to improve the process.
- Metrics: Addresses the visible results-based performance measures, which include target improvement and team rewards recognition.
- Logistics: Provides meaning to operating rules and mechanisms for planning and controlling the flow of material.

Feld (2001:4) believes that different techniques can be used to achieve lean manufacturing with each of these elements. Halevi (1999: 50) disagrees and states that *“the lean system, however, is based on a strong and inseparable relationship between JIT and TQM, leading to a virtual cycle in which quantity is a prerequisite of JIT, and JIT allows quality to be improved through enhanced controls and increased visibility of all productive activities. The lean system is also based on ‘jidoka’, which has the dual meaning of automation and autonomous defect control”*.

Heizer and Render (1999:240) believe JIT should be the main tool to reduce inventory and that the focus should be on inventory reduction to remove any waste. JIT techniques are employed to eliminate virtually all inventories. The reduction of inventory removes the safety nets that allow a poor product too make its way through the production process. This forces the manufacturer to build systems that will help employees to produce a perfect part every time.

Another advantage of JIT is the contribution to space reduction. A close relationship is developed with suppliers, i.e. helping them to understand the company’s needs and its wants as a customer of the supplier. A further attempt is made at maintaining the decline in costs by eliminating all activities that do not add value. Material handling, inspection, inventory and rework jobs are among the likely targets because these do not add value to production.

The workforce is continuously developed with a focus on improved training, employee participation, commitment and work teams. Jobs are made more challenging, spreading responsibility to the lowest post level possible. There is a reduction in the number of posts and worker flexibility is encouraged. Lean manufacturing contributes to the achievement of perfection, no faulty parts and no surplus inventory (Heizer and Render, 1999: 240).

The views of Karlsson and Åhlström (1996) are opposite to those of Heizer and Render (1999: 240). Karlsson and Åhlström (1996) developed a model to put the different principles of lean production in perspective. Lean production consists of lean

development, lean procurement, lean manufacturing, lean distribution and lean enterprise. The following tools are used in lean manufacturing:

- elimination of waste;
- continuous improvement;
- multifunctional teams;
- zero defects;
- JIT;
- vertical information systems;
- decentralised responsibilities and integrated functions; and
- pull instead of push.

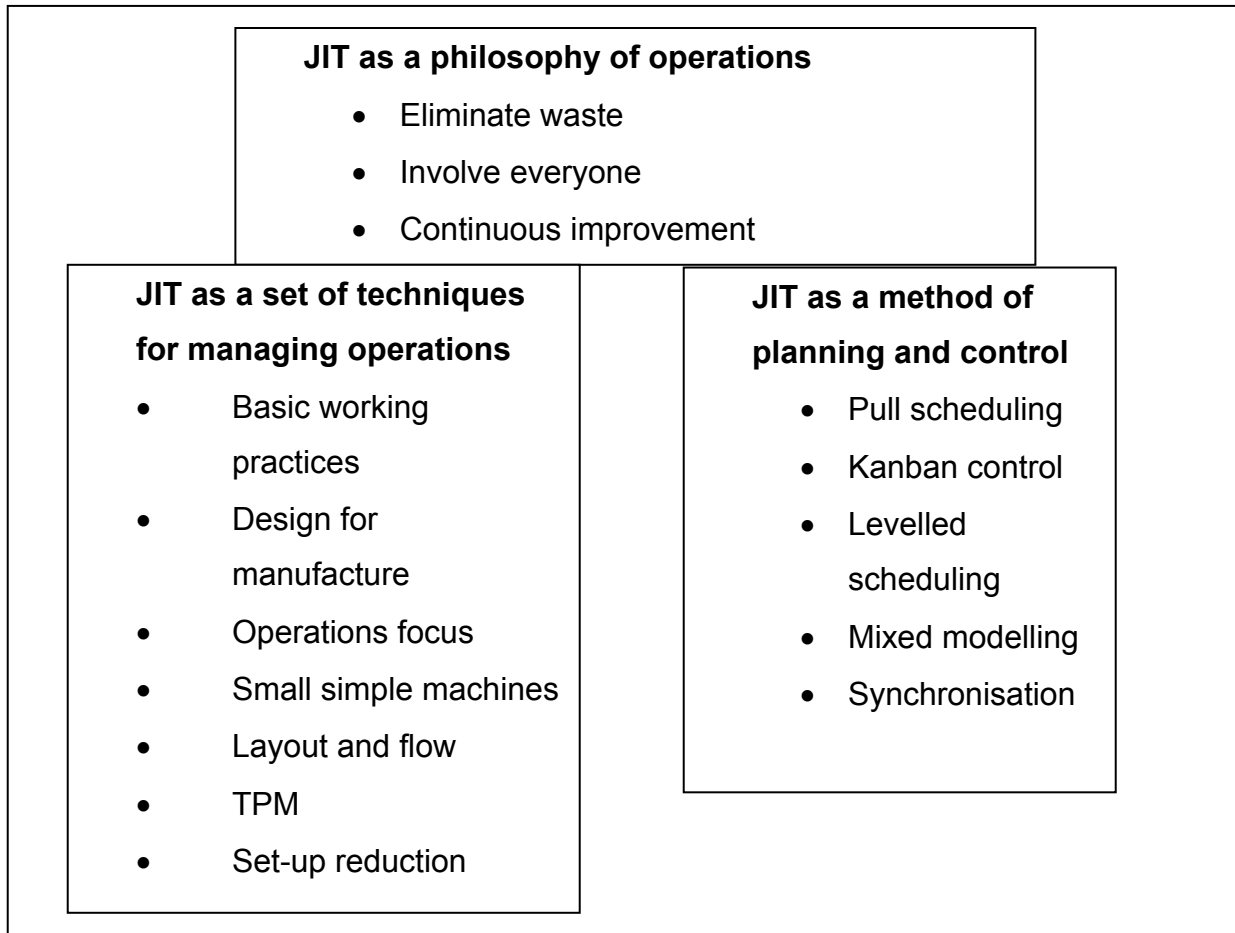
The purpose of elimination of waste is to reduce cost. Karlsson and Åhlström (1996) explain that the elimination of waste is the most fundamental tool of lean manufacturing. Everything that does not add value to the product is waste. Waste is the element that the customer does not want to pay for. The most important forms of waste are inventory, down time of machines, transportation of parts and lack of quality.

Continuous improvement is the second important tool in the lean manufacturing process. Karlsson and Åhlström (1996) state that ongoing improvement implies involvement of everyone who is part of the process in quality circles. This means that employees meet and come up with suggestions and are responsible for the implementation of their suggestions. Zero defects indicate how lean the company works in order to attain quality. The main objective is to prevent defects from occurring by using Poka Yoke instead of controlling the parts produced.

The views of Slack, Chambers and Johnston (2001:482) about lean manufacturing principles are similar to those of Heizer and Render (1999:240), (Halevi 1999: 50) and Adendorff and De Wit (1997:16). Slack et al. believe lean manufacturing is just another phrase to describe JIT, as well as continuous-flow manufacture, high-value manufacture, stockless production, war on waste, fast-throughput manufacture and short-cycle manufacture. They also see JIT as a western personification of a philosophy and its techniques developed by the Japanese. This philosophy espouses doing the simple

things well and reducing waste step by step. The philosophy consists off three elements, namely eliminating waste, involving everyone and continuous improvement (illustrated in Figure 2.2.5 below).

Figure 2.2.5: “Just In Time” Philosophy



Source: Adapted from Slack, N., Chambers, S. & Johnston, R. (2001). 3rd ed. Operations Management. England: Prentice Hall.

JIT uses some of the following techniques to manage, plan and control. The techniques include basic working practices whereby the manufacturer gives employees the responsibility to meet the required safety standards and quality of the product, as well as the authority to stop the line and delegate simple material scheduling to employees, allow shop floor performance and monitoring to be done by employees and to solve shop floor problems. To decrease shop floor problems, designers must design for

manufacturing. This means designers must take manufacturing constraints into consideration and design a manufacturing friendly product. This can save 70% to 80% of manufacturing cost. Operation must also focus on simplicity, standardisation and small manageable sets of production, which include small, simple machines. The principle is using several small machines instead of one large machine. It is important that the layout of the machines promotes a smooth operation flow of materials, data and people in the operation. A final technique that ensures the operation flows smoothly is total productive maintenance (TPM) that aims at eliminating unexpected down time by using employees to do daily routine maintenance (Slack et al., 2001:482).

2.3 TECHNIQUES USED FOR THE PURPOSE OF THIS RESEARCH

According to Halevi (1999:26) there are more than 90 different proposed methods for achieving lean manufacturing. The following techniques were chosen for discussion: ABC product analysis, assembly line balancing, cell manufacturing, continuous flow, cycle time, JIT, one-piece flow, product-quantity analysis, Poka Yoke, single minute exchange of dies, takt time, TPM, TQM, value-stream mapping and elimination of waste.

2.3.1 ABC Analysis

Heizer and Render describe ABC analysis as the process that identifies which items are more important to the organisation than others. Therefore, ABC analysis divides on-hand inventory into three categories based on the demand and cost per unit. Category A are high-value items (high in cost); they make up 70% to 80% of the total inventory cost even though they sometimes contribute to only 15% of the inventory volume. Category B items contribute 15% to 25% to inventory cost and 30% to the inventory volume. Category C items contribute 5% to inventory cost and 55% to the inventory volume. The advantage of ABC analysis lies in the ease to manage resources and control inventory. More time and effort are spent on category A items and less time on category C and D items. The end results include better forecasting and physical control becomes easier in that the right amount of time is spent on the high-value items. As a result supplier

deliveries become more reliable and consequently safety stock is reduced (Heizer and Render, 1999:441).

2.3.2 Assembly Line Balancing

According to Heizer and Render (1999:340) assembly line balancing is achieved by maximum output at each workstation on the production line so that delay is minimised. Each workstation must spend the same amount of time on the work allocated to it before passing it on to the next workstation to prevent a pile-up. A workstation that does not use a similar time period to complete the work allocated to it, is called an unbalanced workstation or an unbalanced cell. Every workstation that is not balanced adds up to the balance loss of the total production line. Slack et al. (2001:199) explain balance loss as the proportion of the production time that is not used productively.

The use of line balancing as a technique has the following advantages: it reduces the idle time at each workstation and the employees become more productive, thereby reducing the operating cost and setting the stage for one-piece flow.

2.3.3 Cell Manufacturing

Slack et al. (2001:191) explain cell manufacturing as all the requirements needed to complete all the stages of the process grouped together in one place. This implies bringing together people and machines, previously dispersed in an arrangement, closer together and arranging them in a straight line or “u-shape”. The condition of a cell is that the volume of the product must be such that it validates the need for a cell. Therefore, a work cell is built around a product or a group of products that require the same processes with minimal changes to the layout. This is done to minimise changeover times from one product to the next. A cell is made up of multiple workstations grouped together, where a workstation is a specific process to be completed before the next process can take place at the next workstation.

According to Slack et al. (2001:199) the advantages of cell manufacturing are as follows: Working close together in a group can result in more motivated employees because of work satisfaction and the possibility of working at different workstations simultaneously. One employee can work at more than one operating station at a time because the stations are closer together, where previously an operator was needed to fill every operating station. This results in higher throughput.

Heizer and Render (1999:331) further explain that cell manufacturing will reduce work-in-progress and inventory, because the layout of the cell is designed to manufacture from machine to machine or from process to process. Where the line is balanced and each process takes more or less the same time as the previous process, there is no need for inventory between processes. This will result in reduced utilisation of floor space; less space will be needed between processes to accommodate work-in-progress. This has a direct impact on the raw material and finished goods inventories. Because the changeover time is shorter and the line is more flexible, less finished goods are needed to cover for long runs of one typical product before changeover to the next, and less work-in-progress allows for less raw material inventory.

Sometimes fewer workers are needed and this results in a reduction in labour cost. The quality improves because each employee is responsible for qualifying the previous person's work, which results in quality improvement and a reduction in the risk of high volumes of rework. The effect of no or little work-in-progress means mistakes can be identified early or immediately. Previously, if there were quality problems all work-in-progress needed to be reworked. Cell manufacturing forces the workers to communicate with each other. The result is improved scheduling which has a positive effect on material flow, resulting in better utilisation of machines and equipment. The improved communication outcome is that employees help each other where there is a sudden build up of work in one process. This also stimulates the employees because they have to be more flexible and learn more than one skill.

According to Slack et al. (2001:199) the disadvantage is that the changeover from the existing method of layout to cell manufacturing layout can be costly. More or different

plant equipment may be required. In some cases it can lead to lower plant utilisation. If there is a breakdown, it can affect the whole cell. A good maintenance plan is therefore needed.

2.3.4 Continuous Flow

Rother and Shook (2001:1) claim that continuous flow is the ultimate objective of lean manufacturing. The production flows continuously from one workstation to the next and from one department to the next without work-in-progress piling up.

2.3.5 Cycle Time

Russel and Taylor (2003:173) describe cycle time as the maximum time a process has to take place at each workstation and Heizer and Render (1999:342) describe it as “*The maximum time that the product is available at each workstation*”. To calculate cycle time, divide demand or production rate per day by the production time available per day. Preferably, the time must be in seconds. The result is the maximum time it takes to complete one product. This concept is illustrated in Figure 2.3.1 below.

Figure 2.3.1: Cycle Time Formula

$$\text{Cycle Time} = \frac{\text{Production time available per day in seconds}}{\text{Demand per day or production rate per day}}$$

Source: Adapted from Heizer, J. & Render, B. (1999:342) 3rd ed Principles of operations management. New Jersey: Prentice Hall.

2.3.6 JIT

Slack et al. (2001:482) defines JIT as follows “*JIT aims to meet demand instantaneously, with perfect quality and no waste.*” or “*JIT is a disciplined approach to improving overall productivity and eliminate waste. It provides for the cost-effective*

production and delivery of the necessary quantity of parts at the right quality, at the right time and place, while using the minimum facilities, equipment, materials and human resources” The main advantage of JIT is the reduction of inventory and waste.

2.3.7 One-Piece Flow

With one-piece flow products are passed one piece at a time from operation to operation with a first-in first-out approach (FIFO) (Feld, 2001:72).

“A company’s customers could be best served by switching from batch-style operations to one piece operations that extent from one-piece ordering to one-piece flow, one-piece production, one-piece inspection and one-piece delivery” (Feld, 2001:72).

Rules and conditions of one-piece flow according to Sekine (1992:3):

- Base the cycle time on market requirements.
- Base equipment capacity utilisation on cycle time.
- Centre production on assembly processes.
- Factory layout must be conducive to one-piece production.
- Goods must be conducive to one-piece production.

Advantages of one-piece flow according to Feld (2001:72):

- The improvement in manufacturing lead-time.
- Drop-in level of inventory.
- The feedback on quality issues are far more superior to the advantages offered by batch and queue systems.
- Faster delivery response to customers.
- Less staff needed to complete the process, which results in employees doing their own quality checks.

