Improving Quality and Productivity through Lean Manufacturing at an Automotive Manufacturing Organisation in Durban

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ABSTRACT

The manufacturing sector, considered to be an important industry in any country, is often plagued with a significant degree of competition due to global marketing. In order to cope with this challenge, organisations attempt to improve their manufacturing operations by using different tools and techniques to reduce costs while remaining profitable.

This study investigated the existing lean production system of an automotive manufacturing organisation in Durban. The objective of the study was to identify the strengths and weaknesses of the current lean manufacturing process in an attempt to improve quality and productivity. An empirical study was conducted, using a survey questionnaire with an assessment score ranking to gather and evaluate employees' responses pertaining to lean application in the production environment. The quantitative method of research was adopted.

The results of the study showed evidence of misalignment and inconsistencies for lean adoption in the organisation. There were significant relationships established between departments and job positions. The analysis demonstrated that operators within production showed the highest sentiment of disagreement for certain lean principles. The validity of the operators' responses was significant as operators are the frontline of all processes and were in the best position to rank the extent of lean adoption.

Several important findings on the implications of lean activities that affect manufacturing performance were revealed. The study concluded that a significant gap exists between the actual adoption of lean principles on the shop floor to those that are documented. It is recommended that organisations develop structured follow up procedures in order to have more control of the production system and thus ensure sustainability. Future research should focus at incorporating better and more efficient lean assessment tools to identify gaps in the production system and to replicate this study to track other South African organisations that claim to manufacture lean.

ACKNOWLEDGEMENTS

This research could not have been completed without the profound strength, patience and inspiration that were presented to me by God.

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- My parents, wife, and two sons for their patience, tolerance and unwavering support in all personal matters.

DECLARATION BY CANDIDATE

I, Raveen Rathilall, declare that unless otherwise indicated, this dissertation is my original work and that it has not been submitted for any degree at another Tertiary Institution.

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LIST OF ACRONYMS

BPS	Behr Production System
DUT	Durban University of Technology
JIT	Just-In-Time
MRP	Material Requisition Planning
PDCA	Plan-Do-Check-Act Cycle
SPSS	Statistical Package for Social Sciences
TPS	Toyota Production System
WIP	Work In Progress

GLOSSARY OF TERMS

Buffer Stock	A quantity of stock planned to be stored in inventory to protect against fluctuations in demand or supply.
Cell Manufacturing	A methodology that groups employees, machines and materials into a semi-circle or U-shape layout to produce a given product or product type.
Continuous Improvement	A concept that seeks ongoing effort to improve products, services or processes. These efforts can seek “incremental” improvement over time or “breakthrough” improvement all at once.
Cycle Time	The maximum time allowed for work to be performed on a product at each process.
Decentralised Responsibilities	The process of transferring and assigning decision-making authority to lower level employees in an organisation hierarchy.
Elimination of Waste	Any activity in production that does not add value to the finished product, such as excess inventory, unnecessary movements of employees, scrap, rework or transportation.
Employee Empowerment	An approach to teamwork that moves responsibility for decisions further down the organisational chart – to the level of the employee actually doing the job.
Five S (5S)	A methodology for organising, cleaning, developing and sustaining a productive work environment.

Integrated Functions	A philosophy that enables employees to perform many different tasks in production.
Just-In-Time	It is a concept that controls inventory and material flow throughout the entire organisation. The philosophy involves providing the required part, in the correct quantity at the exact point in time.
Kanban	A Japanese word meaning “card” or “visible record” that refers to cards used to control the flow of production through an organisation. It signals the manufacture and supply of components.
Lead Time	The amount of time between the initiation of some process and its completion or the elapsed time between the receipt of a customer order and filling it.
Material Requisition Planning	A production planning and inventory control system developed specifically to help manufacturers manage dependent demand inventory and schedule replenishment orders.
Multifunctional Teams	A group of employees that are organised in a particular work area and are able to perform many different tasks. These teams are often organised along a cell based part of the product flow.
One-piece Flow	Refers to the concept of moving one work piece at a time between operations within a work cell.
Poka-Yoke	Mistake-proofing methods aimed at designing failsafe systems that minimise human error.

Process	Any activity or group of activities that takes one or more inputs, transforms them, and provides one or more outputs for its customers. These outputs then serve as inputs for the next stage until a known goal or end result is achieved.
Pull Instead of Push	A philosophy that emphasises production planning to manufacture to order instead of manufacturing to stock. No one upstream should produce a part until the customer downstream requests for it.
Quality at the Source	A philosophy whereby defects are caught and corrected where they were created. It is the responsibility of every employee, work group, department, or supplier to inspect the work.
Quality Circles	Another name for problem-solving teams; small group of supervisors and employees who meet to identify, analyse, and solve process and quality problems.
Replenishment	Manufacturing products for the purpose of replacing stock that has been used up.
Suggestion Programme	A voluntary system by which employees submit their ideas on process improvements. The objective of a suggestion programme is to promote employee involvement, creative thinking, and continuous improvement.
Value Stream Mapping	A sophisticated flow chart that uses symbols and metrics to help understand the sequence of activities, visualise processes and track performance.

Vertical Information Systems	The transfer of information to all employees within the organisation.
Work In Progress	Items, such as components or assemblies, required to produce a final product in manufacturing.
Zero Defects	A way of thinking and doing production tasks right the first time without manufacturing defects. This philosophy increases the organisations profits by eliminating the cost of failure and increasing revenues through increased customer satisfaction.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Satisfying customer expectations and demands are inevitable. The way a business reacts to achieve these expectations and demands makes a difference on competitiveness and profitability. Karatepe and Ekiz (2004:476) cite work conducted by Parasuraman, Berry and Zeithaml (1991:32) where increasing global competition, understanding customers' expectations and meeting customer needs are critical if superior service quality is to be delivered. This places organisations all over the world under tremendous pressure to reduce their costs, increase their service levels and supply goods of superior quality. In order to meet these goals and remain more competitive, organisations embark on the use of many different tools, techniques and strategies to make their production processes more efficient. In addition, organisations are always searching for ways to optimise business processes so that they can lower manufacturing costs**.**

Stemming from the desire to become more effective and efficient, Yandell (2002:19) contends that organisations are turning to lean manufacturing as a way of rapidly reducing production costs, improving quality and providing superior customer service. In a similar contribution, Columbus (2008:2) claims that organisations adopt lean manufacturing to control waste and to concentrate on creating greater value by removing barriers to accomplish the manufactures' objectives. Furthermore, lean manufacturing is reaping astonishing rewards in productivity, quality and customer satisfaction each year. It is the symbol of efficiency and optimal performance since the 1980's, and is mainly due to its association with the Toyota automotive industry (Alony and Jones, 2008:165; Sassenberg, 2008:36).

Traditional manufacturing cannot compete in the present market place with its large batch approaches, extensive inventories and static organisational style. Organisations that employ lean manufacturing typically enjoy a competitive advantage over organisations that use a more traditional approach. According to Stevenson (2005:25) the former organisations have lower processing costs, fewer defects, greater flexibility, and are able to bring new or improved products to the market more efficiently. Lean manufacturing has gained considerable attention by both researchers and practitioners over the years. This is aptly summarised by Bhasin and Burcher (2006:61-62) in support of previous research and history which shows that many organisations which have implemented lean manufacturing have achieved improved performance over time. Stone (2008:1) demonstrates the following benefits from a recent study of organisations which implemented lean manufacturing.

Indicator	**Companies Reporting Improvements**
Distance work travels	90%
On-time Delivery	90%
Number of handlings	87%
Flexibility	82%
Productivity	80%
Morale	76%
Quality	76%
Set-up time	76%
Accuracy of Information	68%
Timeliness of Information	65%
Documentation	52%
Sales	38%

Table 1.1 – Benefits of implementing lean manufacturing (Adapted from Stone, 2008:1)

The results of the survey in Table 1.1 shows notable improvements for distance work travels, on-time delivery, flexibility, productivity, quality, timeliness and accuracy of information. These factors are essential to satisfy customers. In light of these results, it can be suggested that organisations which implement lean manufacturing may be satisfying customers more effectively. With a wide practice in many organisations and consequent improvements, it appears from literature that lean manufacturing is a broad collection of principles and practices that can improve an organisation's performance.

Following the above information, this study is important as the organisation being researched will be able to evaluate their strengths and weaknesses in respect of lean manufacturing, which forms a major part of their current production system. More specifically, the weaknesses will be critically reviewed and addressed to make the organisation more profitable. The study also hopes that other manufacturing organisations will use lean manufacturing in their operations as a result of these research findings.

1.2 PROBLEM STATEMENT

The extent of the current global financial crisis has led to many job losses in South Africa's automotive industry. In 2008, General Motors South Africa reduced its employees by 1000, in line with the decline of new vehicle sales and as part of a drive to improve efficiencies and their overall competitiveness (The Citizen, 2009:Feb.18). Several other motor manufacturers, including Volkswagen South Africa and Mercedes-Benz South Africa, have either reduced the number of employees or are looking at the possibility of doing so. The Ford Motor Company of Southern Africa has implemented a four-day production week, which is expected to remain in place until there is a change in economic conditions (http://www.southafrica.info/news/business/24083.htm, 09-02-09).

As organisations struggle to remain profitable during the current economic slowdown, they must increasingly rely on cutting costs, eliminating waste, improving productivity and enhancing quality as a means of strategically achieving profit objectives (Fliedner and Mathieson, 2009:194). An organisation that produces merchandise and outputs with scrap and defects do not only suffer from losses in production of such substandard products, they also lose customers because their credibility can be tainted and destroyed. Motwani (2003:339) cites specific cases of work conducted by Krafcik (1998) and Nicholas (1998), where studies have shown that lean manufacturing can be used as a competitive philosophy by targeting or initiating ways to produce higher levels of productivity and quality, reduce wasteful practices and behaviours, and provide better customer responsiveness.

Behr South Africa, based in Durban, has established a global footprint in the international automotive industry. Behr is a leading manufacturer of engine cooling systems and service parts and continues to focus on high standards of quality and cost improvement that foreign and local markets demand. The Behr Group’s philosophy of

“Top Performance in vehicle air conditioning and engine cooling” has ensured its place as a preferred partner within the global automotive industry. In keeping with the international Behr Group philosophy for top performance, the local organisation has to continuously develop ways to achieve world class manufacturing to survive in the present economic conditions (Behr Management System Manual, 2004:19).

Currently, Behr faces similar challenges like the rest of the global manufacturing community. The organisation had to reduce their sales forecast for 2008 significantly owing to reduced orders from their customers. Many of these customers have found themselves in an overstocked position due to the fall in market demand and have thus reduced their orders even further. Likewise, Behr had to reduce their planned sales in 2009 to reflect the reality of local and global market demand (Behr Magazine, 2008:3). Profit margins have been eroded as a result of reduced turnover. Although there has been a decrease in sales volumes during the past year, issues such as process defects, excessive scrap, inaccurate inventory levels, and defective products supplied to customers, continue to surface. In an attempt to continually satisfy customer requirements, Behr has adopted selected lean manufacturing practices.

1.3 AIMS AND OBJECTIVES OF THE STUDY

The aim of this research is to analyse an organisation’s response to lean manufacturing principles on process and quality improvement at a local automotive manufacturing organisation based in Durban. This study will identify the challenges and difficulties experienced in the organisation’s current production system and provide a methodology on the practical benefits of lean manufacturing.

The objectives of the study will be to:

- investigate the strengths and weaknesses of the current lean manufacturing process
- establish why excessive scrap, process defects, inaccurate inventory levels and defective products supplied to customers continue to surface even with a reduction of production volumes
- develop a framework to improve current lean manufacturing in the organisation

1.4 HYPOTHESES

H_0 – There is no difference in responses between positions and departments for each statement in the respective category on lean adoption.

H_1 – There is a difference in responses between positions and departments for each statement in the respective category on lean adoption.

1.5 RESEARCH METHODOLOGY

The research approach was based on an empirical study and an explanatory research design was used to fulfil the purpose of this project. In addition, the research was quantitative in nature. The initial step was to systematically study and define the history of lean manufacturing accompanied by its tools and techniques. The next phase examined the strengths and weaknesses of the current lean manufacturing principles used in the organisation chosen for the case study. Close-ended questions were adopted in the survey type questionnaire design.