2.3.8 Product-Quantity (P-Q) Analysis

P-Q analysis uses the different types of products and their respective quantities to arrange products in percentage groups. Group A products are the runners and use the

40/60-rule. This means 40% of the products will account for 60% of the parts volume and the process used to manufacture these products. The suggested manufacturing process is a free flow-line. Group B products are classified as repeaters and will use a flexible manufacturing cell; specifically U-cells for wide-variety, small-lot production. Group C products fall into the group “strangers”, where production of these items may fall into a pattern of once per year. These products are best managed by a separate production area or outsourcing (Sekine, 1992:125 and Feld, 2001:63).

2.3.9 Poka Yoke

Literally translated, Poka Yoke means “fool proof”, i.e. a device or technique that ensures the production of a good unit every time (Heizer and Render, 1999:96). This is a means by which the manufacturer can take the guessing out of employees’ duties. The employee must either use a checklist or a device or technique in order to ensure that the next product or service is defect free. *“A better term for Poka Yoke devices might be ‘mistake proofing’”* (Conner, 2001:114).

2.3.10 Single Minute Exchange of Dies (SMED)

This is *“sometimes called ‘quick changeover’”* (Russell and Taylor, 2003:523), *“zero changeover”* (Sekine 1991:117) or *“set-up reduction”* (Rubrich and Watson, 2000:311). Halevi (2001:265) explains SMED as the objective to reduce set-up times. The aim is to use different techniques to reduce set-up time to a single minute. One of the techniques is to separate internal and external set-up operations: *“Internal set-up can be performed only when a process is stopped ... external set-up can be performed in advance”* (Russell and Taylor, 2003:523).

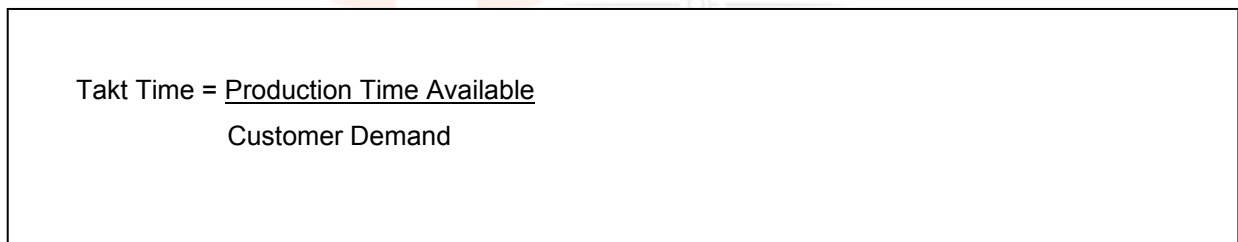
According to Rubrich and Watson (2000:346), when a manufacturer starts to introduce the set-up reduction process, the results after one year can show up to 41% improvement in reducing the set-up time. After four years the reduction time can be improved by 62%. Advantages of SMED have a direct influence on utilisation and productivity will increase. SMED will improve the flexibility of the cell to change quickly to

the next order and therefore smaller orders can be planned and delivery to the customer can be faster. SMED reduces production cost and inventory, and eliminates waste (Rubrich and Watson, 2000:311).

2.3.11 Takt Time

Rother and Shook (2001:13) explain takt time as the synchronisation of production with the demand of the customer. Takt is the German word for pace or beat. This means the manufacturer must manufacture at the rate at which the customer wants the products. If the manufacturer produces at a slower rate, the customer demand will not be met, resulting in a loss in sales. Producing at a faster rate is a waste of resources and it increases inventory - a further form of waste. Inventory is expensive as it involves handling and storage costs, as well as more storing space. The formula to calculate takt time is shown in Figure 2.3.2 below.

Figure: 2.3.2: Takt Time Formula


$$\text{Takt Time} = \frac{\text{Production Time Available}}{\text{Customer Demand}}$$

Source: Adapted from Rother, M. & Shook, J. (2001:13) Creating continuous flow. Massachusetts: The lean enterprise institute Inc. [On-line]. Internet: <http://www.lean.org>.

An advantage of takt time is that the technique forces the manufacturer to manufacture just what the customer requires. Therefore, it reduces overproduction, saves resources, limits overtime and saves on inventory levels. One disadvantage is that no backup inventory is available if something goes wrong.

2.3.12 Total Preventative Maintenance (TPM)

Slack et al. (2001:659) define TPM as *“the productive maintenance carried out by all employees through small group activities.”*

TPM makes use of five goals to establish a good maintenance practice:

- Improve equipment effectiveness by analysing all the losses incurred by down time, and speed and defect losses.
- Achieve autonomous maintenance by allowing employees to be responsible for some of the maintenance tasks.
- Plan maintenance by having a preventative maintenance plan and describing the responsibilities of each operating employee and maintenance employee.
- Train all staff in relevant maintenance skills.
- Achieve early maintenance management by designing equipment to avoid maintenance altogether.

TPM is a continuous process of improving the effectiveness of the production equipment by involving all the people in the organisation (Rubrich and Watson, 2000:209).

Some of the greatest advantages of TPM include the following:

- Improvement of quality.
- Machinery and equipment are in the best operating condition.
- Manufactured components that have less variation.
- Improved productivity.
- Less down time, stoppages, reduced machine speeds to accommodate poorly maintained machines, resulting in a more productive company.
- Improved delivery to customers.
- Improved customer satisfaction because customers can rely on scheduled delivery dates.
- Reduced inventory, no more safety stock in case of breakdowns.
- Improved job satisfaction, because operators will not become frustrated when their machines brake down.

Rubrich and Watson (2000: 216) compare the “before” and “after” of implementation of TPM. Before implementation of TPM operators have down time because of breakdowns; non-conforming products and reworks; loss of operating speed; unnecessary adjustments; idling; or stoppages. Down time adds up to 50% of the total operating time. Customers pay for 100% of the production time where, without TPM, only 39% of the time is productive. With TPM production time increases to 87%, with only 2% of the production time spent on TPM.

2.3.13 Total Quality Management (TQM)

Conner (2001:21) states that doing it right the first time plays a critical role in lean manufacturing. He further states that it does not matter which quality system is used - the ISO 9000, the six-sigma approach or any other quality systems - as long as the system meets the following principles: *“the systems must be sound, the practices defined and the processes capable”*.

Heizer and Render (1999:82) describe TQM as the *“management of an entire organisation so that it excels in all aspects of products and services that are important to the customer.”* They describe five concepts for an effective TQM programme, namely continuous improvement, employee empowerment, benchmarking, just in time (JIT) and the knowledge of TQM tools. The knowledge of TQM tools includes quality function deployment, the tagunchi technique, pareto charts, cause and effect diagrams and statistical process control.

Conner (2001:144) explains that there are more than 700 tools that can be used to solve problems. This proves TQM is a subject to be researched on its own. For the purposes of this research the benefits and explanation of TQM are relevant.

Slack et al. (2001:677) explain TQM as follows: “TQM is best thought of as a philosophy of how to approach quality management.” It lays particular emphasis on the following:

- Meeting the expectations of the customers.
- Covering all parts of the organisation.
- Including every person in the organisation.
- Examining all costs related to quality, especially failure cost.
- Getting things “right the first time”.
- Developing the system and procedures that support quality and improvement.
- Developing a continuous process of improvement

An advantage of TQM, according to Slack et al. (2001:677), is that the expenditure on and effort to prevent defect parts will result in a more than equivalent reduction in other costs. The biggest advantage is a more than satisfied customer. One of the measures to monitor TQM success is the number of customer complaints and claims.

2.3.14 Value-Stream Mapping (VSM)

Rother and Shook (1999:3) claim that plotting the material flow, information flow and the process to manufacture a product on paper (value-stream mapping) will include all the actions needed to manufacture a product. The person doing the mapping work will include all the processes and actions in the current process whether these actions add value or not. Value-stream mapping is to view the overall picture of the business - from supplier to customer. Value-stream mapping is a pencil-and-paper tool where the lean manufacturing specialist will map all the actions needed to get information flowing at the top of the sheet of paper and the material flow at the bottom. From this map the lean specialist will identify the wastes and draw a new map of how value should actually flow.

VSM gives you a big picture of the operating functions of the organisation and helps you understand the business as a whole. Identifying the sources of waste becomes much easier. The map shows a link between the information and material flow, which will help to create and improve on the material flow and create a futuristic map with less waste.

2.3.15 Waste (Muda)

Scodanibbio (2005) defines waste as follows: *“Whatever is not useful is waste.”* and *“Whatever does not contribute to profitability is waste.”* and *“useful = value adding”* and *“adding no value = waste”*

According to Slack et al. (2001:488) waste can be described in seven categories:

- Overproduction: producing more than what is needed immediately through the next process.
- Waiting time is measured in terms of machine utilisation, the efficiency of machines and people, and materials queuing for changeover.
- Transport: moving of materials around the plant, double handling of work in process.
- Processes: some process can be attributed to poor component design or poor maintenance and can be eliminated.
- Unnecessary inventory: inventory in stores (in the form of components or finished goods), buffer stock or safety stock must be reduced to a minimum.
- Defects: the consequences of not doing it right the first time: rework, rejects, unnecessary inspection.
- Motion: excessive reaching and walking to do your normal duties.

Rubrich and Watson (2000: 271) state that 50% of production time is spent on waste and that only 37% of time is actually productive. To improve productivity waste must be removed. When waste is eliminated, the productive time can increase to 87%. By reducing waste, productivity will increase.

2.4 CONCLUSION

Lean manufacturing does not provide a quick fix tool and needs a well thought-out implementation strategy. It takes time to implement and the manufacturing culture must change to adapt to the new way of doing business. A few lean manufacturing advocates believe that lean manufacturing consists of JIT, removing waste and TQM. The other lean manufacturing believers mostly advocate improving value-adding processes and removal of non-value-adding processes. All of the lean manufacturing advocates agree that inventory is the most measurable means to determine whether a manufacturer is lean or not. There is an almost endless list of techniques to be used in becoming lean.



CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

This chapter provides a detailed background to the research design, questionnaire design and methodology used to conduct the survey. This is followed by the discussion concerning the population and sample size. In conclusion an explanation of the method used to analyze the data is provided.

3.1 RESEARCH QUESTION

To what extent does the application of lean manufacturing techniques in assembly manufacturing contribute to an increase in productivity, a reduction in inventory levels and operating cost.

3.2 RESEARCH DESIGN



Research design is a plan or blueprint of the methods employed by the researcher to accomplish his/her objectives (Mouton, 2001:55).

The research took on the form of a quantitative empirical survey. According to Mouton (2001:53) empirical studies address real-life problems by collecting new data or analysing existing data. The researcher collected new data (primary data) for the research by using a structured questionnaire. Primary data is data captured at the point where it is generated and the data is captured with a specific purpose in mind (Wegner, 1999:13).

3.2.1 Quantitative Research

According to De Vos, Strydom, Fouché and Delport (2003:138) quantitative research includes experiments, surveys and content analysis. Quantitative research is more formally structured, more explicitly controlled and more acceptable to the physical sciences than a qualitative approach. In a quantitative approach the researcher is only an objective observer; studies are focused on specific questions or hypotheses; and data collection methods are structured prior to the study and applied in a standardised manner. Measurements are focused on specific variables that are quantified through rating scales, frequency counts and other means. Analysis takes the form of statistical methods to determine associations and differences between the variables (De Vos et al., 2003:363).

3.2.2 Surveys

The term “survey” means to collect data or information, and the opinions of the population. Surveys use structured and predefined questions. The aim of a survey is to determine whether theories are related to the observable facts, to test theories and seek relationships between the data. Surveys assist in bringing models, theories, concepts and variables into better focus (Filippini, 1997).

3.2.3 Questionnaire Design

Mouton (2001:100) states that existing instruments can be used as they have their advantages; or the researcher can design a new instrument. The researcher decided a new design would be more suitable. It was a limitation that the instrument had to be tested for validity. A pilot study was done to test the validity of the questionnaire.

Other errors made in questionnaires, according to Mouton (2001:100), are ambiguous or vague items, double-barrelled questions, the order and sequence of questions and leading questions. The researcher therefore used the help of Statcon at the University of Johannesburg to structure the questionnaire.

The questionnaire was descriptive in nature and the questions were constructed in three sections. The first section covered information about the respondent, the second section covered the respondent's company and section three covered the techniques and the value the techniques might have added to the company. Because the techniques were selected from the literature, it was possible that they might not form part of the respondents' field of reference. Each technique was therefore accompanied by a short description.

Vinten (1995) states that closed questions may be referred to as "check answer", "pre-coded" or "restricted". The advantages are that closed questions are easier to handle and cost less to manage. Another advantage is that they take up less interview time and will therefore possibly increase the responses from respondents. Open questions can lack clarity.

Ranchod and Zhou (2001) find a questionnaire of more than 6 pages intolerably lengthy. The researcher was therefore restricted to 6 pages and had to tabulate the last eight techniques, requesting simple "Yes" or "No" responses – a limitation of this research.

3.2.4 Data Types

Wegner (1999:7) states that the type of data gathered determines the type of analysis that can be performed on the data. The questionnaire used mainly qualitative data. Wegner (1999:7) describes qualitative data as data with non-numeric responses. The data can be broken down into different groups, namely nominal-scale data, ordinal-scale data, interval-scale data and ratio-scale data. Nominal-scale data was used where respondents had to choose between a "Yes" and "No" response. Nominal-scale data, according to Wegner (1999:8), is where there is no implied order between the groups of variables. The researcher used nominal-scale data where the respondents had to indicate whether they were familiar with the technique described. The rest of the questionnaire consisted of ordinal-scale data. According to Wegner (1999:8) ranking is implied between the categories - although there is a difference between categories, the difference cannot be measured exactly. The researcher used ordinal-scale data to

determine how frequently the specified technique was used (“Not at all, Sometimes, Often and Always” - refer to Appendix B). Ordinal-scale data was used to determine the value of the specified technique to the respondent’s organisation (“To no extent, to a small extent, to a moderate extent and to a large extent”) The value of each technique was used as described by the literature and was limited to inventory reduction and productivity improvement, improvement in inventory control, reduction in idle time and reduction of operating cost.

3.3 METHODS USED TO CONDUCT THE SURVEY

A pilot study was conducted to verify reliability and validity, after which minor changes were made. The responses from the pilot study were excluded from the research results. Mouton (2001:103) claims that a common error in questionnaire design is that the questionnaire is not pre-tested.

3.4 POPULATION AND SAMPLING



According to general statistics the following sectors contribute to South Africa’s economy: Manufacturing 18.2%, Mining 6.5%, Agriculture 3.7 % and Finance 13.1%. These statistics show that manufacturing contributes the biggest part of the economy in South Africa (South Africa, 2005). (www.bombaychamber.com/southafrica.htm).

According 1999 census results census, there are 25 788 manufacturers in South Africa, of which 11 099 (or 43%) are situated in Gauteng. (Statistics South Africa, 1996). (www.statssa.gov.za). The number of these manufacturers concerned with assembly manufacturing is however unknown.

Wegner (1999:170) describes sampling as the method to select a representative observation from the population. There are two basic methods of sampling, namely non-probability and probability sampling. Convenient sampling as a non probability sampling technique was used. For these purposes three list were obtained. One list from the

South African Chamber of Business (SACOB), one from the UNISA Quality Forum and another one from the Production Management Institute (PMI).

These list were scrutinised for possible companies that fall under the classification of assembly manufacturers. A total of 222 companies were identified and selected specifically in the Johannesburg surrounding area of Gauteng to form part of this research.

3.5 METHODOLOGY

All potential respondents (222) on the above lists where contacted (where contact numbers/e-mail addresses were provided) to verify their contact details and to request their participation. 40 of the potential respondents contact details could not be verified and they had to be excluded from the lists.

Ranchod and Zhou (2001) stated that, in general, responses from e-mail surveys are low because of lack of anonymity, formal image, incentive and cosmetic features. The lack of formal image was overcome by designing the questionnaire in Microsoft Word and then attaching it to the e-mail message.

The questionnaire was accompanied by a covering letter stating the background and purpose of the research (Appendix A & B). As an incentive for response the covering letter notified respondents that they could apply for the executive summary of the research result. The questionnaire together with the covering letter were sent via e-mail and fax to respondents.

A total of 222 questionnaires were e-mailed, faxed or delivered by hand. The e-mail and fax responses were poor, as predicted by the literature study (Ranchod and Zhou: 2001) Of the 153 questionnaires sent via e-mail only 4 responses were returned. Of the 49 questionnaires which were delivered by hand, 14 of them where unfit to be used for this research. Due to the poor response received via e-mail, other assembly manufacturers not listed on the above lists were randomly approached to participate in this research. A

further 20 questionnaires were completed in this manner of which 17 were fit for purpose of this research.

A total of 215 questionnaires were sent out, of which 56 were returned. During the analyses a further seven questionnaires were declared invalid. This constitutes a response rate of 22,7%.

3.6 METHOD OF DATA ANALYSIS

3.6.1 Chi-Square test

With the help of STATCON at the University of Johannesburg the data was captured and sorted in frequency tables. Thereafter the data was sorted in cross-tables or matrixes as described by Field (2005:140) and then the Pearsons Chi-square test was used to test for significance. Pallant (2005:288) describes the Chi-square test as a test that explores the relationship between two clear-cut variables. Wegner (1999:248) describes the Chi-square test as a measure to test the hypotheses on patterns of outcomes of a random variable in a population. The Chi-square is written as χ^2 and measures the independence of association. "Independence implies that outcomes of one random variable in no way influence the outcomes of a second variable" (Wegner, 1999:249).

In some cases "Fisher's Exact Probability Test" was used. According to Pallant (2005:288) Fisher's test can be used in the place of the Chi-square test. Fisher's test can be used in a case where a 2x2 table is used and the rule of Chi-square of a minimum count in a cell of the table is violated. A Chi-square value of less than 0.05 shows a significant relationship between the data variables. The strength of this relationship (the Pearson relationship) can then be tested. Pallant, (2005:126) uses guidelines suggested by Cohen (see Table 3.6.1 below):

Table 3.6.1 Statistical Strength of Relationship

Correlation value=r	Correlation value=r	Strength of relation ship
r= 0.1 to 0.29	r= -0.1 to -0.29	Small
r=0.3 to 0.49	r=-0.3 to -0.49	Medium
r=0.5 to 1.0	r=-0.5 to -1.0	Large

Source: Adapted from Pallant, J. (2005:126) 2nd. SPSS Survival manual. New York: Open University press.

3.6.2 Cross-Tabulation

Cross-tabulation is when the data of two variables are formatted in table form to test the relationship between them. One variable is prearranged in columns and the other in rows. The point where the two variables cross (row and column) on the table is the point where the value in this cell has a shared influence. The data is expressed in a percentage of the row total or the column total (Eiselen, Uys and Potgieter 2005:139).

3.7 CONCLUSION

The research was conducted in the Johannesburg area of the Gauteng Province, where most of South Africa's industries are concentrated. The main objective was to find out which techniques manufacturers use and to what extent these techniques add increase or reduce inventory, productivity and operating cost for the assembly manufacturer. The research was mainly a quantitative empirical study. STATCON at the University of Johannesburg assisted with data capturing, analysis, interpretation and presentation of the results as presented in Chapter 4.

CHAPTER 4

DATA PRESENTATION AND ANALYSIS

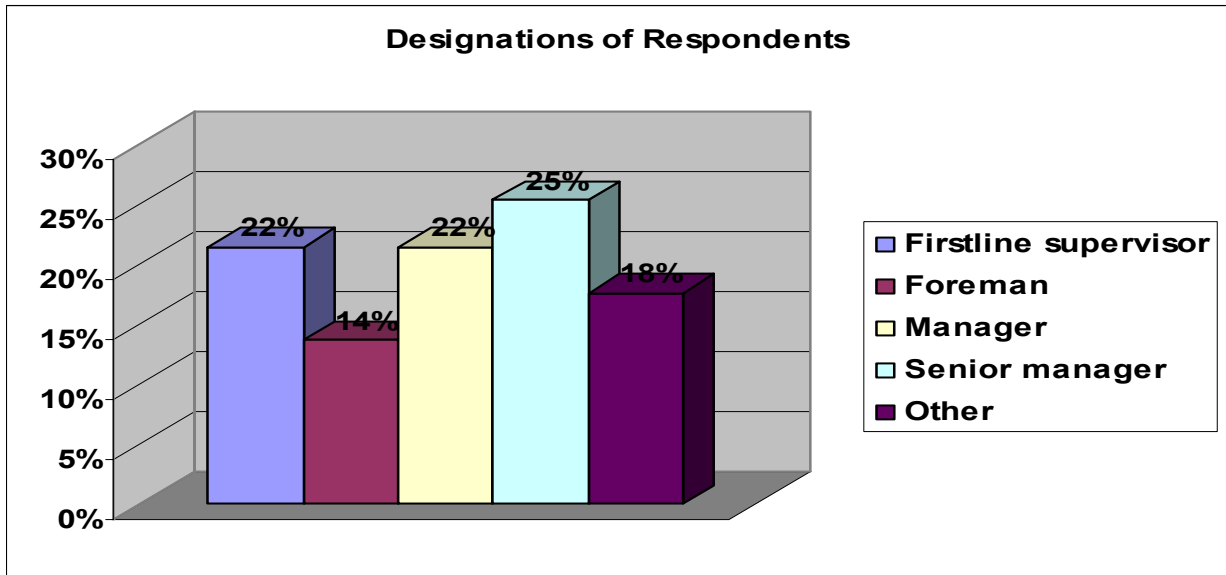
This chapter makes use of bar charts and crosstables to represent the data that was studied and analyzed. Only relevant and significant information was highlighted and commented on. The structured questionnaire consisted of three sections. Section A requested information about the respondents, section B requested information about the nature of the manufacturer and section C requested information about the knowledge, use and results obtained with regard to various techniques implemented by the respondents.

4.1 SECTION A (INFORMATION ABOUT THE RESPONDENT)

4.1.1 Job Designations of Respondents

The positions of the various respondents are summarised in Figure 4.1 below. First-line supervisors and managers each accounted for 22% of the population. The “Foreman” section accounted for 14% (the smallest part of the population), while the senior managers accounted for 25% (the largest part). The “other” section 18% included, inter alia, directors, owners and engineers.

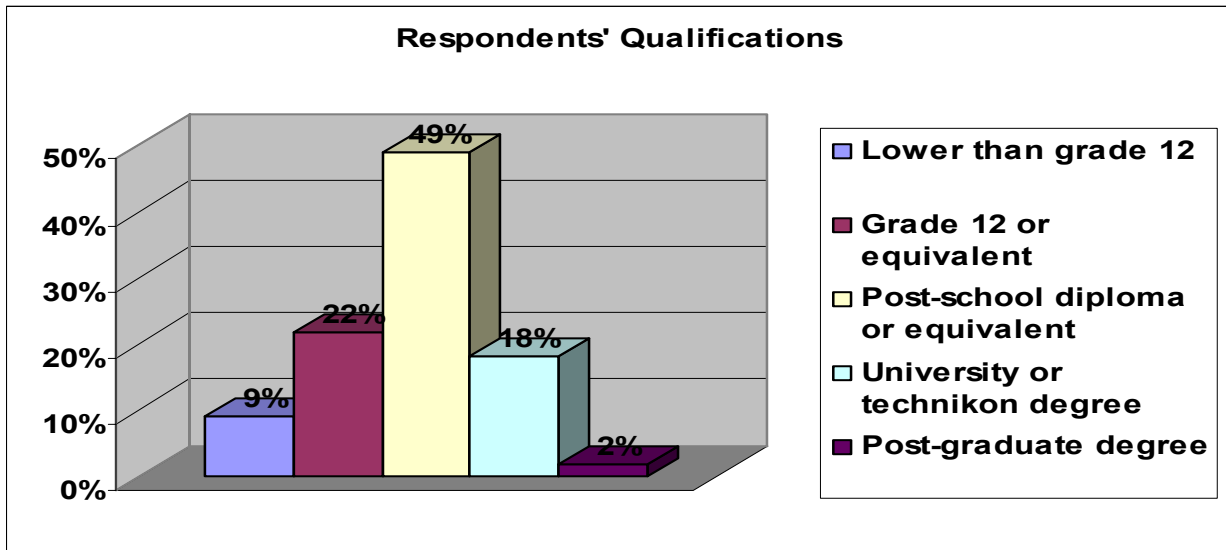
Figure 4.1: Designations of Respondents



4.1.2. Respondents' Qualifications

The respondents were asked to indicate their highest qualifications. This is summarised in Figure 4.2 below. Of the respondents, 9% indicated having lower than grade 12 and 22% indicated having grade 12 or equivalent education. The biggest part of the population 49% had post-school diplomas, 18% had university or technikon degrees and 2% had post-graduate degrees.

Figure 4.2: Respondents' Qualifications

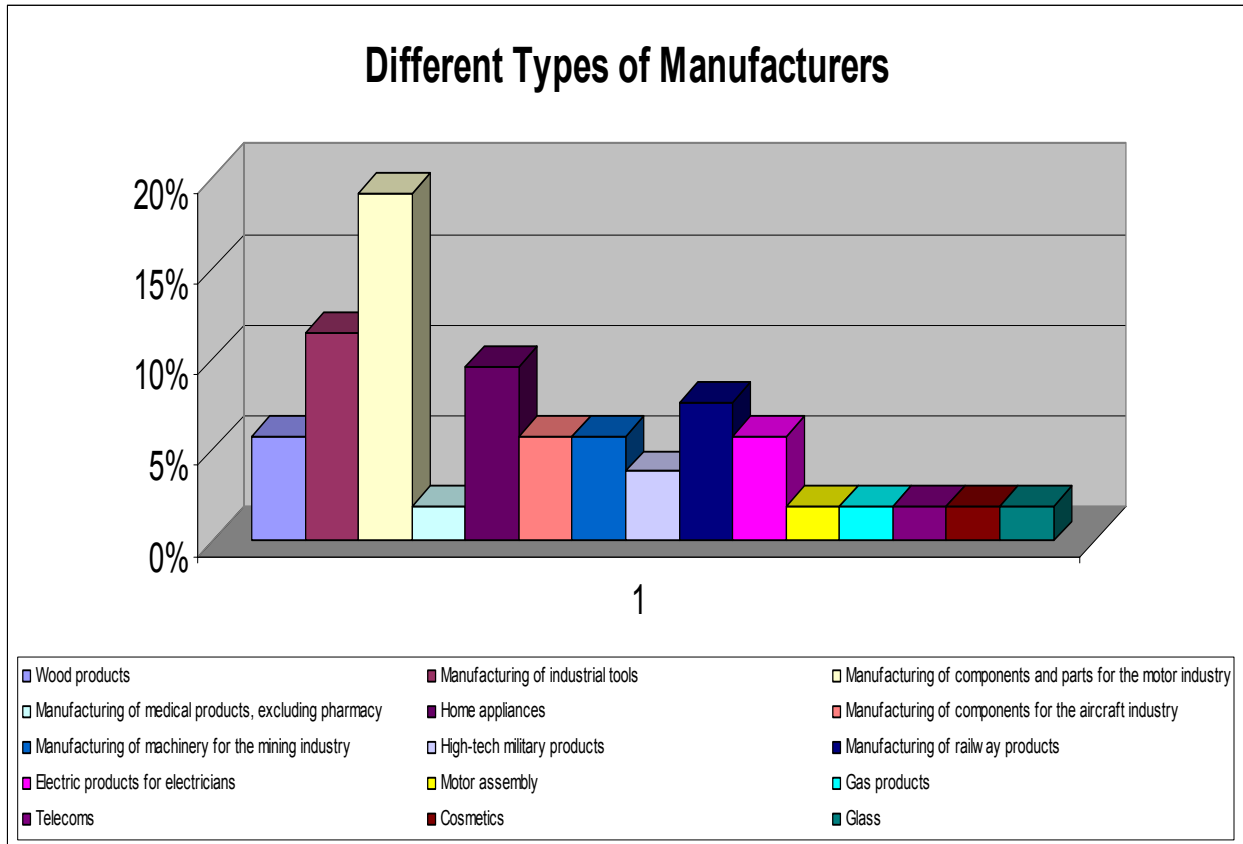


4.2 SECTION B (NATURE OF THE MANUFACTURERS)

4.2.1 Assembly Manufacturers -Nature of Business

Of the assembly manufacturers that responded, the nature of business varied considerably, as illustrated in figure 4.2.1 below. Most of the respondents 19% came from the motor industry, followed by industries who manufacture industrial tools 12%. The remaining respondents 2% to 10% had varied nature of business.

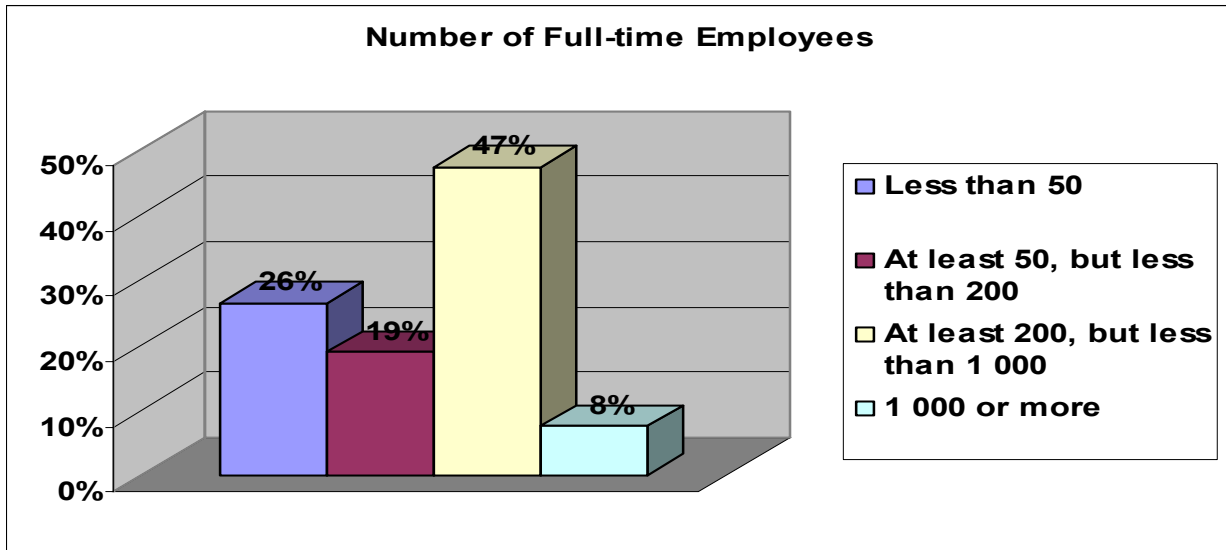
Figure 4.2.1: Different Types of Manufacturers



4.2.2 Size of Manufacturers

According to the “White Paper on National Strategy for the Development and Promotion of Small Business in South Africa” (Government of South Africa: 1995) small businesses are categorised in groups according to the number of full-time employees. Enterprises with 5 to 50 employees are categorised as small enterprises with 26% of the respondents fell into this category. Enterprises that employ up to 200 employees are categorised as medium enterprises and 19% of the respondents falling into this category. Enterprises with more than 200 but less than 1 000 employees are not categorised in the White Paper, but are normally viewed as large enterprises. Most of the responses 47% came from these industries (see Figure 4.2.2 below). The remainder 8% had more than 1 000 employees.