Survey type questionnaires developed by previous researchers of lean manufacturing were reviewed to inform the design instrument of this study. The questionnaire consisted of two sections accompanied by an introductory cover letter explaining the aims of the research and confirming the confidentiality of the information. Section One required information about the respondent and Section Two incorporated questions of the nine lean manufacturing principles developed by Karlsson and Ahlstrom (1996:26) in their lean production model. Each principle was clearly explained in the questionnaire to avoid any misconception or ambiguity.

The questions were evaluated on a 5 point Likert scale; ranging from “do not agree at all” with a value of (1) to “agree fully” with a value of (5). A pilot questionnaire was presented to twenty employees in the quality department at Behr to determine the feasibility of the methodology adopted.

The main study followed the same format as the pilot study; however, it was administered to the entire organisation over a three month period. The population group that formed the main study were the employees at Behr (Plant Durban). The total population of employees at the organisation was 603 permanent employees and 22 contracts, which include directors, managers, engineers, supervisors, technicians, administration, auditors and operators. The sampling frame consisted of employees selected from the different departments which formed the sample of 254 employees used to accomplish this project. The purposeful method of non-probability sampling was used at Behr located in Durban, for which permission was obtained.

The principles of lean manufacturing will serve as the independent variables, whilst the current Behr Production System (BPS) will serve as the dependent variable. Data obtained from the questionnaires were marked individually and then analysed statistically. The Statistical Package for Social Sciences (SPSS) and Durban University of Technology (DUT) assisted with the processing and analysis of the data. Each question was analysed individually in terms of validity, content and the frequency of responses.

1.6 LAYOUT OF THE RESEARCH PROJECT

The dissertation is divided into five chapters. A brief description of the contents of each chapter is as follows:

Chapter 1: The Introduction provides an overview of the global challenge of competitiveness in the manufacturing industry and introduces lean manufacturing and its objectives. This chapter also focuses on the background of the study, the rationale behind the research, the problem statement, the aims and objectives, and the scope of the research.

Chapter 2: The Literature review provides an extensive review of the existing literature on lean manufacturing. It starts by reviewing the origins and history of lean manufacturing. The chapter then seeks to identify the philosophies and core principles of lean manufacturing followed by the different tools, approaches and techniques of lean manufacturing.

Chapter 3: Incorporates the design of Research and Methodology of the study. It provides a description of the production system of the organisation chosen for the study, and contains the data collected and calculations of the preliminary work and its results. The main study will also be introduced.

Chapter 4: Results and Discussion reveal the findings and analysis of the study. It will discuss in detail the findings in order to compare and contrast the issues of lean manufacturing.

Chapter 5: Conclusions and Recommendations form the final chapter of this dissertation and provides discussions and conclusions. It also identifies the limitations and outlines future research.

1.7 SUMMARY OF THE CHAPTER

The background and significance of the study outlined in this chapter provides evidence that lean manufacturing has gained acclaim to achieve world class competitiveness. The chapter also introduced the designing instrument and methodology adopted to accomplish the research project. The next chapter will present the review of related literature and the technology used during this investigation.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will outline the theoretical background and content of lean manufacturing through detailed information sources selected from academic journals, relevant books, periodicals, newspaper articles and websites. The chapter begins by presenting the historic evolution of lean manufacturing, followed by the main principles applicable to the production environment. It will also explain the adoption of the technology used in this investigation and the success factors for achieving total lean transformation.

2.2 EVOLUTION OF LEAN MANUFACTURING

This section provides a brief history on the early developments and origins of lean manufacturing. Acknowledging Toyota as the world benchmark, it is interesting to note that lean manufacturing evolved purposefully over time in North America. It derives from the Toyota Production System (TPS) in Japan, and can be traced back to the borrowed concepts and practices of Henry Ford and other predecessors (Emiliani and Stec, 2005:370). This evolution will be presented in the following section.

2.2.1 EARLY DEVELOPMENTS

The famous inventor of the cotton gin, Eli Whitney, perfected the concept of interchangeable parts in 1799. For the next 100 years, manufacturers concerned themselves primarily with developing systems of engineering drawings, perfecting modern machine tools and developing large scale processes (Lee, 2004:1). The works of early industrial engineers such as Frederick Taylor, Frank Gilbert and Lillian Gilbert in the late 1890's, introduced the era of scientific management (Bayraktar, Jothishankar, Tatoglu and Wu, 2007:846). They developed concepts such as "time study", "standardised work", "motion study", "process charting" and workplace pyschology. Following the aforementioned information, it can be suggested that these specialists originally introduced the concept of what is today referred to as "waste elimination".

2.2.2 THE FORD SYSTEM

In 1910, Henry Ford and Charles Sorensen, developed the first comprehensive manufacturing strategy. They combined all the elements of a manufacturing system such as people, machines, tooling and products and standardised them in an assembly line (Bayraktar et al., 2007:845; Lee, 2004:1). As the popularity of the system increased, Ford's achievement was acknowledged and many others were inspired to copy his methods, which were later known as mass production. The successful era of mass production systems prompted Japanese industrialists to study the American automotive industry, paying particular attention to Ford practices (Papadopoulou and Ozbayrak, 2005:786).

2.2.3 THE TOYOTA PRODUCTION SYSTEM

Early in the 1940's, Taichi Ohno and Shigeo Shingo began to incorporate Ford production, Statistical Process Control and other techniques into the TPS. They recognised the central role of inventory and the importance of respect to employees from the contradictions and shortcomings they identified in the Ford system (Lee, 2004:2). Ohno visualised an ideal production system in terms of a sequential workflow that produced goods Just In Time (JIT) with little or no inventory between workstations (Lee, 2007:15). This prompted a shift from the traditional "batch and queue" mass production philosophy to "one piece flow" pull production. In order to maintain the sequential workflow and keep inventory to a minimum, Shingo worked on reducing machine set-up times by developing the Single Minute Exchange of Dies (SMED) system (Lee, 2007:15).

It was during the 1950's that Ohno developed the concept of "one piece flow" by merging the knowledge and skill of master craftsmen (Worley and Doolen, 2006:229). During this era, many other concepts such as JIT, Kanban, Quality Circles, Kaizen and Cell Manufacturing emerged within the TPS. When the popularity of productivity and quality gains in the TPS became known globally, American executives travelled to Japan to study these concepts. The American executives adopted mainly the superficial concepts like JIT, Kanban and Quality Circles which proved to be successful over time (Lee, 2004:2).

2.2.4 LEAN MANUFACTURING

Toyota captured the world's attention in the 1980's, when it was perceived that their vehicles were lasting longer and required much less repairs than American vehicles. The most remarkable aspect was that the vehicles were designed much faster, with more reliability, and at a more competitive cost than the Americans. According to Liker (2004:3) it was a mystery for a number of years that the Japanese were able to produce automobiles at such high quality and low cost. This, however, lead to the largest and most thorough study ever undertaken in any industry. A research group at the Massachusetts Institute of Technology took five years in the late 1980's to explore the difference between American mass production and the TPS in the automotive industry (Klefsjo, 2008:65).

In 1990, James Womack's book titled "The machine that changed the world" provided an account of the history of automobile manufacturing combined with a study of Japanese, American, and European automotive assembly plants. His objective was to demonstrate to organisations, managers, employees and investors that there was a better way to organise and manage customer relations, the supply chain, product development and production operations. This approach, which was pioneered by Toyota and named the TPS after World War 2, was labelled Lean Manufacturing (Womack and Jones, 1996:9).

The term "lean manufacturing" focuses on producing value-added features while identifying and eliminating non-value-added activities in the production environment. In essence, lean manufacturing aims to reduce wasteful practices while providing increased customer value. The central focus of value, according to Womack and Jones (1996:19), should be on providing products with specific capabilities, offered at predetermined prices, through a dialogue with predefined customers. To understand how this concept applies to industry, Carreira (2005:2) distinguishes "value-added" as an activity that makes a product more complete from "non-value-added" as an activity which does not advance the product to a finished state.

In order to focus on all activities that create value, Hines, Francis and Found (2006:873) propose that it is essential to have an alignment between strategic goals and operational activities. From a more specific point of view, Yandell (2002:19) contends that traditional organisations grow both value-added and non-value-added operations in order to increase production and profits. However, lean organisations should focus on reducing non-value-added activities by transferring efforts to those operations which add value, thus growing both production and profits without added resources. Therefore, to demonstrate this idea, Mekong Capital (2004:4-5) cites the following key implications of lean manufacturing compared to traditional batch manufacturing in Table 2.1:

	Traditional Batch Manufacturing	**Lean Manufacturing**
Orientation	Supply Driven	Customer Driven
Planning	Orders are pushed through factory based on production plan/forecast	Orders are pulled through factory based on customer/downstream demand
Batch size	Large	Small
Quality Inspection	Checking of samples by quality control inspectors	In-line inspection by workers
Inventory	Buffer of work-in-progress between each production stage	Little or no work-in-progress between each production stage
Handoff of works-in-process	Materials after each stage accumulate into work-in-progress storage areas before being retrieved by next production stage	Materials handed off directly from one production stage to the next
Production cycle time	Total production cycle takes significantly longer than actual time spent processing the materials	Total production cycle shortens to approach time spent actually processing the materials

Table 2.1 – Key implications of Lean manufacturing (Adapted from Mekong Capital, 2004:4-5).

Table 2.1 highlights the key differences between two of the most popular manufacturing systems. It is evident from the differences presented in Table 2.1 that lean manufacturing aims to remove all waste from production while coping with erratic customer demands.

In 1996, Womack and Jones published a subsequent book titled “Lean Thinking”. They departed from a specifically functional approach and offered a more general way of understanding lean manufacturing. They outlined the five core principles of the system as follows (Womack and Jones, 1996:10)**:**

- Value - Specify value from the point of view of the customer
- Value Stream - Identify the value stream from raw material to the final customer or from product concept to product launch
- Flow – make value flow, strive for one piece flow and continually reduce batch sizes
- Pull system – Manufacture only what is needed or pulled by the customer. The entire supply chain needs to be synchronised into a “pull system”
- Perfection – Produce perfect products in exactly the correct quantities, exactly when the customer wants them at a fair price and with minimum or no waste. The goal is zero waste

There is extensive literature describing various viewpoints of lean manufacturing and its application in the different industries. Results have shown significant improvement in the operational performance such as cost, quality, on-time delivery and inventory levels (Womack and Jones, 1996:121). Several researchers have investigated the contents and methods of lean manufacturing, which resulted in the development of numerous models (Liker, 2004:6; Sanchez and Perez, 2001:1434; Karlsson and Ahlstrom, 1996:26). Many of the models developed often have a lot of similarities or common points and are not necessarily new.

It is interesting to note that the model developed by Karlsson and Ahlstrom illustrated in Figure 2.1 incorporates the entire value stream lean enterprise network. The model consists of lean development, lean procurement, lean manufacturing and lean distribution. According to Karlsson and Ahlstrom (1996:24-25) the model represented in Figure 2.1 was developed to find measurable determinants in a manufacturing organisation. The main determinants of a lean production system are the actions taken, principles implemented, and changes made to the organisation to achieve the desired performance. Figure 2.1 summarises the functional areas and factors of a lean production system throughout an organisation whilst the fundamental principles of lean are found at the bottom of the model. Since the focus of this study is confined to lean in context of its direct application in the production environment, it is evident that the term “lean manufacturing” in the model (Figure 2.1) indicates the manufacturing function in the production environment of an organisation. Based on the model in Figure 2.1, the subsequent sections will discuss waste elimination, continuous improvement, multifunctional teams, zero defects, JIT, vertical information systems, decentralised responsibilities, integrated functions and pull instead of push.