Figure 4.2.2: Number of Full-Time Employees



4.3 SECTION C (INFORMATION REGARDING THE TECHNIQUES)

This section covered questions about the different techniques, whether the respondents were familiar with the techniques and how frequently the techniques were used in the respondents' place of work. The respondents then indicated to what extent the techniques improved inventory reduction or reduced operating cost and improved productivity.

4.3.1 Technique 1: ABC Analysis

Familiarity with technique

Of the respondents 69% indicated that they were familiar with ABC analysis as a lean manufacturing technique and 39% indicated that they were unaware of this particular technique. 19% of the respondents that were familiar with the technique indicated that they didn't utilise the technique within their particular organisation.

Reduction of Inventory levels and Control

Most of the respondents 54% indicated that this technique resulted in a moderate reduction in inventory levels as shown in Figure 4.3.1 below. Only 4% indicated that this technique to no extent contributed to a reduction in their inventory levels.

Figure: 4.3.1 ABC Analysis: Inventory Reduction

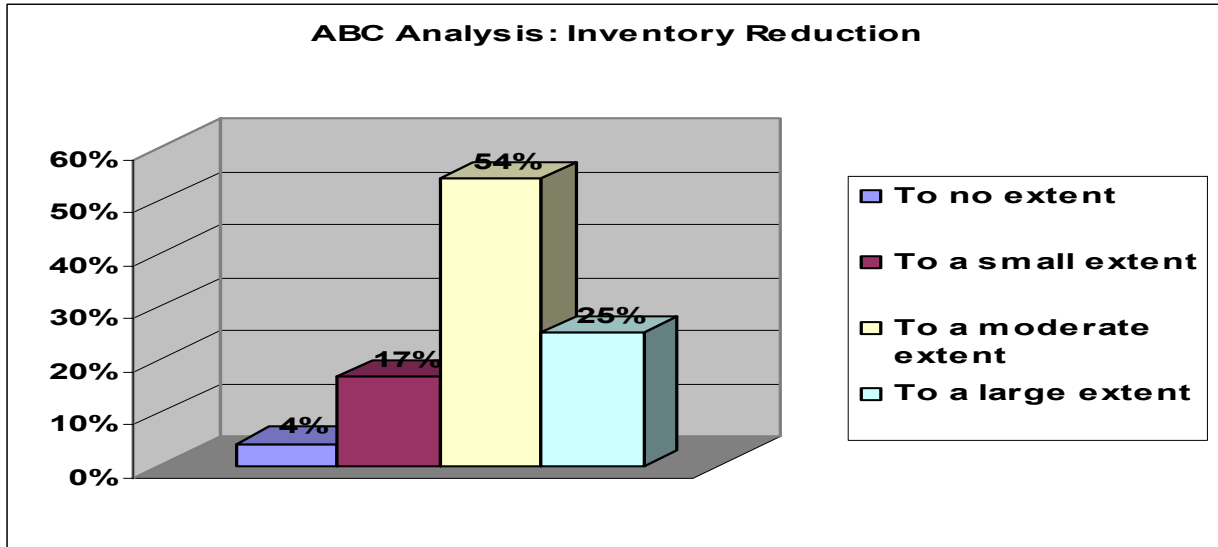
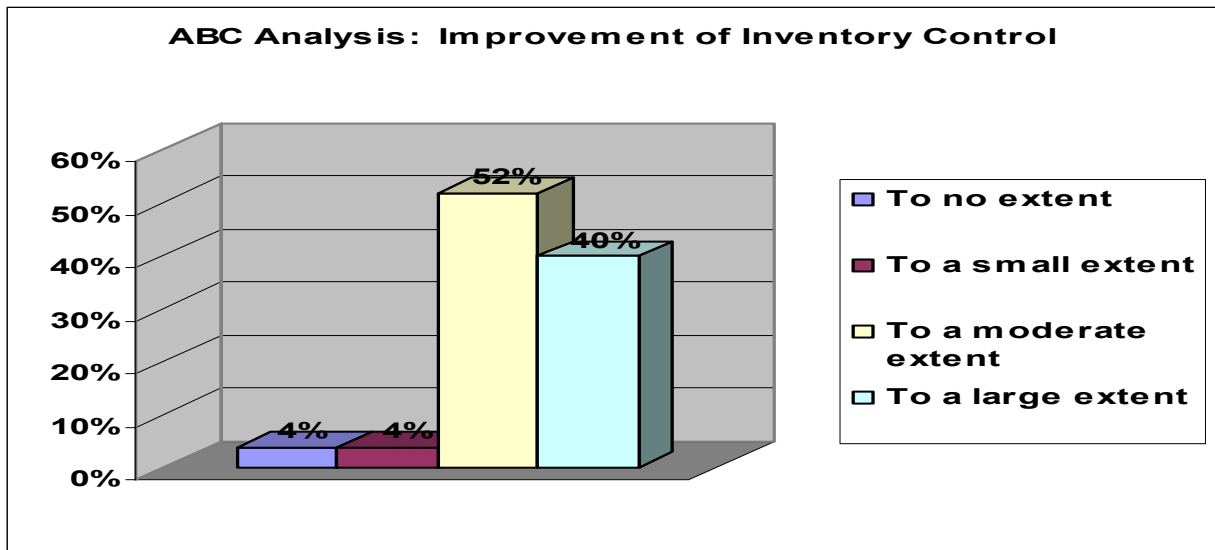


Figure 4.3.2 below shows the response to the question whether or not the ABC analysis assisted them to improve inventory control. 52% indicated "to a moderate extent" and 40% "to a large extent", 4% responded to no extent, this being the same 4% who responded that ABC analyses does not contribute to a reduction in their inventory levels

Figure 4.3.2: ABC Analysis: Improvement of Inventory Control



Qualification versus Knowledge of Technique

A total of 61.2% of the respondents (school and post-school diplomas, and university or technikon degrees) were familiar with ABC analysis. Respondents with post-school diplomas were the most familiar with the technique 53.3%, as indicated in Table 4.3.1 below.

Table 4.3.1: Qualification versus Knowledge of Technique

	ABC analysis	School	Post-school diploma or equivalent	University or technikon degree and Post-graduate	Row Total
YES	% of row total	23.3%	53.3%	23.3%	61.2%
	% of column total	50%	66.7%	63.6%	
NO	% of row total	36.8%	42.1%	21.1%	38.8%
	% of column total	50%	33.3%	36.4%	
	Column Total	28.6%	49%	22.4%	100%

Usage versus Inventory Reduction

The responses to the question whether ABC analysis reduced inventory were cross tabulated as follows: The responses “sometimes” and “often” were grouped together, and “always” separately (Table 4.3.2 below). A total of 72.4% of the respondents who used the technique indicated a “moderate to large extent” reduction. Most respondents used the technique only “sometimes to often” 65.5%. Only 34.5% indicated that they used the technique “always” and 90% of this 34.5% indicated a “moderate to large extent” reduction.

Table 4.3.2: Usage versus Inventory Reduction

ABC analysis		Sometimes to often	Always	Row Total
Inventory Reduction				
No extent to small extent	% of row total	87.5%	12.5%	27.6%
	% of column total	36.8%	10%	
Moderate to large extent	% of row total	57.1%	42.9%	72.4%
	% of column total	63.2%	90%	
Column Total		65.5%	34.5%	100%

Usage versus Improved Inventory Control

Table 4.3.3 below illustrates responses to the question whether ABC analysis improved inventory control. 86.7% of the respondents indicated that the technique resulted in a “moderate to large extent” improvement of inventory control. Most of the respondents used the technique only “sometimes to often” 65%. A total of 34.5% of the respondents indicated that they used the technique “always” and all of them 100% indicated that it resulted in a “moderate to large extent” improvement in inventory control.

Table 4.3.3: Usage versus Improved Inventory Control

ABC analysis		Sometimes to often	Always	Row Total
Improved inventory control				
No extent to small extent	% of row total % of column total	100% 20%	0% 0%	13.3%
Moderate to large extent	% of row total % of column total	61.5% 80%	38.5% 100%	86.7%
Column Total		65.5%	34.5%	100%

4.3.2 Technique 2: Assembly Line Balancing

Familiarity with technique

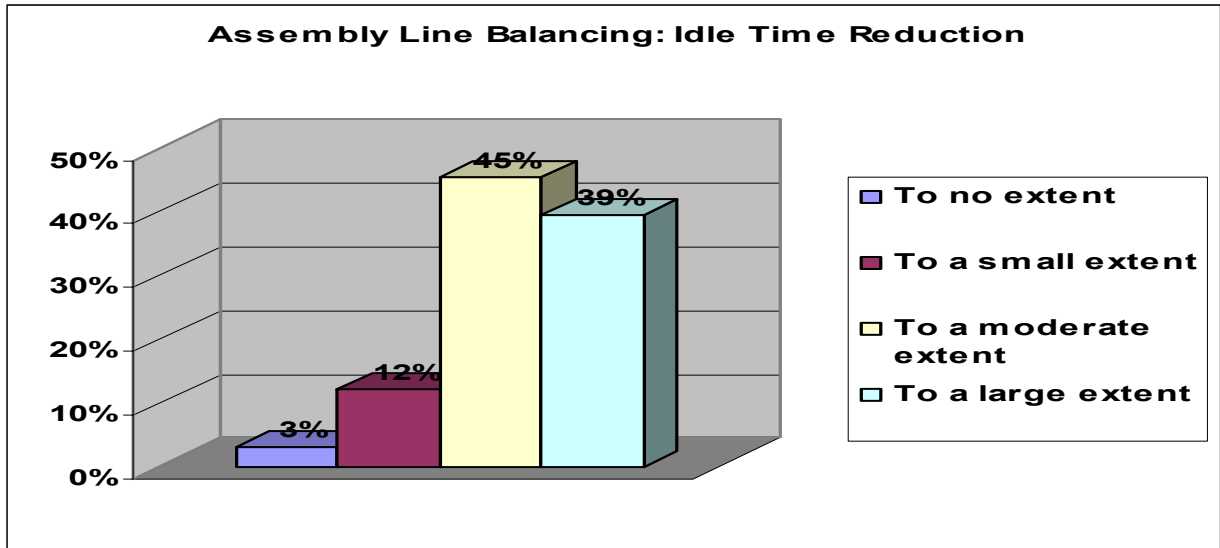


76% of the respondents were familiar with assembly line balancing. 89% of the respondents that were familiar with this technique applied it in their organisations. A further 39.5% of the respondents who applied the technique, used it “always”.

Reduction of idle time

It was further found that of the above 89% the technique assembly line balancing contributes positively “to a large extent” to a reduction in idle time 39%. 45% of the respondents reported that assembly line balancing (ALB) contributed to a “moderate extent” to are reduction in idle time as illustrated in Figures 4.3.3 below.

Figure 4.3.3: Assembly Line Balancing: Idle Time Reduction

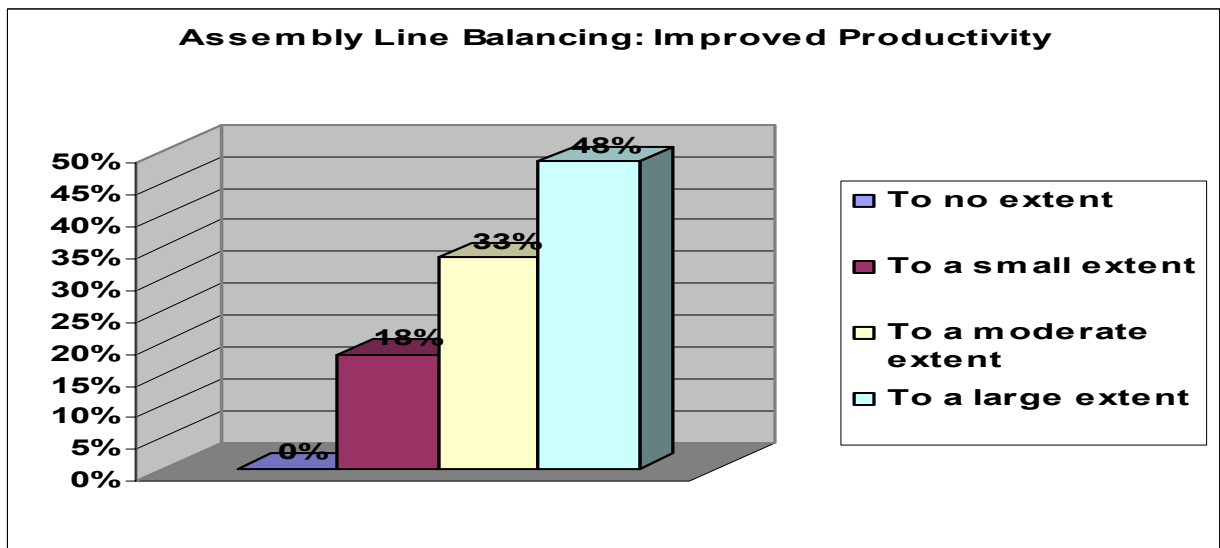


Productivity Improvement

Figure 4.3.4 below illustrates that productivity did improve “to a large extent”, 51% indicated that their productivity did improve ranging from “a small to moderate extent” .



Figure 4.3.4: Assembly Line Balancing: Improved Productivity



Usage versus Idle Time Reduction

Table 4.3.4 shows that 83.7% of the respondents indicated that the assembly line balancing technique reduced idle time from a “moderate to a large extent”. A total of 39.5% indicated that they used the technique “always” and 88.2% of these indicated that idle time was reduced from a “moderate to a large extent”.

Table 4.3.4: Usage versus Idle Time Reduction

Assembly Line Balancing Idle time reduction		Sometimes to often	Always	Row Total
No extent to small extent	% of row total % of column total	71.4% 19.2%	28.6% 11.8%	16.3%
Moderate to large extent	% of row total % of column total	58.3% 80.8%	41.7% 88.2%	83.7%
Column Total		60.5%	39.5%	100%

Usage versus Improved Productivity

Table 4.3.5 below shows that 76.7% of the respondents indicated that the assembly line balancing technique resulted in a “moderate to large extent” improvement in productivity. Most of the respondents 60.5% used the technique “sometimes to often”. A total of 88,2% of the 39.5% of respondents who indicated that they used assembly line balancing “always”, indicated that the technique resulted in a “moderate to large extent” improvement in productivity.

Table 4.3.5: Usage versus Improved Productivity

Assembly Line Balancing Improved Productivity		Sometimes to often	Always	Row Total
No extent to small extent	% of row total % of column total	80% 30.8%	20% 11.8%	23.3%
Moderate to large extent	% of row total % of column total	54.5% 69.2%	45.2% 88.2%	76.7%
Column Total		60.5%	39.5%	100%



4.3.3 Technique 3: Cell manufacturing

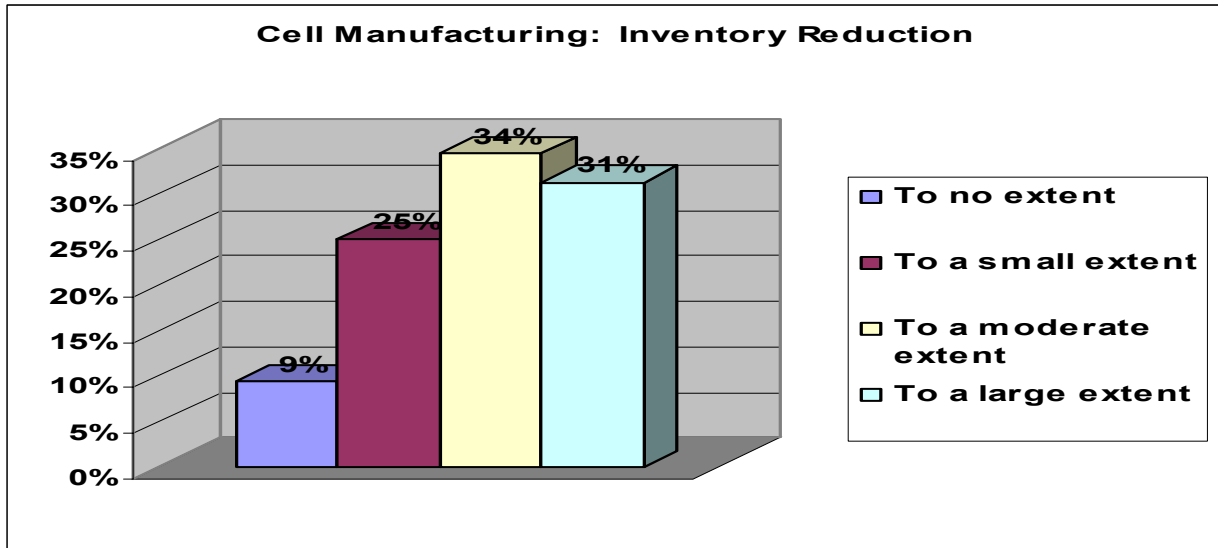
Familiarity with technique

70% of the respondents indicated that they were familiar with cell manufacturing as a lean manufacturing technique. 46.7% of the respondents indicated that they “always” use the technique.

Reduction in inventory levels

As for the question whether cell manufacturing reduced inventories, most respondents 34% replied “to a moderate extent” as shown in Figure 4.3.5 below. 31% of the respondents reported that they use the technique to “a large extent”.

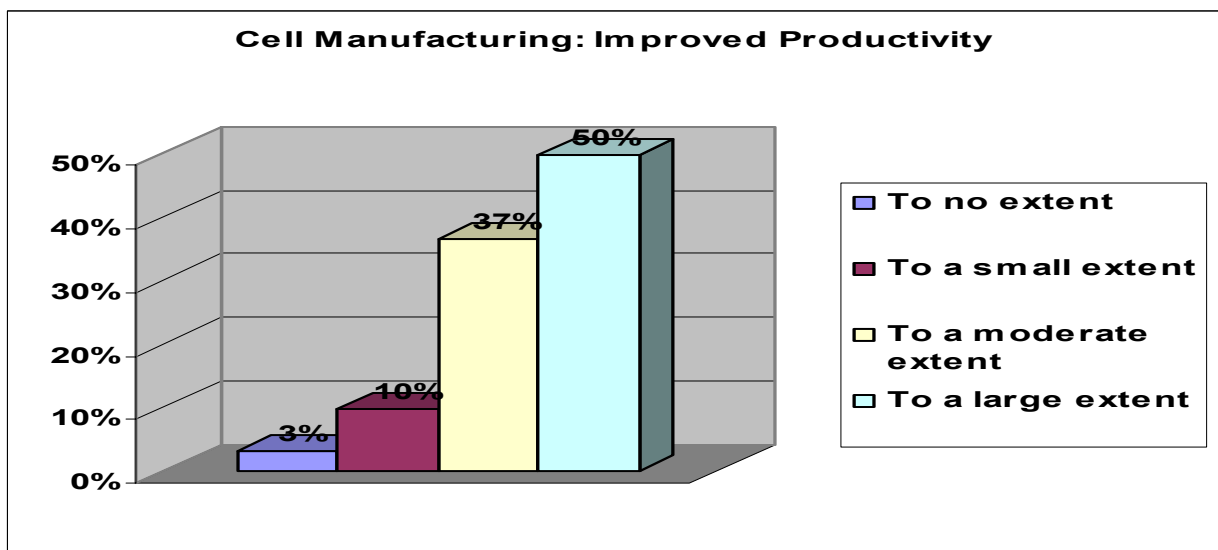
Figure 4.3.5: Cell Manufacturing: Inventory Reduction



Productivity Improvement

Figure 4.3.6 illustrate the responses received for the question whether cell manufacturing improved productivity, 97% responded indicated that it does improve productivity of the 97% 10% reported to "a small extent" and 50% "to a large extent".

Figure 4.3.6: Cell Manufacturing: Improved Productivity



Size of Manufacturer versus Knowledge of Technique

A two-tailed Fisher's exact probability test ($p = 0.011$) showed that the number of participants from companies with less than 200 employees (55.9%. $n=21$) that were familiar with the cell manufacturing technique was significantly greater than that of companies with more than 200 employees (44.1%. $n=28$). This relationship between familiarity with the technique and company size was moderate ($r = 0.396$). As illustrated in Table 4.3.6, manufacturers with less than 200 employees were more conversant with the technique than larger manufacturers with more than 200 employees.

Table 4.3.6: Size of Manufacturer versus Knowledge of Technique

Cell Manufacturing Familiarity		Less than 200 employees	At least 200 employees	Row Total
YES	% of row total	55.9%	44.1%	69.4%
	% of column total	90.5%	53.6%	
NO	% of row total	13.3%	86.7%	30.6%
	% of column total	9.5%	46.4%	
Column Total		42.9%	57.1%	100%

Qualification versus Knowledge of the Technique

A full sample was used. This means that both assembly and non-assembly manufacturing were used. As indicated in Table 4.3.7 below the Chi-square test showed that the number of participants with a post-school qualification (53.1% post-school or equivalent, $n = 26$ and 30.6% university or technikon degree, $n = 15$) that were familiar with the cell manufacturing technique was significantly greater than the number of participants with only a school qualification (16.3%, $n = 8$), [$\chi^2 (2, N = 73) = 17.204$, $p < 0.001$]. This relationship between familiarity with the technique and level of

qualification was moderate (Cramer's $V = 0.485$). Employees with degrees and post-graduates all responded positively 100% that they were familiar with the technique whereas only 72.2% of the respondents with post-school diplomas indicated that they were familiar with the cell manufacturing technique.

Table 4.3.7: Qualification versus Knowledge of Technique

	Cell Manufacturing	School	Post-school diploma or equivalent	University or technikon degree and Post-graduate	Row Total
YES	% of row total % of column total	16.3% 36.4%	53.1% 72.2%	30.6% 100%	61.2%
NO	% of row total % of column total	58.3% 63.6%	41.7% 27.8%	0% 0%	38.8%
	Column Total	30.1%	49.3%	20.5%	100%

Usage versus Inventory Reduction

The responses to the question whether cell manufacturing reduced inventory are illustrated in Table 4.3.8 below. A total of 64.4% of the respondents indicated that the cell manufacturing technique resulted in a “moderate to large extent” inventory reduction and most of these respondents 76.2% used the technique “always”. The “sometimes to often” users was the biggest group, namely 53.3%.

Table 4.3.8: Usage versus Inventory Reduction

Cell Manufacturing Inventory Reduction		Sometimes too often	Always	Row Total
No extent to small extent	% of row total % of column total	68.8% 45.8%	31.3% 23.8%	35.6%
Moderate to large extent	% of row total % of column total	44.8% 54.2%	55.2% 76.2%	64.4%
Column Total		53.3%	46.7%	100%

Usage versus Improved Productivity

A two-tailed Fisher's exact probability test ($p= 0.022$) showed that the number of participants that indicated that they "always" used the cell manufacturing technique and that productivity had improved to a "moderate/large extent" (100%, $n=20$) was significantly greater than the number that indicated that they only used the cell manufacturing technique "sometimes or often" (72.7%, $n= 16$). This relationship between extent of usage of the technique and rating of productivity was moderate ($r= 0.389$). From Table 4.3.9 below it is clear that when the technique was used "always", the benefit was a 100% "moderate to large extent" improvement in productivity. Even when the technique was used "sometimes to often", it resulted in a "moderate to large extent" improvement in productivity 72.7%.

Table 4.3.9: Usage versus Improved Productivity

Cell Manufacturing Improved productivity		Sometimes to often	Always	Row Total
No extent to small extent	% of row total % of column total	100% 27.3%	0% 0%	14.3%
Moderate to large extent	% of row total % of column total	44.4% 72.7%	55.6% 100%	85.7%
Column Total		52.4%	47.6%	100%

4.3.4 Technique 4: Cycle Time



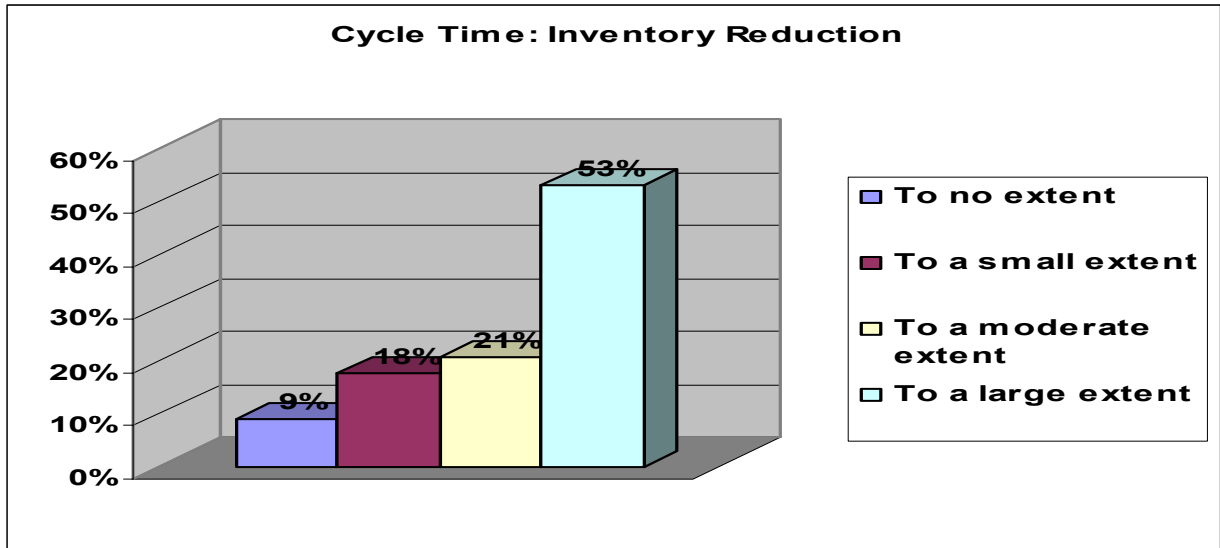
Familiarity with technique

78% of the respondents indicated that they were familiar with cycle time as a lean manufacturing technique.

Reduction in inventory levels

As for the question whether cycle time leads to reduced inventory levels, most respondents 92% replied positively as shown in Figure 4.3.7 below. 53% of the respondents reported that it reduces their inventory to “a large extent”. 18% and 21% respectively reported to a “small and moderate extent”.

Figure 4.3.7: Cycle Time: Inventory Reduction

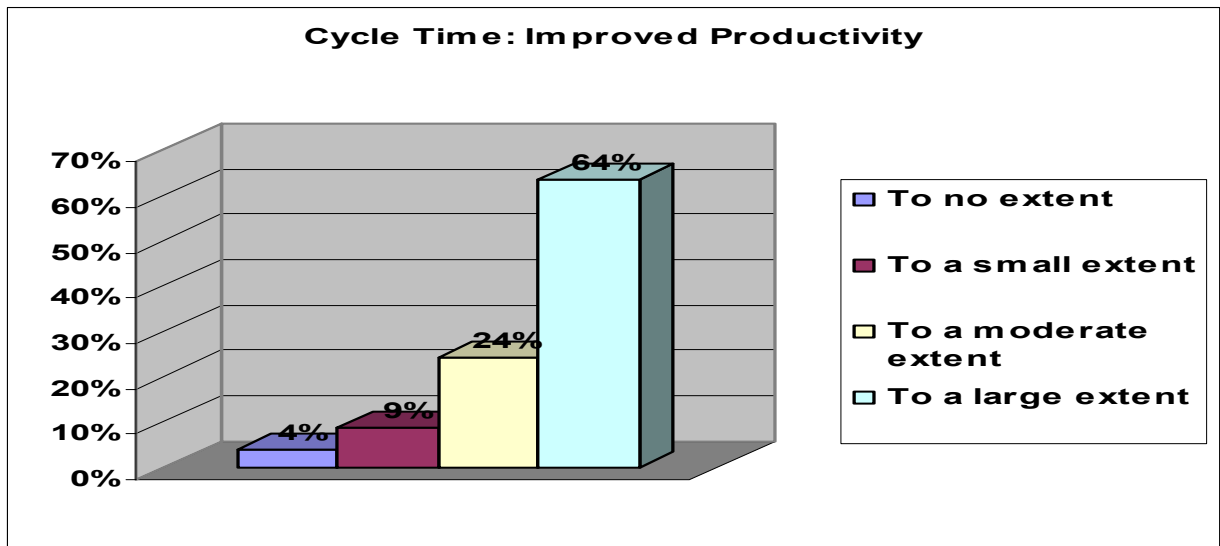


Productivity Improvement

Productivity did improve to a large extent as reported by 64% of the respondents. 33% reported productivity did improve from a small to a moderate extent. As shown in figure 4.3.8



Figure 4.3.8: Cycle Time: Improved Productivity



Usage versus Inventory Reduction

Cycle time as a lean manufacturing technique and its relation to reduced inventory was as follows: The Chi-square test using Yates' correction showed that the number of respondents who indicated that they "always" used the cycle time technique and that it resulted in reduced inventory from a "moderate to a large extent" (87%. $n= 20$) was significantly greater than the number that indicated that they used the cycle time technique "sometimes to often" (41.7%, $n= 10$), [$\chi^2 (1, N= 47) = 8.565, p= 0.003$]. The relationship between extent of usage of the technique and the rating of inventory reduction was moderate ($r= 0.471$). The results indicated that inventory was reduced more specifically when the technique was used "always". 87% of the "always" users indicated the technique resulted in a "moderate to large extent" reduction as illustrated in Table 4.3.10 below). The reverse happened when the technique was used "sometimes to often" - the effect was a "no extent to small extent" reduction in inventory. The most respondents 51.1% again indicated that they used the technique "sometimes to often" in comparison to the 48.9% who used it "always".