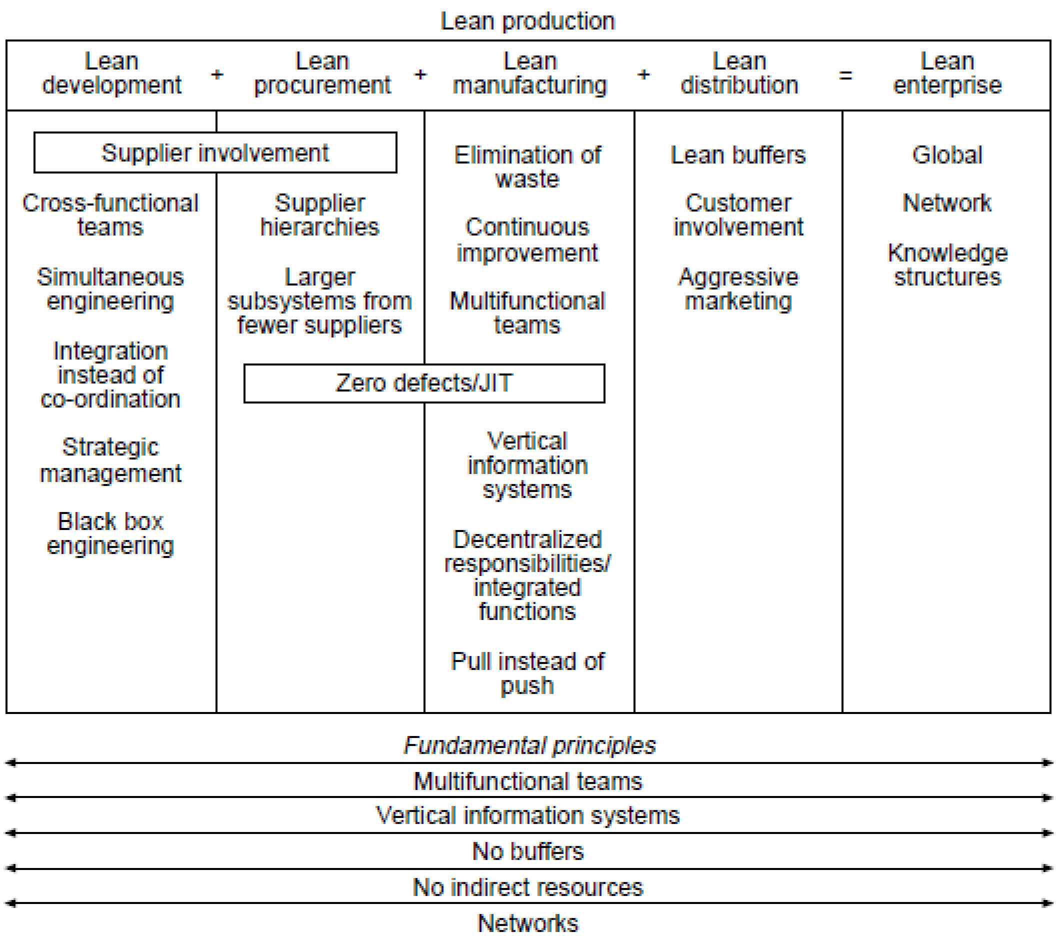


Figure 2.1 - The principles of lean manufacturing (Adapted from Karlsson and Ahlstrom, 1996:26)

The views of the various authors presented in this section highlight lean manufacturing as a structured system of thoughts and actions which has been refined over the years. In addition, it is also evident that through the passage of time, lean manufacturing has become a dominant factor in manufacturing. Furthermore, Carreira (2005:2) is in agreement with Womack and Jones (1996:19) where the central focus of lean manufacturing is the methodical elimination of waste in manufacturing. Due to the critical aspect of customer satisfaction, quality and cost, the views of Hines et al. (2006:873), Carreira (2005:2), Yandell (2002:19) and Womack and Jones (1996:19) concur in that the primary focus of organisations should be on creating value in all operational activities. After providing some background information, the following section of the literature review discusses the elimination of waste.

2.3 ELIMINATION OF WASTE

In this section, the various authors' views on waste elimination are presented. These are accompanied by the most common sources of waste identified in production.

According to the various authors (Taj, 2008:219; Chase, Jacobs and Aquilano, 2006:472; Heizer and Render, 2004:596; Yandell, 2002:19), waste can be defined as any activity that does not add value to the finished product, such as excess inventory, unnecessary operations, scrap, rework or transportation. Therefore, based on these conceptions, Bendell (2006:257) and Gaither and Frazier (2002:470) divulge that eliminating waste of all kinds is the deep-seated ideology behind lean manufacturing. The core feature of this concept is that reducing waste activities frees resources to concentrate on those activities that add value to the product or service.

Lean manufacturing's inventor, Taichi Ohno, compared an organisation to a ship which floats on "water" of inventory. This water covers "rocks", each of which represent production problems, such as quality problems, supplier problems, process imbalances, delays, and unreliable machines that often break down. If the water level is high, the ship will not hit the rocks; that is, no problems will appear. When the lot-size inventory is reduced, it represents the tide going out, and the cause of these errors is likened to dangerous exposed rocks (Schroeder, 2007:397; Chase et al., 2006:474; Heizer and Render, 2004:601; Liker, 2004:88). Under such circumstances, Taj and Berro (2006:335) and Taj (2005:629) are of the opinion that most organisations are unaware that they waste about seventy to ninety percent of their available resources.

In relation to the above, Liker (2004:27) declares waste elimination as the heart of the TPS. Consequently, Toyota defines waste in its original form as Muda, Muri and Mura

(Figure 2.2). According to Figure 2.2, these are the three main types of waste that are prevalent in the manufacturing environment.

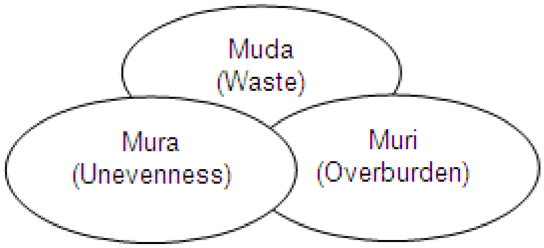


Figure 2.2 - The three M's in Production (Adapted from Liker, 2004:115)

Muda is a traditional Japanese term related to activities that are wasteful, do not add value or are unproductive. Taj (2008:219) and Liker (2004:114) allege that these activities significantly lengthen lead times, generate extra movement to get parts or tools, creates excess inventory, or results in unnecessary waiting for preceding processes. Muri, on the other hand, refers to overburden, unreasonableness or absurdity caused by pushing a machine or employee beyond natural limits. Overburdening employees can result in safety and quality problems whilst overburdening equipment causes breakdowns and defects. Lastly, Mura means unevenness, inconsistency in physical matter or human spiritual condition. Unevenness results from an irregular production schedule or fluctuating production volumes due to internal problems such as downtime, missing parts or defects (Liker, 2004:114). To a great extent, Heizer and Render (2004:596) insist that Mura is usually avoided through JIT systems, which is a key ingredient in lean manufacturing. Following the conception of waste classification by the Japanese, it is evident that each of them reflects a critical disposition towards ensuring a relatively low manufacturing cost while maintaining a high value proposition for the consumer.

The seven categories of non-value-added waste in a production frame that lean manufacturing can assist are: alleviating over-production of work in progress inventory, warehouse inventory, transportation of components, waiting for preceding processes, motion of unnecessary operations, inappropriate processing, and correction of defects (Womack and Jones, 1996:15). Aside from these, Taj and Berro (2006:335) and Liker (2004:29) declare that unused employee creativity is another type of waste that was identified and added to the set of non-value-added activities as the eighth category.

From a more fundamental perspective, Rawabdeh (2005:802) categorises the seven wastes into three main groups relative to man, machine and material (Figure 2.3). It is evident from Figure 2.3 that these activities or conditions have a direct effect on money. Under these circumstances, it is essential for organisations to identify the unnecessary processing costs resulting from man, machine and material.

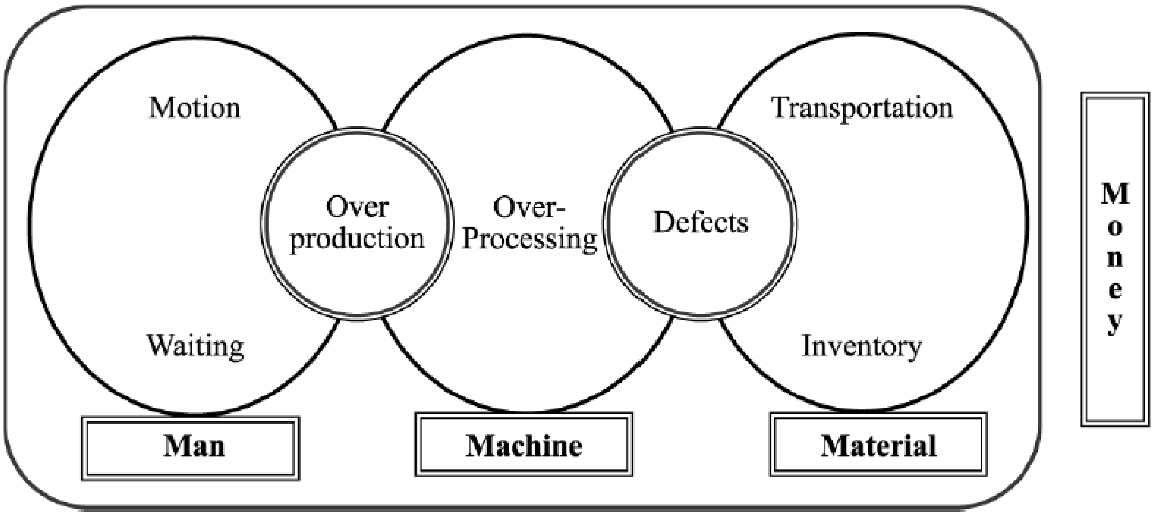


Figure 2.3 – The three main categories of waste (man, machine, materials) and its effect on money (Adapted from Rawabdeh, 2005:802)

According to Figure 2.3, the "man" group indicates unnecessary motions during operations, employees waiting for preceding processes and over-production; the "machine" group represents inappropriate processing of products and the "material" group identifies waste resulting from transportation, excess inventory and defects. On closer examination, Rawabdeh (2005:802) maintains that over-production overlaps man and machine while defects overlap machine and material. The central focus in Figure 2.3 reveals that the main sources of waste in production overlap each other. Indeed, by removing one source of waste it can lead to the reduction or elimination of others.

It is evident that lean manufacturing aims to lower product costs through the constant elimination of waste. Identifying waste is not easy due to the large number of parameters and overlap between different processes that may cause waste activities to be concealed between other activities. Therefore, in order to accomplish the methodical classification of waste in production, this study explores the different sources of lean manufacturing waste in existing and past literature. The eight sources of waste are explained in the following sub-sections together with tools to detect and eradicate them.

2.3.1 WASTE OF OVER-PRODUCTION

The waste of over-production overshadows all other forms of waste in the manufacturing environment. Consequently, Liker (2004:29) and Karlsson and Ahlstrom (1996:27) contend that over-production induces excess inventory in the form of Work in Progress (WIP) and is regarded as the most important source of waste since it prevents immediate correction and improvement. In most cases other wastes are generally easier to identify and correct. There is no value added to these parts or products if they are kept in stock. It leads to higher costs for storage, excessive lead times and difficulty in detecting defects. Santos, Wysk and Torres (2006:4) warn that as a natural consequence, there is also a high risk of these parts becoming obsolete.

In the contemporary business, Lee-Mortimer (2008:105) asserts that the amount of WIP levels that result from over-production reflects the amount of variability in production batch sizes. It may sound paradoxical, but in most cases defects that remain hidden in WIP inventory will only be discovered when the downstream process demands the product. This waste might not be noticeable when the market is strong; however, when demand drops, it can lead to serious problems. The main factors contributing to this type of waste, according to Liker (2004:28) and ReVelle (2002:174), are when organisations produce finished products or WIP for which they do not have any customer orders or if they produce parts faster than required by the downstream process. During all manufacturing operations, Santos et al. (2006:7) maintain that over-production can be categorised as “quantitative” or “early”. Quantitative over-production means producing more than is needed and early over-production occurs when products are manufactured before it is needed.