Table 4.3.10: Usage versus Inventory Reduction

Cycle Time		Sometimes to	Always	Row Total
Inventory		often		
Reduction				
No extent to small extent	% of row total % of column total	82.4% 58.3%	17.6% 13%	36.2%
Moderate to large extent	% of row total % of column total	33.3% 41.7%	66.7% 87%	63.8%
Column Total		51.1%	48.9%	100%

Usage versus Improved Productivity

In response to the question whether cycle time reduced productivity, 82.6% indicated that the technique improved productivity from a “moderate to a large extent” (see Table 4.3.11 below). 50% of the respondents indicated that they used cycle time “sometimes to often” and 50% indicated that they used it “always”. A total of 95.7% of the 50% that “always” used cycle time indicated that productivity improved from a “moderate to a large extent” and 69.6% of those who used the technique “sometimes to often” indicated that productivity improved from a “moderate to a large extent”.

Table 4.3.11: Usage versus Improved Productivity

Cycle time		Sometimes to often	Always	Row Total
Improved Productivity				
No extent to small extent	% of row total % of column total	87.5% 30.4%	12.5% 4.3%	17.4%
Moderate to large extent	% of row total % of column total	42.1% 69.6%	57.9% 95.7%	82.6%
Column Total		50%	50%	100%

4.3.5 Technique 5: Just in Time (JIT)

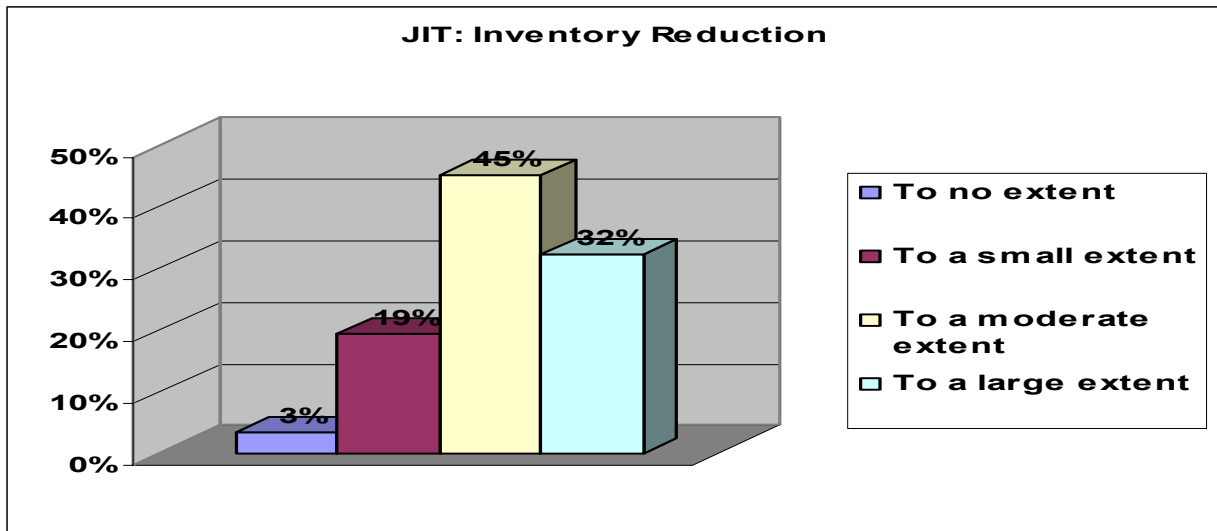
Familiarity with technique

69% of the respondents were conversant with JIT as a lean manufacturing technique and most of these used it “always”.

Reduction in Inventory levels

With regard to the question whether JIT reduced inventory, the responses were almost evenly spread - from “to a moderate extent” 45% to “to a large extent” 32%, as illustrated in Figure 4.3.9 below.

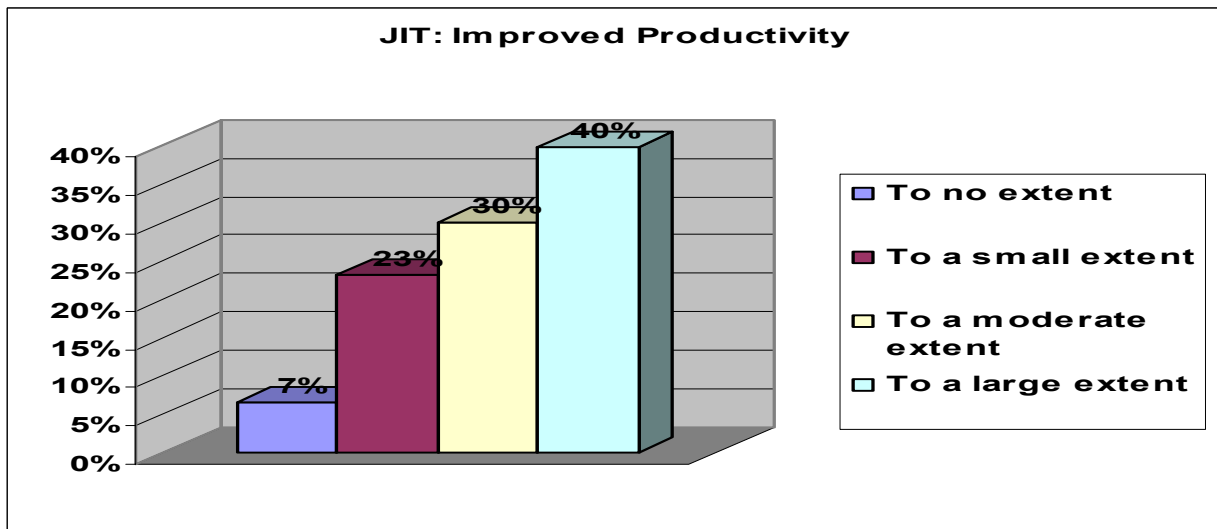
Figure 4.3.9: JIT: Inventory Reduction



Productivity Improvement

As shown in figure 4.3.10 below JIT does contribute to improvement of productivity as reported by 93% of the respondents.

Figure 4.3.10: JIT: Improved Productivity



Usage versus Inventory Reduction

25% of the respondents indicated that JIT resulted in a “no extent to small extent” inventory reduction. 91.7% of these respondents indicated that they used the technique “some times to often”, as illustrated in Table 4.3.12 below. 94.4% of the 37.5% who used the technique “always” indicated that it resulted in a “moderate to large extent” inventory reduction. This indicates that the more the technique is used, the more it leads to inventory reduction. On the other hand, the majority of users of this technique used it only “sometimes to often” 62.5%.

Table 4.3.12: Usage versus Inventory Reduction

JIT Inventory Reduction		Sometimes to often	Always	Row Total
No extent to small extent	% of row total % of column total	91.7% 36.7%	8.3% 5.6%	25%
Moderate to large extent	% of row total % of column total	52.8% 63.3%	47.2% 94.4%	75%
Column Total		62.5%	37.5%	100%

Usage versus Improved Productivity

70.2% of the respondents indicated that JIT resulted in a “moderate to large extent” improvement in productivity. Most of the respondents used the technique “sometimes too often” 61.7%, as illustrated in Table 4.3.13 below. On the other hand, the majority of users of this technique used it only “sometimes to often” 61.7%, indicating that the technique is not used to its fullest potential.

Table 4.3.13: Usage versus Improved Productivity

JIT Improved Productivity		Sometimes to often	Always	Row Total
No extent to small extent	% of row total % of column total	78.6% 37.9%	21.4% 16.7%	29.8%
Moderate to large extent	% of row total % of column total	54.5% 62.1%	45.5% 83.3%	70.2%
Column Total		61.7%	38.3%	100%

4.3.6 Technique 6: SMED or Quick Changeover

Familiarity with technique

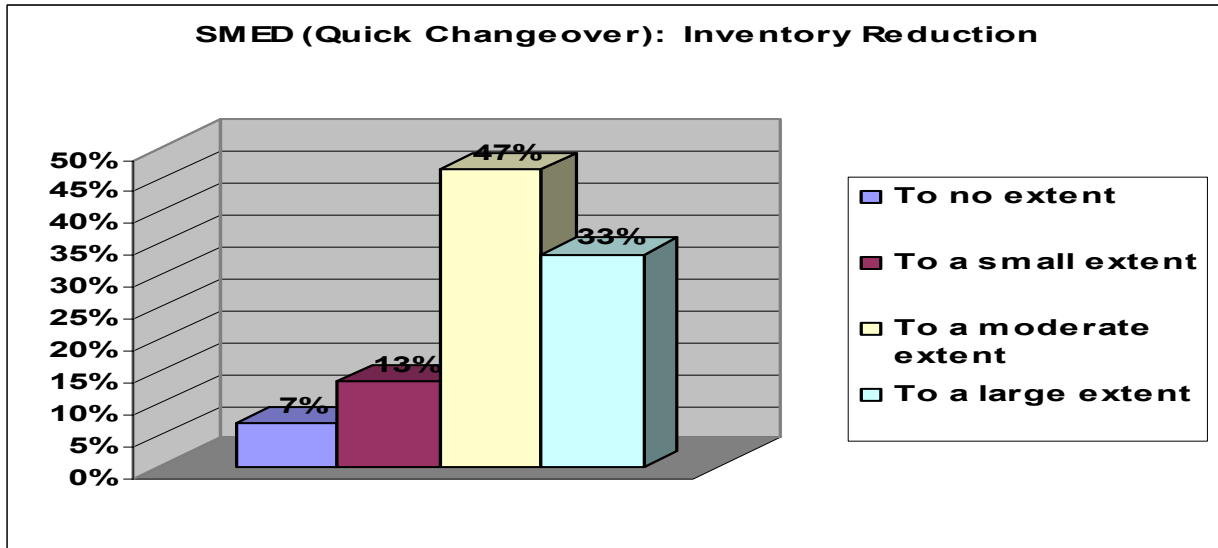


Only 49% of the respondents indicated that they were familiar with the technique SMED.

Reduction in Inventory Levels

In response to the question whether the technique reduced inventory, 7% stated “to no extent”, 47% stated “to a moderate extent” and 33% stated “to a large extent” (illustrated in Figure 4.3.11 below).

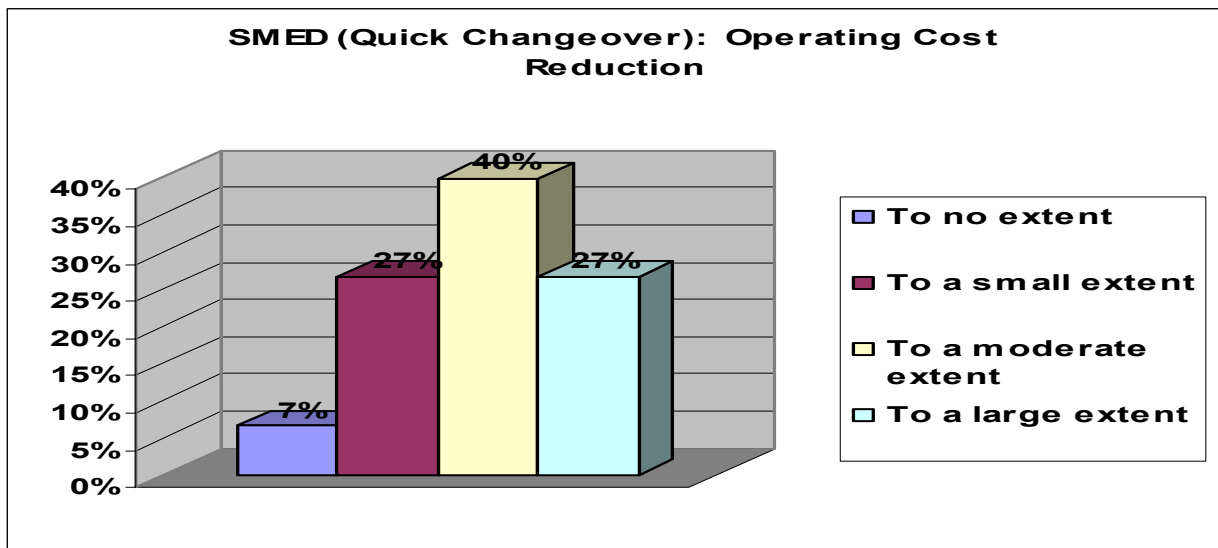
Figure 4.3.11: SMED: Inventory Reduction



Operating Cost Reduction

Of the respondents 96% indicated that SMED leads to a reduction in operating cost of which 40% of the respondents who applies the quick changeover technique indicated that it reduced operating cost “to a moderate extent”. 27% reported that SMED reduces operating cost to “a large extent” as illustrated in Figure 4.3.12 below.

Figure 4.3.12: SMED: Operating Cost Reduction



Usage versus Inventory Reduction

In response to the question whether the technique SMED reduced inventory, 71.4% of the respondents indicated that the technique resulted in a “moderate to large extent” reduction. 87.5% of the respondents who used the technique “always” indicated a “moderate to large extent” reduction, as illustrated in Table 4.3.14 below. Most of the respondents 61.9% applied the technique “sometimes to often”.

Table 4.3.14: Usage versus Inventory Reduction

Quick Changeover Inventory Reduction		Sometimes to often	Always	Row Total
No extent to small extent	% of row total % of column total	83.3% 38.5%	16.7% 12.5%	28.6%
Moderate to large extent	% of row total % of column total	53.3% 61.5%	46.7% 87.5%	71.4%
Column Total		61.9%	38.1%	100%

Usage versus Operating Cost Reduction

In response to the question relating to the SMED technique and operating cost reduction, 66.7% of the respondents indicated that the technique resulted in a “moderate to large extent” reduction in operating cost, as illustrated in Table 4.3.15. Of the 38.1% who used the technique “always”, 75% indicated a “moderate to large extent” reduction. The majority of the respondents 61.9% used the technique “sometimes to often”.

Table 4.3.15: Usage versus Operating Cost Reduction

Quick Changeover Operating cost Reduction		Sometimes to often	Always	Row Total
No extent to small extent	% of row total % of column total	71.4% 38.5%	28.6% 25	33.3%
Moderate to large extent	% of row total % of column total	57.1% 61.5%	42.9% 75%	66.7%
Column Total		61.9%	38.1%	100%

4.3.7 Technique 7: Total Preventative Maintenance (TPM)

Familiarity with technique

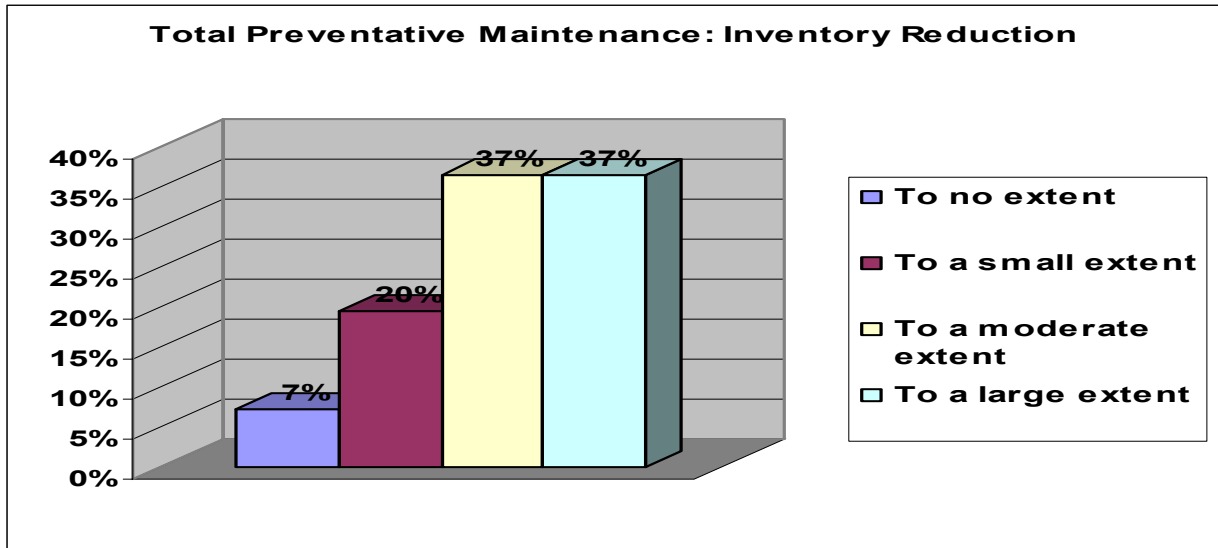


90% of the respondents indicated that they familiar with the TPM technique. Of the 90% the technique was “always” used by 50.9%.

Reduction in Inventory Levels

Figure 4.3.13 shows that 94% positively indicate that TPM does lead to a reduction in inventory levels. Of the 94%, 37% respectively reported a reduction in inventory from a “moderate to a large extent” 20% reflected a reduction of inventory to a “small extent”. Only 7% reported no effect.

Figure 4.3.13: TPM: Inventory Reduction

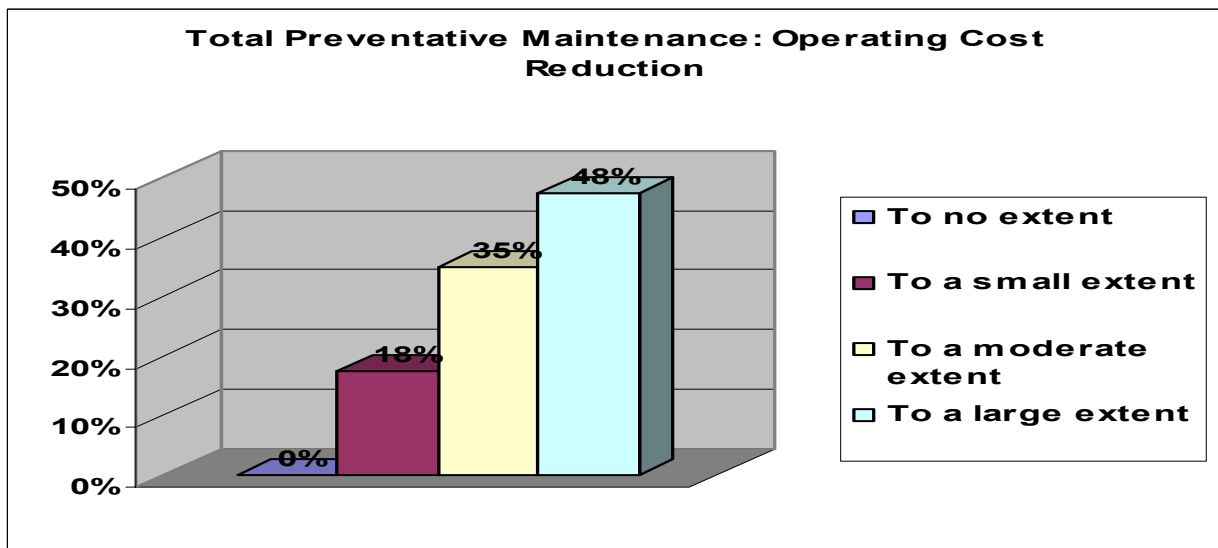


Operating Cost

100% of the respondents reported that TPM leads to a reduction in operating cost 83% reported respectively "moderate to large extent" reduction. This is illustrated in Figure 4.3.14 below.



Figure 4.3.14: TPM: Operating Cost Reduction



Usage versus Inventory Reduction

Most of the respondents indicated that the TPM technique resulted in a “moderate to large extent” reduction in inventory 61.4%, as illustrated in Table 4.3.16 below. Where the technique was used “sometimes to often”, the majority indicated a “moderate to large extent” reduction 57.1%. The usage of the technique was almost equally divided between “sometimes to often” 49.1% and “always” 50.9%.

Table 4.3.16: Usage versus Inventory Reduction

TPM		Sometimes to often	Always	Row Total
Inventory Reduction				
No extent to small extent	% of row total % of column total	54.5% 42.9%	45.5% 34.5%	38.6%
Moderate to large extent	% of row total % of column total	45.7% 57.1%	54.3% 65.5%	61.4%
Column Total		49.1%	50.9%	100%

Usage versus Operating Cost Reduction

The more the JIT technique was utilized, the greater the reduction in operating cost 96.6% of the respondents who used the technique “always” indicated a “moderate to large extent” reduction, as illustrated in Table 4.3.17 below. Where the technique was used “sometimes to often”, the result was a 90% “no extent to small extent” reduction. Almost the same number of respondents used the technique “sometimes” 49.1% and “always” 50.9%.

Table 4.3.17: Usage versus Operating Cost Reduction

TPM		Sometimes to often	Always	Row Total
Operating cost Reduction				
No extent to small extent	% of row total % of column total	90% 32.1%	10% 3.4	17.5%
Moderate to large extent	% of row total % of column total	40.4% 67.9%	59.6% 96.6%	82.5%
Column Total		49.1%	50.9%	100%

4.3.8 Technique 8: Waste Elimination

Familiarity with technique

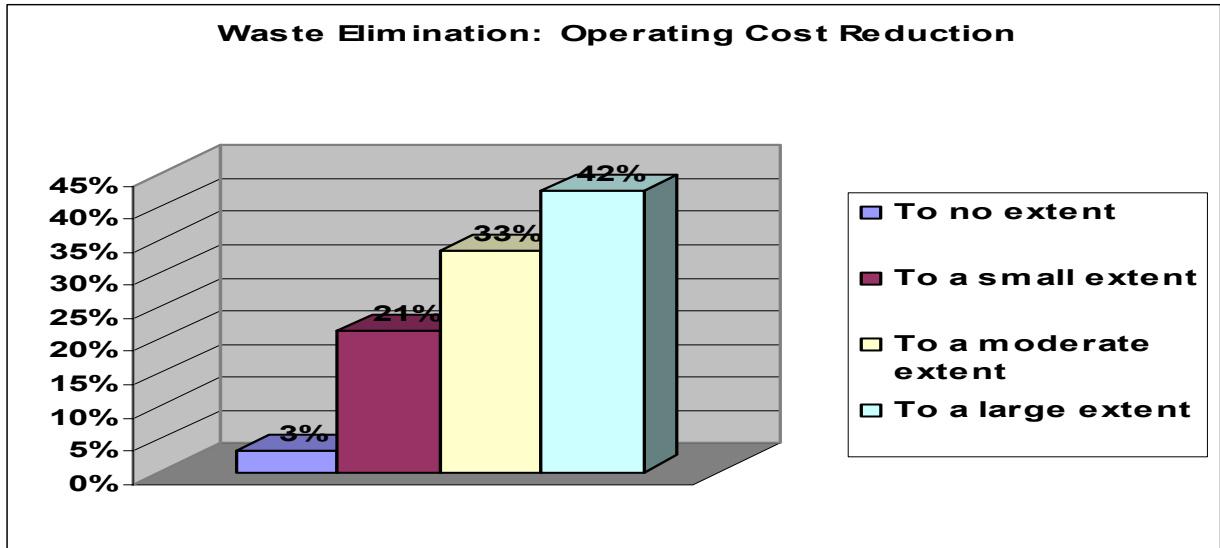


A total of 71% of the respondents indicated they were familiar with waste elimination as a lean manufacturing technique.

Operating cost Reduction

Of the respondents 3% indicated that waste elimination does not lead to cost reduction. With 42% indicating that operating costs are reduced to “a large extent” as illustrated in Figure 4.3.15 below.

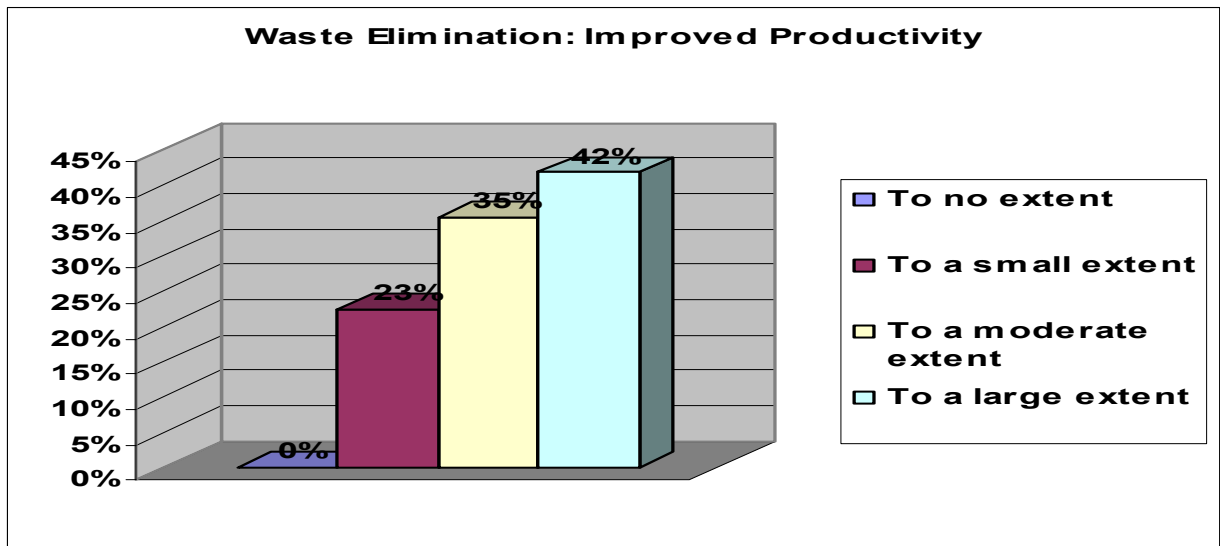
Figure 4.3.15: Waste Elimination: Operating Cost Reduction



Improved Productivity

When asked whether the technique added value by improving productivity, 100% replied positively, with 42% indicating “to a large extent” and 35% indicating that productivity did improve “to a moderate extent”, as illustrated in Figure 4.3.16 below.

Figure 4.3.16: Waste Elimination: Improved Productivity



Usage versus Operating Cost Reduction

A two-tailed Fisher's exact probability test ($p= 0.32$) showed that the number of participants that indicated that they "always" used the waste elimination technique and that operating cost had been reduced to a "moderate/ large extent" (94.4%. $n= 17$) was significantly greater than the number that indicated that they only used the waste elimination technique "sometimes or often" (64.3%, $n= 18$). This suggests that the relationship between extent of usage of the technique and rating of operating cost reduction was moderate ($r= 0.345$). As illustrated in Table 4.3.18, 94.4% of the 39.1% of the respondents who used the technique "always" indicated that the technique resulted in a "moderate to large extent" reduction in operating cost. The majority of respondents 60.9% indicated that they used the technique "sometimes to often". 35.7% of this 60.9% indicated that operating cost was reduced from "no extent to a small extent". The most respondents 76.1% indicated a "moderate to large extent" reduction.

Table 4.3.18: Usage versus Operating Cost Reduction

Waste Elimination		Sometimes to often	Always	Row Total
Operating cost Reduction				
No extent to small extent	% of row total % of column total	90.9% 35.7%	9.1% 5.6%	23.9%
Moderate to large extent	% of row total % of column total	51.4% 64.3%	48.6% 94.4%	76.1%
Column Total		60.9%	39.1%	100%

Usage versus Improved Productivity

A Shi-square test using Yates' correction showed that the number of participants that indicated that they "always" used the waste elimination technique and that utilising this technique reduced operating cost to a "moderate/large extent" (83.3%, $n= 15$) was significantly greater than the number that indicated that they only used the waste elimination technique "sometimes to often" (50%, $n= 14$), [$\chi^2 (1, N= 46) = 3.8.92, p= 0.49$]. This suggests a "moderate" relationship between extent of usage of the technique and the rating of Improved productivity ($r= 0.337$). Most respondents used the technique "sometimes to often" 60.9%. 50% of the 60.9% of the respondents who use the technique "sometimes to often" indicated that there was a "no extent to small extent" improvement in productivity and the other 50% indicated a "moderate to large extent" improvement. 83.3% of the 39.1% of respondents who indicated that they used the technique "always" indicated that there was a "moderate to large extent" improvement in productivity.

Table 4.3.19: Usage versus Improved Productivity

Waste Elimination Improved Productivity		Sometimes to often	Always	Row Total
No extent to small extent	% of row total % of column total	82.4% 50%	17.6% 16.7	37%
Moderate to large extent	% of row total % of column total	48.3% 50%%	51.7% 83.3%	63%
Column Total		60.9%	39.1%	100%

4.3.9 More Techniques

The rest of the techniques were listed on the questionnaire and respondents simply had to answer “Yes” or “No” as to whether these techniques were utilised by the various manufacturers or not. Most of the respondents indicated they did not use “Product-quantity (P-Q) analysis” “Poka Yoke” and “value-stream mapping” as illustrated in Table 4.3.20 below. The following techniques attracted a positive response with a 70% or higher utilisation: continuous flow, tact time and total quality management.

Table 4.3.20: Utilisation of More Techniques

Technique	Yes	No
Continuous Flow	78%	22%
Takt Time	72%	28%
Total Quality Management	71%	29%
One-Piece Flow	59%	41%
Poka Yoke	53%	47%
Value-Stream Mapping	53%	47%
Product-Quantity (p-q) analysis	42%	58%

Statistical Analysis

The Chi-square test was used to determine various relationships and dependencies. No significant dependencies and relationships were found other than results on the utilization of the P-Q analysis technique. The Chi-square test indicated that the number of respondents with a post-school or equivalent diploma (77.8%, $n=23$) who were familiar with the P-Q analysis technique was significantly greater than the number of respondents with either a school qualification (16.7%, $n= 14$) or a university or technikon degree (5.6%, $n= 11$), [$\chi^2 (2, N= 48) = 10.690, p= 0.005$]. This suggests a “moderate” relationship between familiarity with the technique and level of qualification (Cramer’s $V = 0.472$). Most respondents (62.5%) indicated that they did not use the technique. Of the 37.5% respondents who used the technique, 77.8% had post-school or equivalent qualifications, as illustrated in Table 4.3.21 below. Of the 62.5% who indicated that they did not use the technique, 90.9% had university, technikon or post-graduate degrees and 78.6% had school qualifications.