Since customer demands and requirements are uncertain, accurate forecasting is crucial in controlling the production to determine the optimum order quantity (ReVelle, 2002:360). One of the key assumptions is that over-production can be eliminated by a strict “pull logic” system called the Kanban which was developed by Taichi Ohno at Toyota (Naslund, 2008:275). The most distinguishing feature, according to Bicheno

(2004:16), is that the traditional Material Requisition Planning (MRP) system works on a "push system" that generally produces products to stock whilst the Kanban system prevents unplanned over-production by allowing work to move forward only when the next work area is ready to receive it. Apart from the above, Rawabdeh (2005:806) is emphatic that operators tend to lessen their attention towards the quality of parts when they are produced in excessive amounts. They somehow sense that there exists enough material to substitute for defects. Sometimes, over-production forces the organisation to consistently change the number of employees in the work force, thus making standardisation extremely difficult and resulting in quality problems and waste of competencies (Wu, 2003:1367).

Since over-production results in excessive WIP inventory, it leads to the physical separation of operations and the discouragement of communication. It also entails making and moving things that are not immediately required which impacts on the waste of motion. Most commonly, Bicheno (2004:16) maintains that over-production is often the natural state in which employees do not have to be encouraged to overproduce; they often do so in order to have stock available should a customer require it. Thus, drawing from these debates, over-production usually discourages a smooth flow of goods and takes the focus away from what the customer really wants.

The views of Santos et al. (2006:7) on the two main contributing factors of over-production are similar to those of Liker (2004:28) and ReVelle (2002:174). Rawabdeh (2005:806) and Bicheno (2004:16) concur in their views that employees over-produce to be safe and to accommodate for defects. Therefore, it can be suggested that by utilising a Kanban system, as well as planning production schedules accurately, in line with customer demands, the waste of over-production can be eliminated.

2.3.2 WASTE OF INVENTORY

Inventory is regarded as the enemy of quality and productivity (Bicheno, 2004:18). It is closely associated with over-production as it tends to increase lead time, space and prevents the rapid identification of problems which discourages communication. The implication here, according to Koumanakos (2008:355), is that unnecessary inventory creates significant storage costs which lowers the competitiveness of the organisation or value stream wherein they exist.

In general, inventory is an accumulation of finished products, WIP and raw materials at all stages of the production process. Related to this, Zylstra (2006:93), holds that organisations generally have inventories somewhere in the system that acts as a buffer against variation and change. The buffer inventory depends on product characteristics, operational processes, and customer service expectations. It hides a myriad of other underlying problems such as defects, production imbalances, longer set-ups, equipment downtime and late or defective deliveries from suppliers (Naslund, 2008:275; Chase et al., 2006:474; Rawabdeh, 2005:806; Liker, 2004:29; Heizer and Render, 2004:602). In addition, inventory waste affects every production process that depends on a previous process for parts and materials. Under these circumstances, Liker (2004:101) debates that since inventory hides problems it reduces the urgency to solve them.

On the other hand, Fullerton and Wempe (2009:231) challenge that simply eliminating buffers does not solve production, quality, or delivery problems but merely reveals them. The methods employed for eliminating unnecessary inventory which does not add any value should not be removed mindlessly. Karlsson and Ahlstrom (1996:27) recommend that the reasons for the existence should first be identified and then removed.

According to Marsh and Blau (2007:204) lower WIP buffers create leaner production systems which are usually measured by counting the amount of work yet to be completed. In a similar view, Zylstra (2006:159) and Santos et al. (2006:4) put forward that inventory buffers limit flexibility as demand and variation patterns change, resulting in excess or obsolete inventory. It is therefore essential to dispose of obsolete material and to produce only what is required by the next process.

Organisations primarily utilise inventory as a buffer because it is easy to quantify, track and control. Zylstra (2006:132) reflects that most organisations view inventory buffers as an asset, good for customer service. Koumanakos (2008:356) is in agreement with Zylstra (2006:132) and argues that too little inventory often disrupts manufacturing operations, and increases the likelihood of poor customer service. Customers may become irate and take their business elsewhere if the desired product is not immediately available. In practice, unnecessary inventory can be attributed mainly to poor information flow and batch processing. If inventory is not produced to meet customer demand, it impacts on cash flow and uses valuable floor space. A sufficient inventory level target should be analytically calculated and maintained to complete the tightest possible linkage with customers. Both Koumanakos (2008:356) and Zylstra (2006:159) accept that too much inventory will undermine lean disciplines and extend lead time, whilst too little inventory will result in stock-outs or excessive expediting.

As a useful strategy, Wu (2003:1354) claims that standard size containers usually help to reduce inventories. Since standard size containers are required for lean manufacturing, it aids in producing parts according to the pre-defined standard size container quantities that are available between processes. On a final note, Zylstra (2006:196) observes that the parameters such as lead time, demand variation and customer's usage patterns are commonly used to set consistent inventory levels.

After providing some background information on excess inventory, the following graphical representation in Figure 2.4 illustrates the consequences thereof. It is evident from Figure 2.4 that over-production often leads to excess inventory which in turn has an impact on several other sources of wastes such as lead-time, quality problems, storage costs, wasted space, transport and obsolescence. When inventory is maintained at a minimum level it will prevent or reduce the other forms of wastes.

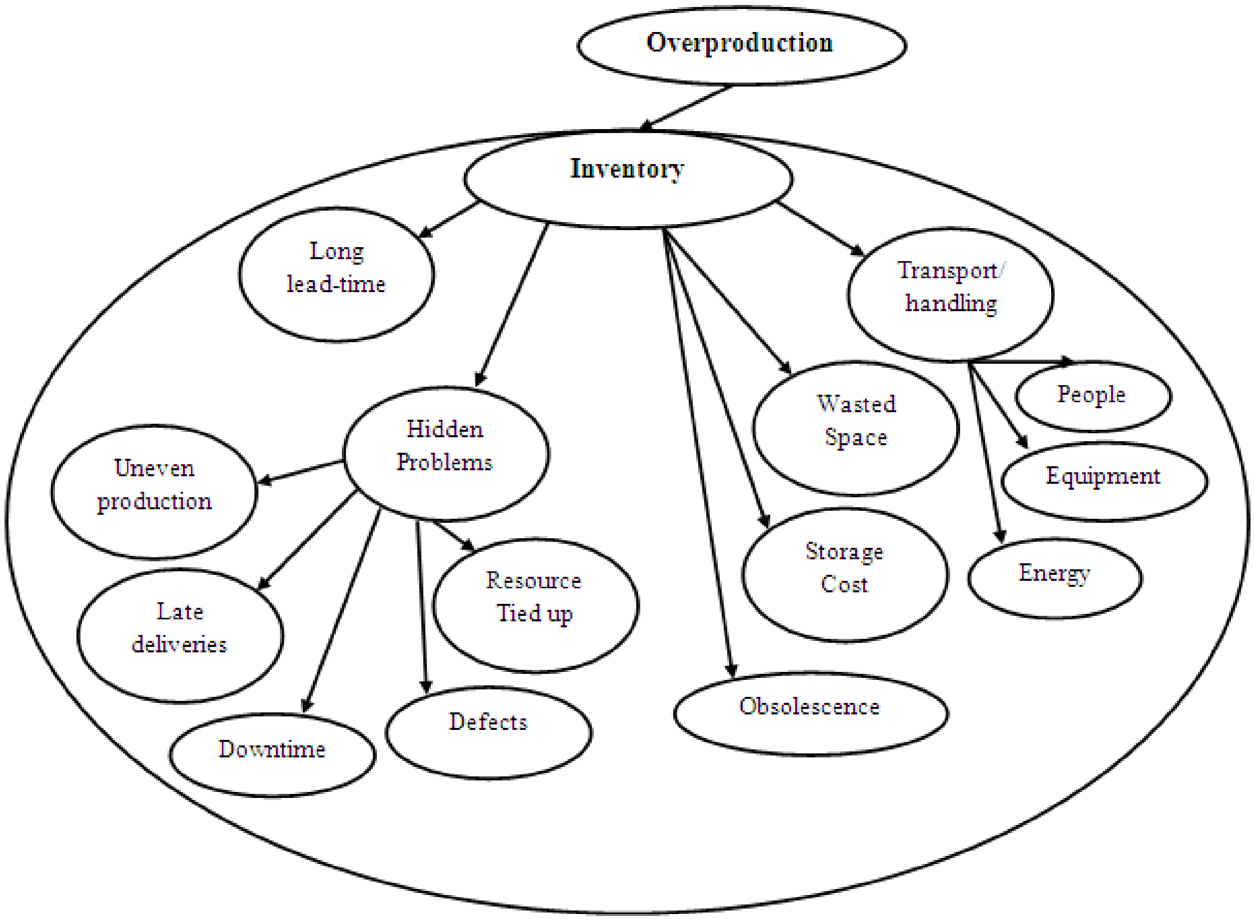


Figure 2.4 – Impact on Inventory (Adapted from ReVelle, 2002:175)

Both Koumanakos (2008:356) and Zylstra (2006:159) concur about maintaining the correct inventory levels as opposed to the views of Naslund (2008:275), Chase et al. (2006:474), Rawabdeh (2005:806), Liker (2004:29) and Heizer and Render (2004:602) who believe that the potential problems caused by excess inventory include defects, production imbalances, longer set-ups, equipment downtime and late or defective deliveries from suppliers. It would appear that the inventory level is regulated by customer demand. Therefore, the main barriers are to maintain the correct inventory level and identify problems before inventory accumulates.

2.3.3 WASTE OF TRANSPORT

The waste of transport is generally identified as moving products from one location to another. Carreira (2005:60) and Liker (2004:28) are adamant that transportation waste involves any movements of materials in an organisation. In the same theoretical line, Karlsson and Ahlstrom (1996:28) endorse caution that transporting parts or products from one location to another does not add any value, but rather creates added manufacturing lead times. The central drive behind this waste, according to Bicheno (2004:17), is that customers only pay for activities that add value to a product and do not pay to move goods unnecessarily. As an important consideration, Carreira (2005:61) discloses that organisations usually utilise a great amount of capital for moving materials around.

Traditionally, parts are transferred from a large storage pallet to a smaller one and then placed on the machine several times before they are finally processed. This results in material moving unnecessary distances, being stored temporarily or being re-arranged at the work stations which lead to wasteful practices (Rawabdeh, 2005:806). The most significant factors that contribute to transportation waste, as highlighted by ReVelle (2002:176), includes poor shop layout, poor workplace organisation and housekeeping, wrong work order information, misallocated material and excessive inspections.

Bicheno (2004:17) is of the opinion that transportation can be closely linked to communication and if the distances between two processes are not in close proximity or not in a logical sequence, communication is hindered and this could affect quality. In most cases the time it takes for employees to communicate between a long process is proportionate to the time it takes to report a quality problem and commence with the necessary corrective action. This is important as lean manufacturing requires a continuous workflow with minimum or no interruptions. Perhaps, if the distance between two work centres is kept to a minimum, it will enable employees to access quality problems and to take the necessary corrective actions immediately, without interrupting the workflow.

Furthermore, Bicheno (2004:17) reports that the number of transport and material handling operations is directly proportional to the likelihood of damage and deterioration of the material. This affects productivity and quality. When transportation waste is taken to the extreme, it can be inferred that any movement in an organisation could be viewed as waste. Therefore, unnecessary transportation cannot be completely eliminated; however, it is essential to continuously reduce it. As a means of intervention, transportation waste can be reduced by grouping products and equipment into product families along cell based systems, better process coordination, better transportation methods and minimising the distances materials should travel.

The views of Carreira (2005:60), Liker (2004:28) and Karlsson and Ahlstrom (1996:28) are similar to those of Rawabdeh (2005:806) and Bicheno (2004:17) in that transporting parts from one location to another does not add any value. In particular, considering the views of Bicheno (2004:17), excessive transportation can lead to unnecessary damages imposed on products which may require reworking or even the possibility of scrapping. When transportation is kept to a minimum it will reduce the time and energy consumed in moving products and perhaps eliminate unpredictable or unforeseen reworking or scrapping costs.

2.3.4 WASTE OF WAITING

Carreira (2005:64) provides strong empirical support where this waste is the enemy of smooth flow. The waste of waiting can be attributed to many different factors during the course of production. In a manufacturing environment, this type of waste occurs whenever goods are not moving or being processed. It is a type of waste that results from ineffective use of time and occurs whenever employees or parts wait for a cycle to be completed. According to Bicheno (2004:16) the waste of waiting is directly relevant to continuity because lean manufacturing is concerned with the continuous flow of the product.

This type of waste can be strongly associated with batch processing and the time of waiting is very high in comparison to JIT processing. When an employee stands idle and watches an automated machine, he or she does not add any value to the process. Instead, the employee is only monitoring the machine to ensure that it functions smoothly. This should not be the case since an automated machine should be designed to stop automatically and signal an alarm if it detects a problem. As a possible means of recovery, Bicheno (2004:16) proposes that the waste of employees waiting time may be used as a benefit to the organisation in the form of training, maintenance, cleaning or even Kaizen activities. Another common form of wasted time, according to Santos et al. (2006:8) and Liker (2004:28), is when the preceding process fails to deliver parts needed in the present process. It is probable that this situation will significantly interrupt the sequential workflow during production.

The frequent contributors to the waste of waiting are identified by ReVelle (2002:174) as bottlenecks or inefficient flow on the factory floor. These are caused mainly by poor communication, uneven scheduling, unreliable suppliers and poor equipment reliability. It is worth noting that much of a product's lead time is utilised in waiting for the next process or operation. Rawabdeh (2005:806) draws on previous research to suggest that parts or products waiting in inventory does not add value and remains idle while waiting to be transported to the next process. As mentioned earlier in section 2.2.2, inventory reduction is important as it can assist in reducing waiting time.

Although waiting is detrimental to smooth work flow, Bicheno (2004:16) establishes that it is difficult to reduce it to zero; however, it should always remain a goal. Furthermore, he declares that in some instances the waste of waiting also affects lead time which is an important source of competitiveness and customer satisfaction. As a means of control, waiting time can be effectively reduced by linking processes together so that one feeds directly into the next, through JIT and value stream mapping.

The views of Santos et al. (2006:8), Carreira (2005:64), Rawabdeh (2005:806), and Liker (2004:28) concurs that waiting disrupts the smooth flow of production. The positive views of Bicheno (2004:16) suggests that significant value is added when employees participate in training programmes or perform different tasks during waiting time.

2.3.5 WASTE OF MOTION

Unnecessary motion is a type of waste that refers to the ergonomics for quality and productivity which consumes time and energy. Liker (2004:29) admits that this type of waste is most often revealed in the actions of operators as they search for tools, their selection and placement of tools and parts that are kept out of immediate reach of the workstation, and the time spent walking among machines between workstations.

ReVelle (2002:176), on the other hand, remonstrates that motions of employees or machines which do not add value to the product or service can lead to employee fatigue or wear and tear on machines and sometimes also lead to injury. The factors contributing to motion waste are poor process design, an ineffective human-machine inter-face, bad workplace design or inadequate planning. Although not dominant, material handling system changes that improve the material flow through value-added operations provide a major opportunity to reduce motion wastes.

According to Rawabdeh (2005:806) a non-standardised work method is another common form of motion waste that results in excessive WIP and in higher percentage of defects. In a similar contribution, Carreira (2005:65) reveals that the compounded costs associated with this type of waste includes injury, compensation costs, and costs associated with ergonomic issues. Therefore, Bicheno (2004:17) stresses that an awareness of the ergonomics in the workplace is not only ethically desirable, but economically sound. The value stream mapping tool is often used to identify this type of waste whilst "5S", cell designs and ergonomic workspace designs are commonly used to reduce wasted motions.

The views of Liker (2004:29) and Bicheno (2004:17) revolve around ergonomic issues in the workplace. On the other hand, Carreira (2005:65), Rawabdeh (2005:806) and ReVelle (2002:176) highlight their concern of unnecessary costs incurred through wasted motions. Finally, this leads to the conclusion that any motion which does not add value to the product can be regarded as waste.

2.3.6 WASTE OF INAPPROPRIATE PROCESSING

The waste of inappropriate processing is characterised by unnecessary tasks that employees perform in the product flow. Bicheno (2004:17) alleges that inappropriate processing occurs in situations where overly complex solutions are found for simple procedures such as using a large inflexible machine instead of small flexible ones. As a result, this discourages ownership of employees who implement these solutions and encourages over-production to recover the investment in complex machines. In a similar contribution to Bicheno (2004:17), Liker (2004:29) perceives that inappropriate or inefficient processing also refers to tools and processes that are not capable of producing quality goods. These tools and processes cannot help but continue to cause unnecessary movements and make defects.

Since maintenance and manufacturability are key elements for eliminating waste from process methods, well-maintained fixtures and machinery would require less employee labour to produce a quality product. Therefore, Rawabdeh (2005:807) stresses that if processes and machines are not continuously maintained and monitored, defects will be produced. Processing waste can also be attributed to inappropriate operations. A typical example of this type of waste occurs when a guide pin in a jig does not function efficiently and the operator has to hold the jig with his hand to complete the process. Based on this example, Carreira (2005:61) anticipates that this process does not go smoothly and time is also wasted. Along similar lines, Santos et al. (2006:7) urge that only necessary tasks should be adopted and accepted to maintain a smooth flow in the production processes.

Any processing efforts or steps that add no value to the product or service from the customers' perspective can lead to this waste (ReVelle, 2002:176). The contributing factors include redundant approvals, poorly defined customer requirements, lack of standard operating procedures and redundant steps to make up for lack of process quality. Consequently, Carreira (2005:62) classifies "set-up" and "change-over" costs as process waste since these activities are process sensitive. Therefore, it is essential to conduct regular preventive maintenance and to include total preventive maintenance programs.

In certain situations, Liker (2004:29) asserts that this type of waste can be generated when the production process tries to provide higher quality products than is necessary. Tools such as "value stream maps" are commonly used to identify and eliminate non-value activities. This is usually done by investing in smaller and more flexible machines, creating manufacturing cells, and combining steps in processes to reduce the waste of inappropriate processing. When process efficiencies are improved, fewer resources are utilised to achieve the same customer satisfaction.

Similar abstractions by Rawabdeh (2005:807), Liker (2004:29) and Bicheno (2004:17) dwell on tools or processes that are not capable of producing quality goods. The views of Carreira (2005:62) states that machine set-ups and change-overs contribute significantly to process defects. Thus, based on the views presented by the various authors, it appears that it is necessary to develop procedures that continuously improves and upgrades processes and equipment to reduce processing waste.

2.3.7 WASTE OF DEFECTS

The waste of defects occurs as a result of poor quality work. Both Santos et al. (2006:7) and Liker (2004:29) contend that defects, rework, scrap and inspection generates wasteful handling, time and loss of additional effort which interferes with productivity and stops the smooth flow of the production process. In particular, Carreira (2005:62) intimates that defects are regarded as the bottom-line waste as these bear direct costs to the organisation. When defective parts or products are reworked they do not add any value to the customer (Karlsson and Ahlstrom, 1996:28). This also leads to delaying delivery orders to customers or having to maintain excess inventory to make up for quality problems.

According to ReVelle (2002:176) the implication of severe quality problems can also create lower customer confidence and lead to loss of future business. The common causes of this waste can be attributed to weak process control, poor product design, poor equipment maintenance, inadequate measurement systems, or ineffective employee training.

In essence, this type of waste causes other types of waste throughout the process. These include “wait time” that increases costs and lead times for subsequent processes, rework that increases labour costs to make parts usable, additional labour required for disassembly and re-assembly, additional materials needed for replacement parts, extra labour involved in sorting defective from acceptable parts and scrapping defective pieces. As indicated by Rawabdeh (2005:806) all of these activities waste both materials and work already performed.

Bicheno (2004:18) mentions that Toyota regards defects as challenges and opportunities to improve, rather than something attributed to poor management. Manufacturing defective products means investing materials, equipment and labour in something that cannot be sold. Bendell (2006:258) widens the debate that this is the worst offense against cost reduction. The total cost of defects is sometimes a significant percentage of total manufacturing costs in many organisations. Even the most stable processes are likely to produce defects due to human error or variances in upper/lower tolerances in machine operations. Sharing a similar view, both Liker (2004:130) and Bicheno (2004:153) claim that identifying defects at the source eliminates this type of waste as it occurs.

The views of Bendell (2006:258), Rawabdeh (2005:806), Carreira (2005:62) and Liker (2004:29) highlight the significant financial losses that results from producing defects. In addition, ReVelle (2002:176) addresses the issue of customer dissatisfaction. The point to understand is that defective parts affect every process throughout the value chain from the supplier to the customer. Perhaps, the first step in ascertaining quality products would be to eliminate defect waste at the source as highlighted by Liker (2004:130) and Bicheno (2004:153).

2.3.8 WASTE OF UNTAPPED HUMAN POTENTIAL

This type of waste refers to the under-utilisation of employees' creativity. According to Bicheno (2004:18), the real objective of the TPS was to create a working environment that allowed employees to think more effectively. In addition, Bicheno (2004:19) stands to reason that there is also the concern in which the human potential should not be set free. This means that the communication channels between employees and management should be clearly defined. Employees should clearly understand what is expected from management and management should also understand what is expected from employees. Another contemporary issue is that un-capping human potential can sometimes be seen as a threat to first line and middle managers, therefore it is essential for commitment, support, a culture of trust and mutual respect.

Liker (2004:13) reports that labour advocates and humanists have always criticised assembly line employees as being oppressive and menial labour, thereby robbing employees of their mental faculties. As a method of capitalising on human potential, Chase et al. (2006:479) and Liker (2004:13) claim that Toyota challenges its employees to use their initiative and creativity to experiment and learn more about their processes, and also challenges them to grow in their jobs by constantly solving problems.

Generally, time, ideas, skills, improvements, and learning opportunities are lost by not engaging or listening to the employees (Liker, 2004:29). Since employees are the centre of an organisation, they should be trained to see waste and solve problems at the source by repeatedly asking why the problem really occurs. Under these circumstances, Liker (2004:33) stresses that problem solving is most beneficial at the actual place where the problem occurred to make an assessment.

In a recent survey conducted at a Fortune 500 organisation in the USA, Sim and Rogers (2009:37-46) found that employees do not feel valued when they contribute to improvement activities although they are in the best position to offer suggestions for improving the efficiency of the process. The study also found that shop floor employees do not believe that the organisation views them as the most important asset. Comm and Mathaisel (2005:136) are of the opinion that an open and honest organisational culture empowers employees to develop suggestions and actively participate in process mapping activities without fear of repercussions. According to Dahlgaard and Dahlgaard-Park (2006:275) employees will get negative motivational effects in the form of frustration when they participate in decision making processes and when their opinions or suggestions are not respected. Worley and Doolen (2006:231) concur with Dahlgaard and Dahlgaard-Park (2006:275) and are adamant that discouragement may arise and that the lean manufacturing effort will fail if employees' efforts are not respected by the executive team. Employees are likely to perform at their best to achieve quality goals set by management when they feel acknowledged and treated fairly for their contributions (Lee and Peccei, 2008:9).

On a more practical approach, Emiliani and Stec (2004:636) suggest that a leader who questions all processes and supports continuous improvement opportunities motivates the employees to do so as well. Based on this idea, the employees will accept their suggested risks and enjoy work more because they are able to use their knowledge and skills in the workplace. In addition, Emiliani and Stec (2005:372) encourage that lean management practices help employees to realise their full potential and to actualise innate desires to make positive contributions to the workplace. The common causes that result in this waste include organisational culture, inadequate respect for employees, no provision for training and high employee turnover. When organisations capitalise on their employees' creativity, they can eliminate the other seven wastes and continuously improve their performance.

The views of the authors presented are in agreement that respect and culture are the two main determinants for uncapping human potential. It is apparent that employees contribute significantly to production. Therefore, on closer examination, the main objective of capitalising on employees' creativity assists in identifying and removing all forms of waste from production.