Table 4.3.21: Usage versus Qualification

	P-Q analysis	School	Post-school diploma or equivalent qualification	University or technikon degree and Post-graduate	Row Total
YES	% of row total	16.7%	77.8%	5.6%	37.5%
	% of column total	21.4%	60.9%	9.1%	
NO	% of row total	36.7%	30%	33.3%	62.5%
	% of column total	78.6%	39.1%	90.9%	
	Column Total	29.2%	47.9%	22.9%	100%

4.4 FAMILIARITY WITH THE TECHNIQUES VERSUS UTILISATION

Table 4.4.1: Familiarity with the Techniques versus used always

Technique	familiar		Always
	yes %	No %	%
Total Preventative Maintenance	90	10	50.9
Cycle Time	78	22	48.9
Assembly Line Balancing	76	24	39.5
Cell Manufacturing	69	31	46.7
JIT	69	31	37
Waste Elimination	69	31	39.1
ABC analysis	62	38	34.5
SMED (quick changeover)	51	48	38.1

Most respondents (90%) were informed about total preventative maintenance (TPM), as illustrated in Table 4.4.1. The table further shows that this technique came first with a usage of 50.9% in the “always” category. Cycle time came second with 48.9% of the respondents indicating that they use it “always”. Respondents indicated that they were less informed about single minute exchange of dies (SMED) and ABC analysis (35%) was the technique utilised the least.

CHAPTER 5

DISCUSSIONS AND CONCLUSIONS

This chapter contains a discussion of the findings and results of the survey with regard to lean manufacturing techniques and techniques preferred by manufacturers. The limitations are highlighted and discussed, together with further possible topics for research.

5.1 TECHNIQUES

Only techniques with a statistically significant result will be discussed under this heading.

5.1.1 Cell Manufacturing

There was a significant medium-strength relationship between the familiarity with the technique and the qualifications of those using the technique. Employees with post-school diplomas and university degrees seem to know more about the technique.

There was also a medium-strength relationship between utilisation of the technique and productivity improvement. Manufacturers using the technique “always” showed a 100% productivity improvement from a “moderate to a large extent“. This correlates with the opinion of Slack et al. (2001) as discussed in Chapter 2, par. 2.3.3. They state that cell manufacturing improves the motivation of employees and that the throughput will be higher. According to Slack and most other advocates of lean manufacturing, reducing inventory should be the focus. In cell manufacturing manufacturers tend to use the technique to improve productivity and not to reduce inventory. There was, however, a notable trend with regard to value being added to both inventory reduction and productivity improvement. The more cell manufacturing was used, the greater the benefit to inventory reduction and productivity improvement. The tendency of manufacturers to use the technique to improve productivity rather than reduce inventory contradicts the statements of Heizer and Render (1999) as discussed in Chapter 2, par 2.3.3.

There was a medium-strength relationship between the size of the business and the knowledge of the cell manufacturing technique. Manufacturers with less than 200 employees (small to medium enterprises) tended to know more about cell manufacturing than larger firms.

5.1.2 Waste Elimination

69% of the respondents indicated that they were familiar with the technique. Only 39.1% of the 69% used the technique “always”. There was a significant medium-strength relationship between productivity improvement and operating cost reduction when the technique was used “always” in comparison to “sometimes to often”. This correlates with the opinions of lean manufacturing advocates, for example Bicheno (2000) (Chapter 2, par. 2.2) and Rubrich and Watson (2000) (Chapter 2, par. 2.3.15). The problem, however, is the low utilisation of this technique by manufacturers in the Johannesburg area. This may indicate that these manufacturers are not really lean manufactures. This technique is one of the major techniques recommended by lean manufacturing advocates, as discussed in Chapter 2, par. 2.2.

5.1.3 Cycle Time

There was a significant medium-strength relationship between the technique used “always” and productivity improvement, in comparison to the technique used “sometimes to often”. The results indicated a significant medium-strength relationship between the technique used “always” and inventory reduction. Cycle time is second on the list of most known techniques and it is also used second most of all the techniques.

5.1.4 More Techniques

Apart from the above techniques, seven more techniques were covered under the heading “more techniques” in the questionnaire. They were continuous flow, takt time, total quality management, one-piece flow, Poka Yoke, value-stream mapping and product-quantity analysis (P-Q analysis).

Respondents indicated that they used the P-Q analysis technique the least (see Chapter 4, Table 4.3.20). The technique was significantly different from the rest of the techniques in that statistically there was a medium-strength relationship between respondents with post-school diplomas and the utilisation of the technique. The rest of the techniques marked in the category “other techniques” did not show a statistically significant relationship between qualification and utilisation although the results displayed the same trend as P-Q analysis. Value-stream mapping had the second lowest utilisation. The findings of this study are contradictory to the opinions of Scodanibbio (2005) (Chapter 2, par. 2.2), as well as those of Rother and Shook (1999) (Chapter 2, par. 2.3.14), who prefer P-Q analysis and value-stream mapping as techniques for lean manufacturing.

5.2 TECHNIQUES PREFERRED BY MANUFACTURERS AND USED “ALWAYS”

The techniques preferred by manufacturers and used “always” were sorted from the highest to the lowest percentage. Total preventative maintenance (TPM) was at the top of the list, followed by cycle time and then cell manufacturing, assembly line balancing, waste elimination, single minute exchange of dies (SMED), just in time (JIT) and ABC analysis.

Utilization of the technique were reported mainly as some times to often. The assumption can therefore be made that Gauteng assembly manufacturers are only in the first phases of implementing lean manufacturing. This supports the statement of

Womack et al. (1990) (Chapter 2, par. 2.1) that it takes proximately 10 years with guidance to become a lean manufacturer.

TPM is the technique that was used the most (50.9% - “always”). Techniques like JIT, waste elimination and SMED are the main techniques promoted by the advocates of lean manufacturing.

5.3 VALUE ADDING

5.3.1 Inventory Reduction

Most respondents felt that the techniques only to a “moderate extent” resulted in inventory reduction as illustrated in Table 5.3.1 below. This is contradictory to the opinions of most lean manufacturing advocates. The assumption can therefore be made that Gauteng assembly manufacturers do not apply the techniques fully to reduce inventory levels and control and therefore supports the assumption that they are in the first stages of implementing lean manufacturing.

A total of 54% of the respondents who used ABC analysis felt that the technique resulted in a “moderate” reduction in inventory. This technique received the lowest score where respondents had to indicate how often they used the technique. Therefore, it can be assumed that manufacturers tend not to use the technique.

Cycle time was the technique with the second highest score. A total of 53% of the respondents who utilised this technique felt that it reduced inventory to a “large extent”. In addition, the respondents also indicated that this technique was the most preferred.

At 47% single minute exchange of dies (SMED) or quick changeovers scored the third highest with regard to inventory reduction. The respondents indicated that SMED reduced inventory to a “moderate extent”. However, 38.1% of the respondents indicated that they used the technique “always”, which is very low. It was interesting to note that of all the respondents who were familiar with SMED, 30% did not use the technique at all.

Only 51% of the respondents indicated that they were familiar with the technique – the lowest score of all. It can therefore be assumed that manufacturers need to be made aware of the advantages of this technique. The results showed that where the technique was used “always”, inventory reduction benefited from a “moderate to large extent” (see Chapter 4, par. 4.3.14). This is also confirmed by the literature (Chapter 2, par. 2.3.10).

JIT was the fourth highest reducer of inventory, but only reduced inventory to a “moderate extent”. According to Slack et al. (2001:482), Heizer and Render (1999) and Halevi (1999: 50) (Chapter 2, par. 2.2), JIT should play a major role in reducing inventory. The research results showed that Gauteng manufacturers felt that JIT did not play a major role in their manufacturing processes. It can therefore be assumed that Gauteng manufacturers are either not lean manufacturers or they do not use the technique correctly. They either need proper education with regard to the technique or the lean manufacturing advocates’ theories on JIT are wrong. An interesting comment was that of a respondent who believed that JIT only worked in Japan. This statement opens the possibility for further research.

Table 5.3.1: Order of value added by each technique in the category “inventory reduction”

Large extent	25	53	33	32	37	31
Moderate extent	54	21	47	45	37	34
Small extent	17	18	13	19	20	25
No extent	4	9	7	3	7	9
Inventory Reduction	ABC analysis %	Cycle time %	SMED %	JIT %	TPM %	Cell manufacturing %
Order of value added	1	2	3	4	5	6

5.3.2 Improved Productivity

The research showed that all the techniques identified to improve productivity improved it to a “large extent” (Table 5.3.2 below). A total of 64% of the manufactures using cycle time felt that the technique contributed to a “large extent” to improving productivity. This was followed by cell manufacturing where 50% of the manufacturers felt that the technique contributed to improving productivity. Then came assembly line balancing and waste elimination where 42% and 40% respectively indicated that these techniques improved productivity to a “large extent”. These results correlate with the findings of the literature study (Chapter 2, par. 2.3).

Table 5.3.2: Order of value added by each technique in the category “improved productivity”

Large extent	64	50	48	42	40
Moderate extent	24	37	33	35	30
Small extent	9	10	18	23	23
No extent	3	3	0	0	7
Improved Productivity	Cycle time %	Cell manufacturing %	Assembly line balancing %	Waste elimination %	JIT %
Order of value added	1	2	3	4	5

5.3.3 Operating Cost Reduction

Table 5.3.3 below illustrates that 48% of the respondents indicated that total preventative maintenance was believed to reduce operating cost to a “large extent”. This correlates with the opinions of Rubrich and Watson (2000) as discussed in Chapter 2, par. 2.3.12. Another finding that correlates with those of Rubrich and Watson (2000)

(Chapter 2, par. 2.3.15) is that 42% of the respondents indicated that they believed waste elimination reduce operating cost to a “large extent”. Contrary to the opinions of Rubrich and Watson (2000) (Chapter 2, par. 2.3.10), only 27% of the respondents believed that (SMED) would reduce operating cost. Rubrich and Watson claim that a manufacturer can improve setup time by 41% in the first year. This last finding therefore needs further investigation. The possible reason for the negative feelings about SMED may be education as the technique scored the lowest response with regard to familiarity - 49% of the respondents did not know the technique.

Table 5.3.3: Order of value added by each technique in the category “operating cost reduction”

Large extent	48	42	27
Moderate extent	35	33	40
Small extent	18	21	27
No extent	0	3	7
Operating Cost Reduction	TPM %	Waste Elimination %	SMED %
Order of value added	1	2	3

5.4 LIMITATIONS AND FURTHER RESEARCH OPPORTUNITIES

According to Ranchod and Zhou (2001) a questionnaire of more than 6 pages is intolerably lengthy - the researcher was therefore restricted to 6 pages. The last eight techniques had to be tabulated and requested simple “Yes” or “No” responses – a limitation of this research.

The research did not measure the implementing time period of the techniques that can give a perspective to the value the techniques may add to the organization over a period

of time. The literature study in Chapter 2 showed that implementation of lean manufacturing may take from 10 to 20 years.

Another limitation is that the size of a manufacturer is determined in terms of Value added tax (VAT) or income tax turnover (IT), according to Statistics South Africa “the real estate and business services’ industry, 2003”. This is a problem in that most manufacturers classify this information as confidential and therefore the researcher used the number of permanent employees as a determiner of size. This is a limitation because Statistics South Africa only classifies manufacturers with maximum of 200 employees. Manufacturers with more than 200 employees are not classified.

The fact that Statistics South Africa could not determine how many assembly manufacturers there were at the time of the survey was also a limitation. Therefore, a representative sample size could not be calculated and the research use of a convenient sample. This implies that the results might not be representative of all assembly manufactures in Gauteng area.

Further research might reveal the reasons why the techniques are not applied or utilised by assembly manufactures. Lean manufacturing can be extended to other types of industries such as the service and food industries this needs to be researched as the current application and utilization of these techniques as these fields are unknown. Consequently, there are opportunities to measure the value of lean manufacturing in these fields as well. Lean manufacturing starts at the supplier and ends at the customer. This research measured current affairs in a definite appoint of time follow up research might reveal whether the companies have benefited more over the long term. therefore only measured a small part of a lean enterprise. “Lean” includes lean manufacturing, lean procurement and lean logistics.

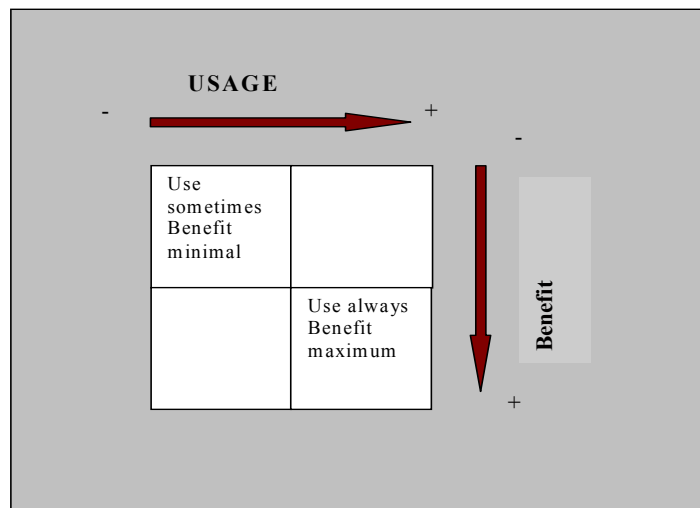
5.5 CONCLUSION

A relationship was found between employees with a post-school diploma and knowledge of the techniques. In most of the cases employees with post-school diplomas had more knowledge of the techniques than the other groups.

With the exception of cell manufacturing, there was no specific relationship between the size of the firms and knowledge of the techniques.

Upon analysing the cross-tabulations in Chapter 4, the following was found: techniques that were used “always”, displayed a high degree of benefit in terms of added value. Figure 5.5.1 below illustrates how value was added from a “moderate to a large extent” in all categories.

Figure 5.5.1: Conclusion of the Cross-Tabulation



The statement can therefore be made that the more frequently the technique was used, the greater the benefit. The categories included productivity improvement, operating cost reduction and inventory reduction. This result correlates with the findings of the literature study (see Chapter 2). When the technique was used “less” the results were negative. In almost all the cases, most manufacturers indicated that they used the techniques “sometimes to often”. Therefore it can be stated that the most manufacturers in this study are not lean producers or are in the process of becoming lean.

Analysis of the order in which techniques added value showed that respondents applied techniques in a different order to that preferred by the advocates of lean manufacturing. Most advocates of lean manufacturing placed JIT and waste elimination in the top ranks (refer to Chapter 2, par. 2.2, where the different views of the lean developers were discussed). More research needs to be conducted to find the reason why Gauteng manufacturers do not want to use JIT and waste elimination and why they focus on productivity rather than reducing inventories.

The respondents viewed TPM as a key function in the manufacturing process and it appeared that respondents with diplomas were most aware of the techniques covered by this research. It seemed that the attention was focused on improving productivity rather than reducing inventory. The majority of respondents indicated that they used the techniques only "sometimes to often". When the techniques were used "always", they contributed the greatest advantages to the manufacturers. It can therefore be concluded that Gauteng assembly manufacturers are limited lean manufacturers and that there is great potential for improvement.

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