Further to the above information reviewed on the eight wastes identified in production, Lee-Mortimer (2006:265) observes that organisations which take a wider focus on lean manufacturing often discover hidden waste even in the most effective operations. It is interesting to note that even the best lean manufacturers probably waste thirty percent of their available resources (Taj and Berro, 2006:335; Taj, 2005:629). In concluding this section, it is evident that there are similar abstractions on waste elimination that have been proposed by various authors over the years. They have noted and are in agreement that from a lean manufacturing point of view, waste means any activity which the customer is not willing to pay for. Finally, this leads to the conclusion that organisations should manage the elimination of waste as a long term initiative.

It can be inferred that some of the sources of wastes explained in the above subsections are more prevalent than others while there are some that cannot be completely eliminated. After providing some in-depth explanation and various opinions and points of views on waste elimination, the following section of the literature review discusses the principle of continuous improvement.

2.4 CONTINUOUS IMPROVEMENT

This section presents an explanation and various authors' views on continuous improvement followed by four successive tools required for working with continuous improvement.

As the name suggests, it can be surmised that continuous improvement means discovering better ways of manufacturing. According to Bicheno (2004:140), continuous improvement is the essence of lean manufacturing that needs to reach all levels of employees and involves all value streams or processes internally and along the supply chain. In arguing the main concept of continuous improvement, Bhuiyan and Baghel (2005:761) insist that it should be based on a culture of sustained improvement that targets the elimination of waste in an organisation. Along similar lines as Bhuiyan and Baghel (2005:761), Santos et al. (2006:2) articulate that typical production systems consist of evolutionary and revolutionary changes which are supported through product and process innovations. Evolutionary changes consist of continuous improvement being made in products and processes while revolutionary changes make use of methodologies such as process re-engineering and major product re-design.

Various authors (Bhuiyan and Baghel, 2005:769; Bateman, 2005:271; Sanchez and Perez, 2001:1436; Karlsson and Ahlstrom, 1996:29) share similar views in that continuous improvement is a process which requires the involvement of production employees and the support of top management to continuously improve products and processes. In relation to this, Khan, Bali and Wickramasinghe (2007:355) and Emiliani (2006:178) also make a distinction where management support and participation in continuous improvement should indicate true commitment instead of just compliance. The point to understand, according to Sim and Rogers (2009:46), is that continuous improvement is about change and requires employees to work with a different mindset.

The continuous work of improvement is often accomplished through Quality Circles where employees gather in groups to brainstorm possible improvement. Quality Circles evolved in Japan and contributed to significant quality improvement, methods improvement, morale-enhancing improvements, and employee motivation (Bhuiyan and Baghel, 2005:763). From an operative point of view, Bicheno (2004:143) maintains that group problem solving teams undertake improvement workshops that affect their collective work area such as work flows, cell layout, line re-balances, “5S”, foot printing, and cell level quality. Khan et al. (2007:355) suggest that it is extremely important for any continuous improvement project to have a designated leader or champion to monitor the progress and achieve the desired results.

Overall, it is essential to define and understand the source of the organisations core problem in order to improve quality, cost, and time in production activities. Bicheno

(2004:143) divulges that individual employees need to be recognised as experts of their own processes and understand the process and applicability to the wider value stream. Thus, the emphasis on “root cause” problem solving is another fundamental aspect to the lean manufacturing philosophy which solves problems at the source rather than at superficial levels (Bicheno, 2004:153). Aside from these, Khan et al. (2007:355) and Heizer and Render (2004:609) advise that employees’ views should never be underestimated since they have firsthand knowledge and experience of processes on the shop floor. According to Sanchez and Perez (2001:1436), employees sometimes identify and adjust defective parts during production. This is another technique that is often recommended in achieving continuous improvement.

Subsequently, Sim and Rogers (2009:46) found that appropriate feedback and communication plays an essential role for continuous improvement initiatives, its maintenance and effectiveness. All improvements should be measured to sustain the improvement. If there is no measure, Bateman (2005:270) stipulates that employees will not know the standard and, as other priorities occur, the performance level will degrade. Measuring the improvement also aids in finding solutions to problems.

Santos et al. (2006:3) claim that poor quality, increased production cost and increased cycle time are the three main factors that affect production. Therefore, whenever variability arises in quality and productivity it should be considered a major problem for the organisation. As a useful strategy, Comm (2005:69) advocates that organisations are able to produce higher quality products with shorter lead times through proper training and the formation of quality improvement focus groups.

In practice, Bhuiyan and Baghel (2005:761-769) and Comm (2005:65) explain that continuous improvement does not entail making huge capital investment since the focus is mainly on employees working together to make improvements. It is perhaps ironic that continuous improvement in traditional organisations concentrate mainly on work improvement in the production environment whereas the modern day continuous improvement initiatives are associated with organised and comprehensive methodologies for the entire organisation from top management to employees on the shop floor. As suggested by Bhuiyan and Baghel (2005:762), the continuous improvement paradigm has developed over the years and has become imperative for organisations to follow in order to reduce waste, simplify the production line and improve quality. Similarly, Emiliani and Stec (2004:642) comment that when continuous improvement activities are facilitated correctly, it becomes fun and memorable to work with and it changes employees' beliefs about business, people, and processes.

The views of the above authors concur in that continuous improvement provides successful strategies to improve the performance of organisations. The views of Bhuiyan and Baghel (2005:762), in particular, encourage the shift of continuous improvement from the production floor to the entire organisation. This is essential for the success of the entire organisation. Following the discussion of continuous improvement, details of the suggestion scheme programme, Kaizen, PDCA methodology and "5S" are presented in the following subsections. These tools are the essential features of continuous improvement. Each reflects a critical disposition towards the important constructs in production and waste elimination.

2.4.1 SUGGESTION SCHEME

A suggestion scheme programme is a common concept that many organisations use to motivate their employees in the support of continuous improvement activities. Santos et al. (2006:1) associate continuous improvement as a management philosophy based on employees' suggestions. In most cases, Chase et al. (2006:327) and Karlsson and Ahlstrom (1996:29) believe that this is often accomplished through suggestion scheme programs. According to Bhuiyan and Baghel (2005:766), employees are encouraged to concentrate on problem areas and find best possible solutions since suggestions generally provide cash rewards, which, along with the chance to participate, improve motivation. Sharing a similar view, Olivella, Cuatrecasas and Gavilan (2008:807) anticipate that the suggestion scheme usually provides individual rewards as well as collective rewards for team based improvements. Certain organisations have rated incentive programs that reward employees according to the problem and solution provided.

Previous research and history shows that reward systems are highly affected by trust and value (Dahlgaard and Dahlgaard-Park, 2006:275). Any rewards for improvement initiatives should be transparent and recognised. Although employee's suggestions are first reviewed by management and specialists before implementation, Bhuiyan and Baghel (2005:766) contend that it is also important to give employees clear explanations for suggestions that are rejected. Dahlgaard and Dahlgaard-Park (2006:275) argue that a reward system will have no motivational effect if there is no trust between leaders and employees. It will decrease employees' intrinsic motivation when the managerial climate is controlling rather than supporting and acknowledging. In a study between two Korean organisations, Lee and Peccei (2008:22) found that employees' commitment to quality changes during the different levels of lean implementation, shifted in the general direction of rewards intrinsic to the job itself.

Bicheno (2004:146) is not in agreement with Olivella et al. (2008:807) and Bhuiyan and Baghel (2005:766) and contest that the suggestion scheme is a classic type of passive incremental improvement which does not always pay but it should create a culture of the importance of continuous improvement. The number of suggestions per employee should be measured and it is also beneficial to evaluate the percentage of suggestions implemented. The suggestion scheme program forms an integral part of the organisation's continuous improvement initiatives as it provides valuable opportunities for employees' self-development and helps them to evaluate the current way they perform their tasks.

2.4.2 KAIZEN

Kaizen is a Japanese term for continuous improvement and is a key strategy to implement the "support-the-worker" principle in lean manufacturing (ReVelle, 2002:188). According to Liker (2004:24), it involves the constant elimination of waste through incremental improvements on processes and quality, while improving employee safety and reducing costs. In a similar contribution to Forza (1996:52), Bhuiyan and Baghel (2005:766) point out that the successful implementation of Kaizen involves the collective efforts of employees at every level of the organisation.

The intent of Kaizen events is to substantially improve the performance of the targeted work area and to create a positive human resource outcome. In terms of theory, Khan et al. (2007:349-350) claim that Kaizen does not only identify better ways of working, but also rewrites and redefines previously set standardised work. It is a methodology that strengthens employee involvement (management and shop floor) in the improvement process and aids the change process that is enhanced through proactive training.

Doolen, Van Aken, Farris, Worley and Huwe (2008:638) refer to a structured continuous improvement project as a Kaizen event that uses a dedicated cross-functional team to target radical improvements in a particular work area. In practice, Bhuiyan and Baghel (2005:766) insist that whenever any Kaizen activities are performed by management, it should focus on the organisation's strategy that includes all employees. Similar views by Doolen et al. (2008:652) concur with Bhuiyan and Baghel (2005:766) where management support is key to improving human resource outcomes in successful Kaizen events.

Kaizen activities usually develop employees' skills to work effectively in small groups, to solve problems, to document and to improve processes and to self-manage within a peer group. Consequently, Liker (2004:24) stresses that decision making is left upon the employees and requires open discussions and a group consensus before implementing any decisions.

Another argument by Emiliani (2006:173) and Emiliani and Stec (2004:640) states that employees should not lose their jobs as a result of productivity improvements achieved through Kaizen as it would undermine future efforts to improve. From this point of view, Khan et al. (2007:355) warn that implementing Kaizen or other philosophies induces fear in employees, therefore management support and assurance is necessary to remove these fears.

2.4.3 PDCA

The Plan-Do-Check-Act (PDCA) cycle illustrated in Figure 2.5 is a cornerstone of continuous improvement. Within the context of waste elimination, Liker (2004:264) explains that the cycle relates to creating a one-piece flow, surfacing problems, counter measures and evaluating results.

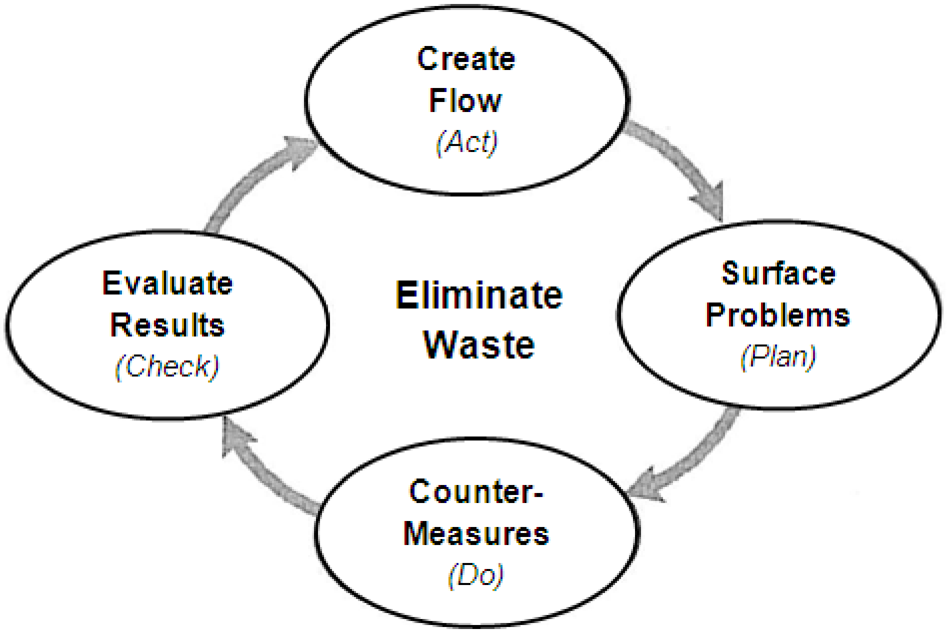


Figure 2.5 – Creating flow and PDCA (Adapted from Liker, 2004:264)

Sharing a similar view as Liker (2004:264) and from a more fundamental perspective, Bicheno (2004:140-141) declares that the PDCA methodology is used across several levels in an organisation since it forms part of the measurement cycle. For the PDCA cycle to be effective, however, any problem situation should follow the investigation process as shown in Figure 2.5. The planning phase identifies the concern or problem and sets the objectives and working plan. The next step requires implementing the improvement after which the check phase reviews if the objectives were met. The act phase entails adopting the new standards and identifying further improvements.

Contributions by Bateman (2005:274) suggest that an important enabler for any improvement activity is to follow the PDCA loop to close actions. The final theme suggests that there is a need for an enabling process to allow continuous improvement to take place and a supportive management structure.

2.4.4 "5S" METHODOLOGY AND STANDARDISATION

The "5S" tool demonstrated in Figure 2.6 is a basic housekeeping discipline that applies in the office and shop floor to organise and visualise workstations. It is one of the most effective tools used for continuous improvement. The "5S" tool is as follows: sort, straighten, shine, standardise and sustain. So from looking at the "5S" tool in Figure 2.6, Sort requires separating what is necessary from those items that are not used in a workstation. Simplify or set in order is to locate items that are used in the best place. Sweep or Shine means keeping up the good work by physically tidying up on an ongoing basis. Standardise means that it is now possible to adopt standard work. Sustain entails participation of all employees in "5S" on an ongoing basis (Bicheno, 2004:52).

According to Liker (2004:142), strong emphasis has been placed on standardising and stabilising processes before any continuous improvement can be made. Since this is an area of significant efficiency potential, Motwani (2003:345) contends that the "5S" tool lays the foundation for all other improvements. When the "5S" tool is applied correctly it will maintain a clean and organised working environment to ensure a smooth flow of production.

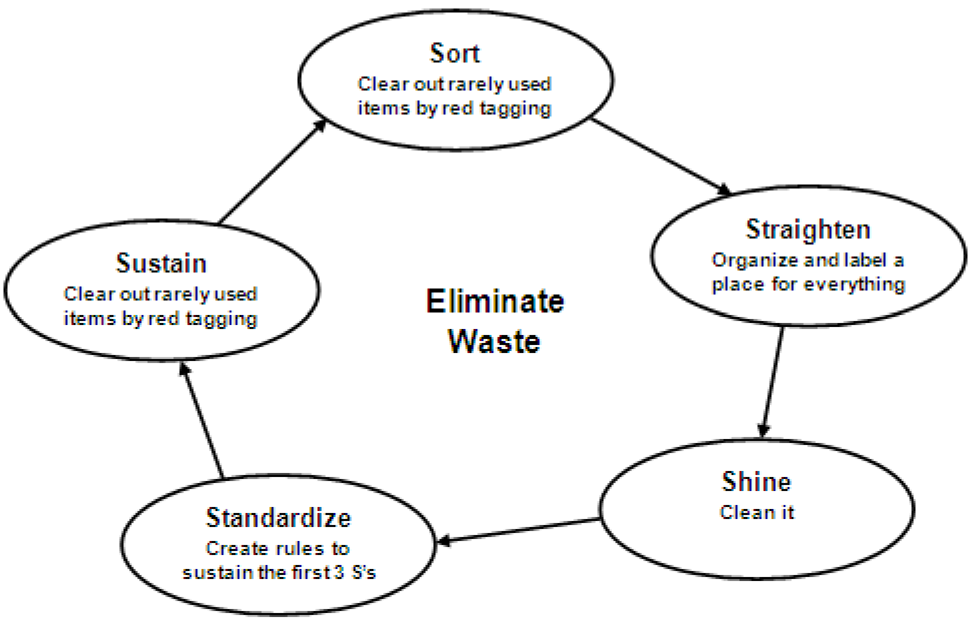


Figure 2.6 – The 5 S's (Adapted from Liker, 2004:151)

From the tools discussed above, it is apparent that the positive views of the authors suggest that these initiatives are necessary to promote continuous improvement. In summary, this section presented several important concepts that are necessary for the success of continuous improvement. First, the suggestion scheme program motivates employees to participate in continuous improvement. Second, the concept of the Kaizen methodology encourages employees to focus on pursuing continuous improvements for all processes. Third, the PDCA cycle is effective for identifying problems and closing gaps consistently. Forth, the “5S” methodology is used successfully to maintain a clean and organised working environment. The following section of the literature review discusses the concept of multifunctional teams.

2.5 MULTIFUNCTIONAL TEAMS

This section starts by differentiating two phenomena, namely multifunctional team and team work. According to Bicheno (2004:144) and Heizer and Render (2004:375), a multifunctional team consists of employees working together towards some common purpose whilst teamwork refers to an environment that creates and sustains relationships of trust, support, respect, interdependence and collaboration.

Some authors (Olivella et al., 2008:803; Santos et al., 2006:68; Karlsson and Ahlstrom, 1996:34) dwell on the perception that multifunctional teams are a salient feature and common concept of lean manufacturing and are best described as a group of employees that are organised along a cell-based part of the product flow and are able to perform many different tasks. This is known as cellular or flow manufacturing and is a type of process-based layout that allows material and parts to flow through the process steps in small batches or even a one-piece flow. Considering that multifunctional teams are arranged around families of similar products performing different functions within the cell, ReVelle (2002:187) claims that they take full responsibility for the production unit.

Various authors (Schroeder, 2007:403; Wallace, 2004:807; Sanchez and Perez, 2001:1437) maintain that multifunctional teams do not assume productive tasks only but also indirect functions such as quality control, maintenance and material handling. With multifunctional teams accepting more responsibility, indirect departments and indirect costs are consequently reduced. This is beneficial to the organisation and is another key concept of lean manufacturing.

Employees within these teams are subjected to frequent job rotation which enables them to learn and acquire extensive skills and knowledge for various functions within the organisation. Most commonly, Chase et al. (2006:435) and Womack and Jones (1996:122) comment that multi-skilling and job rotation makes use of each employee’s skills. According to Santos et al. (2006:69-70), this is a good strategy to maintain the multi-functionality of employees since it reduces work-related accidents, improves relationships among employees and enhances knowledge sharing. Since workforce optimisation is another tool that is essential in the lean philosophy, multifunctional teams make it possible to use available employees.

It is important to note that all team members of multifunctional teams should be properly trained in the different functions such as quality control, maintenance and material handling to become multi-skilled. In this setting, Sanchez and Perez (2001:1437) argue that team members should not resist performing the increased number of tasks that are required. The ultimate goal of training programs is that it creates a comfortable learning environment which promotes the self-improvement of other employees (Santos et al., 2006:69).

Another popular view of multifunctional teams is that the organisation's dependence or reliance on specialised employees is eliminated through workforce flexibility. The authors (Comm, 2005:65; Sanchez and Perez, 2001:1447; Forza, 1996:53; Womack and Jones, 1996:60) concur that the production system will also not be sensitive to employees who are absent. Wallace (2004:803) reports that the introduction of multifunctional teams in Swedish organisations was used as a strategy in response to the increasing levels of absenteeism and labour turnover.

Creating multifunctional teams requires a thorough understanding of the core principles of lean manufacturing and a change in leadership style. According to Bicheno (2004:144), creating a team is easy but establishing an environment for team working is a lot more difficult. It usually takes two years for a team to evolve into full self-directed status, and in the beginning there may well be a drop in productivity as the team becomes fully functional. Olivella et al. (2008:803) point out that team members should have good interpersonal skills as it is critical to the success of the team. Furthermore, Wallace (2004:803) contemplates that the success of teamwork involves the unique ways in which they are implemented, used, developed and the experience of them interchanged between different units in the organisation. Management support is necessary to resolve conflicts due to tension that may arise from differing points of view within the team and to help the team to grow and to deepen their knowledge as they learn to work together.

Since it is important to assess the performance of multifunctional teams, Forza (1996:46) is of the opinion that the performance should be evaluated in terms of the output of the entire team rather than an individual employee from the team. This view is contradicted by Liker (2004:185) who suggests that teams do not conduct value-added work but individuals do. Teams co-ordinate the work, motivate and learn from each other; however, the expert is the employee nearest to the actual job.

Despite the potential difficulties, the following authors (Lee and Peccei, 2008:10; Khan et al., 2007:356; Comm and Mathaisel, 2005:136; Wallace, 2004:813) share similar views: that multifunctional teams play a vital role in decision-making changes as it makes employees personally invested in continuously improving quality and productivity. Since more responsibility is given to team members, process improvements and problem-solving are identified and resolved at an early stage closer to the source, which improves performance (Bicheno, 2004:155; Niepce and Molleman, 1996:82; Forza, 1996:48).

Although the various authors are in agreement on the principles and benefits of multifunctional teams, the views of Olivella et al. (2008:803), Wallace (2004:803) and Bicheno (2004:144) stand out in that they specify special requirements for establishing the correct multifunctional teams. It would appear that establishing the correct team is the main barrier to overcome. This is the underlying reason that selected competent employees are chosen and put together to form multifunctional teams. The point to understand is that the organisation cannot randomly select employees to form multifunctional teams. The positive views suggest that organisations should focus on team work rather than individuals working independently. The following section discusses the concept of zero defects.

2.6 ZERO DEFECTS

In this section the problems related to quality and preventing defects are presented. The concept of zero defects is a way of thinking and doing production tasks right the first time without manufacturing defects. It is a philosophy that increases profits by eliminating the cost of failure and increasing revenues through increased customer satisfaction. According to Karlsson and Ahlstrom (1996:30), an organisation that operates with zero defects indicates that the organisation works lean towards attaining quality. Lean organisations work towards greater process control and strive towards keeping the processes under control instead of controlling the part produced. Wu (2003:1353) advocates that lean places strong emphasis on problem detection and problem solving.

The increasingly volatile manufacturing environment has made it imperative that management commits to achieving zero defects and investing in employees skills. According to Lee and Peccei (2008:5) and ReVelle (2002:183), management should provide the necessary training in visual inspection techniques, statistical tools and quality principles to secure a competitive advantage on the shop floor for achieving high quality work. Lee and Peccei (2008:11), Chase et al. (2006:474), Liker (2004:129), ReVelle (2002:183), Sanchez and Perez (2001:1436) and Karlsson and Ahlstrom (1996:30) are in agreement that in most cases, the production line employees are responsible for identifying and adjusting defects in order to maintain a smooth flow of production.

Liker (2004:129) is of the opinion that the built-in quality created by Autonomation ensures automatic devices are used to stop production so that employees can fix the problem before proceeding downstream. "Autonomation" is a term that refers to equipment endowed with human intelligence to stop production when a defect is detected (Liker, 2004:129-130; Womack and Jones, 1996:231). Furthermore, Liker (2004:130) confirms that another salient feature of maintaining zero defects is the term "Andon" which refers to light signal for "help". When in operation, the light signal, accompanied by an alarm, indicates that there is a quality defect at a specific work centre and help is needed urgently to solve the problem.

As a reference source, Santos et al. (2006:76) and Chase et al. (2006:333) reveal that in challenging the concept of zero defects, Shigeo Shingo proposed the use of Poka-Yoke devices and "self inspection" so that the focus of inspection moves away from detection to prevention. Poka-Yoke is a Japanese term that means "fail-safing" or “mistake-proofing”. In application, Bicheno (2004:138) documents that the aim of Poka-Yoke is to design devices that prevent defects moving to the next stage of production. In addition, Santos et al. (2006:81) suggest that Poka-Yoke devices should be designed in such a way that they are ingenious, simple and cheap. In the lean philosophy, this tool is considered one of the pillars for improving overall equipment efficiency. The “self inspection” method proposed by Shingo could result in employees making subjective judgments and accepting items that should be rejected. Consequently, Santos et al. (2006:78) corroborate that these inspection errors could be made unintentionally. It is also important to note that “self inspection” provides the most immediate feedback. This is necessary to maintain the smooth flow of production without interruptions.

Liker (2004:130) suggests that solving quality problems at the source saves time and money because it identifies, fixes and eliminates defects. According to Olivella et al. (2008:800-802), employees should have a high degree of influence and a great body of knowledge to solve problems and develop improvements since they witness production events first hand. Employees usually strengthen their knowledge from previous encounters and continuous training accompanied with experience.

Lean manufacturing emphasises that quality control should be applied to all levels in an organisation since employees are responsible for the manufacture of products and influence the quality of these products. Lee and Peccei (2008:5) explain that the traditional organisational perspective requires specialists to be responsible for product quality. This has changed over the years in best practice organisations where employees on the shop floor have taken the responsibility for quality improvement. The lean manufacturing settings rely on the entire organisation from top management to shop floor employees to manage and control quality.

This section reviewed the concepts of maintaining zero defects to produce quality products. The views of the various authors have many similarities where the ultimate goal of maintaining zero defects is to ensure that there is a smooth flow of production. Further to the views of Lee and Peccei (2008:5), it is important to note that everyone in the organisation is responsible for quality. The JIT methodology is discussed in the following section.

2.7 JUST-IN-TIME

The JIT concept was envisioned by Taichi Ohno at Toyota in the 1950's as a method for facilitating smooth flow (Womack and Jones, 1996:58). According to Cooney (2002:1132), JIT is central to the lean manufacturing concept as it drives the use of visual factory controls, continuous improvement activities and the delegation of enhanced responsibilities to the front line employees. In addition, Schroeder (2007:394) and Rawabdeh (2005:802) advise that the aim of JIT is the systematic allocation and reduction of wasteful practices at all levels of an organisation to improve profits and return on investment.

Santos et al. (2006:5) notes that the Japanese refer to the principle of JIT as parts that arrive exactly at the appointed time. Bayraktar et al. (2007:849), Chase et al. (2006:474), Sanchez and Perez (2001:1437) and Karlsson and Ahlstrom (1996:32) are in agreement that in the production environment JIT simply means providing the required part, in the correct quantity, at the exact point in time. It can be seen as a "hand-to-mouth" operation with production and delivery quantities approaching one single unit. This means that only one component will move to the next operation when required at the correct time.

Schroeder (2007:396), Heizer and Render (2004:609) and Karlsson and Ahlstrom (1996:32) perceive that JIT is closely related to zero defects since the parts that arrive at the process needs to be fault free to achieve the sequential flow. Dahlgaard and Dahlgaard-Park (2006:265) stipulate that JIT is not an easy task to implement, especially if the system often produces defects. A small defective part can stop the entire production system. Therefore, Naslund (2008:275) supports the claim that JIT reduces Muda such as wasted space, over-production and defects by exposing hidden problems in inventory at the source. Since JIT keeps inventory to a minimum, problems that arise are more easily noticeable. The aim of JIT is to provide one part at a time when needed and this can be achieved through reduction in lot sizes, buffer sizes and order lead time (Schroeder, 2007:411; Chase et al., 2006:474; Heizer and Render, 2004:605; Sanchez and Perez, 2001:1438).

Karlsson and Ahlstrom (1996:33) observe three different levels of JIT which are characterised by parts moving between different processes in lots, product variants and sequential JIT. The sequential JIT level signifies that parts will arrive on the line with reference to the individual products and this can also vary depending on the nature of products.

According to Sanchez and Perez (2001:1437-1438), the practice of JIT is widely adopted among first tier suppliers in the automotive industry. The degree of integration between the suppliers' delivery program and an organisation's product line should be properly co-ordinated and structured such that the supplier delivers parts in the same sequence as parts that are manufactured internally and moved between processes.

Under changing conditions, Liker (2004:23-24) establishes that JIT allows the organisation to be responsive for day to day shifts in customer demand. Since JIT works off a "pull system", the preceding process should comply with specifications otherwise JIT will not work. Domingo, Alvarez, Pena and Calvo (2007:141) encourage that it is also important to acknowledge that the flow of material from each workstation depends on production conditions and characteristics of each workspace. In ideal conditions, Liker (2004:37) recommends that when material replenishment is initiated by consumption, the organisation will achieve a smooth flow and an ideal JIT situation. Similarly, Zylstra (2006:91) confirms that speed and consistency of replenishments enables inventory to flow to the place required at the correct time much faster. The lean manufacturing approach requires linking replenishments directly to shipment of customer orders using the "pull system".

Furthermore, Zylstra (2006:91) urges that lean manufacturing allows replenishments to occur with little oversight while planners focus primarily on managing the overall process. In this approach, Zylstra (2006:198) further concludes that planners should spend less time on replenishment orders and more time updating and managing the parameters and methods used in triggering replenishments. Ideally, replenishments and service will improve by focusing more on variability. The key ingredient in controlling buffers entails adjusting the inventory target level and replenishing process parameters in order to maintain expected customer service levels.

Summers and Scherpereel (2008:1302) indicate that a traditional MRP system controls production with plans whilst JIT builds control into the production system itself. On a further note, Schroeder (2007:407) and Stevenson (2005:618) contend that the MRP system is considered a system for batch production. Heizer and Render (2004:596-597) explain that it works on a "push system"; a system that pushes materials into downstream workstations regardless of their timeliness or availability of resources to perform the work.

On the other hand, the concept behind JIT is that of a "pull system"; a concept that results in material being produced only when requested and moved to where it is needed just as it is required. Summers and Scherpereel (2008:1303) demonstrate the following differences between a traditional MRP and a JIT system in Figure 2.7 and how it affects decision making in production.

Distinction	MRP	JIT
1	Seek perfection	Seek consistency
2	Control system from the outside	Control system from the inside
3	Plan and then push decisions into the system	Allow system to show where and when decisions are needed
4	Explicitly model decision situations	Guide decisions with rules, tools, and policies built into the system
5	Give decision makers many "degrees of freedom"	Constrain decision making
6	Adjust to problems	Eliminate problems
7	Embrace complexity	Seek simplicity

Figure 2.7 – Differences between MRP and JIT in decision making (Adapted from Summers and Scherpereel, 2008:1303)

Reviewing the seven differences presented in Figure 2.7, there is significant evidence indicating that the JIT system was developed in direct opposition to the MRP system. Wu (2003:1353) mentions that good housekeeping is a basic discipline for JIT. According to Fullerton and Wempe (2009:216), several studies indicate that employee involvement is a critical element for the successful adoption of JIT. In addition, Bayraktar et al. (2007:849) summarise that JIT attempts to create a self-disciplined simplicity in the work environment which allows employees to know exactly their tasks under each circumstance. Sharing similar views as Fullerton and Wempe (2009:216), Bayraktar et al. (2007:849) explain that employees are the main drivers of a manufacturing system under the JIT philosophy. In essence, employee involvement is a prerequisite of many other efforts with the collaboration of JIT.

Pettersen (2009:134) is of the opinion that JIT is assumed to reduce cost and highlight problems by reducing resources in the system. One of the main principles of JIT is questioning everything in the system such as labour forces, processes and the entire organisation. Meybodi (2009:90) asserts that JIT is not restricted to the production environment but can also be utilised in the service industry. Since there is no physical inventory in the service industry, the JIT concepts such as waste elimination and respecting people will apply.

Meybodi (2009:99-100) draws on previous research to suggest that JIT enables better alignment between organisational goals and objectives and proactive development of core competencies. While traditional organisations places higher emphasis on price, JIT organisations emphasise the elements of time-based competition. There is also a better balance between the importance of competitive priorities and the strength of organisational core competencies. Consequently, the modes of application for JIT are focusing on manufacturing re-organisation, linking manufacturing strategy into corporate strategy, developing collaborative supply chain, and integrating information systems into the supply chains.

The JIT concept is the core of Japanese production management and productivity improvement. In the JIT-based operation, day-to-day activities are driven by continuously replenishing the “customer-demand-driven” finished goods inventory targets. Just-in-time enhances radical inventory reduction, reduces system variation and provides usefulness of supplier relationships to improve quality and controls the flow of work. The ideal situation in JIT, according to Rawabdeh (2005:801), is for all materials to be actively in use as elements of work are in progress and never at rest collecting unnecessary storage costs. It is clear from the literature presented above that the JIT concept controls the entire supply chain from the customer to the supplier.

Fullerton and Wempe (2009:216) and Bayraktar et al. (2007:849) highlight that the employees are the main drivers to ensure the success of JIT. Furthermore, the authors in this section also indicate that when it comes to its core operations, JIT is the main driver to eliminate waste from production. Perhaps it can be suggested that JIT is the heart of lean manufacturing. In the next section, the concept of vertical information systems is discussed.

2.8 VERTICAL INFORMATION SYSTEMS

This section examines how important information is filtered through to the employees in production. Womack and Jones (1996:26) declare that transparency is the most important spur to perfection in a lean organisation. In addition, they stress that when important information is transparent and continuously provided to employees at all levels of the organisation, it allows them to discover better ways to create value.

In view of the content of information that should be filtered through to the employees, Lee-Mortimer (2006:270), Comm and Mathaisel (2005:137), Sanchez and Perez (2001:1440) and Karlsson and Ahlstrom (1996:38-39) believe that it should be in the form of a strategic type as well as operational type which includes internal business processes and external outcomes. The organisation's market plans, production plans and financial performance refers to the information of a more strategic type, while the organisation's performance on productivity, timeliness and quality refers to the information of a more operational type. In addition, management should have a clear understanding of how and when to communicate important information to the employees. The objective is to continuously provide information on time. According to Forza (1996:47), information gathered during inspections and audits should also be immediately distributed to employees to enable them to facilitate immediate intervention and corrective action.

The two most commonly used modes of providing information, according to Karlsson and Ahlstrom (1996:39), are classified as verbal or written. In general, verbally presented information allows the employees to comment and clarify any misunderstandings. On the other hand, written information is usually documented and displayed in dedicated spaces. A common tool used for displaying information is visual management. Bicheno (2004:61) reiterates that visual management complements other lean themes such as speed, improvement, up to date and clear schedules, making problems apparent, involvement, team working, standardisation and responsiveness.

Lee-Mortimer (2006:270) concurs with Bicheno (2004:61) and asserts that visual management, also known as “Gembi Kanri”, enables employees to identify and to resolve specific problems faster. On the basis of this relationship, Motwani (2003:342) proclaims that open communication and information sharing promotes an organisation’s culture and innovative behaviour. Therefore, Comm and Mathaisel (2005:136) strongly recommend that any change that occurs in an organisation should be properly explained to the employees. In a similar light, Lee and Peccei (2008:11) propose that when important information is shared and filtered to employees, it allows them to exchange knowledge, experiences and skills to perform their tasks better and also assists them in addressing problems and defects.

It is the responsibility of the organisation’s leadership to develop an environment in which it constantly provides information to the employees and encourages the same from them (Comm and Mathaisel, 2005:136). The critical success factor to any business process change, according to Naslund (2008:269) and Schroeder (2007:412), involves top management support and the communication of information.

This section reviewed the flow and type of information that should be provided to employees. All authors mentioned in this section are in agreement that important information should be constantly provided timeously to the employees in production. The views of Motwani (2003:342) are important in that it signifies an organisation’s true culture and commitment to its employees by filtering information. The following section of the literature review discusses the principles of decentralised responsibilities.

2.9 DECENTRALISED RESPONSIBILITIES

This section examines the views on allocating responsibilities to employees in production. It also discusses the reduction of middle management functions within lean manufacturing organisations. In terms of theory, decentralisation is the process of transferring and assigning decision-making authority to lower levels of an organisational hierarchy (Karlsson and Ahlstrom, 1996:36). The lean thinking concept abolishes the employee’s focus away from hierarchy such as departmental roles and responsibilities. Comm and Mathaisel (2005:135) maintain that this is usually achieved by remaining focused on the customer and on the core competencies that they value from an organisation such as higher education.

According to Marsh and Blau (2007:202), managers generally serve as facilitators in lean organisations. In addition, Sanchez and Perez (2001:1437) and Karlsson and Ahlstrom (1996:36) articulate that there is also no supervisory level in the hierarchy since responsibilities are decentralised onto employees and teams. Consequently, supervisory tasks are performed by multifunctional teams which are usually accomplished by rotating team leadership among employees that have been trained for the task. Olivella et al. (2008:804) posit that the leadership style moves away from hierarchical superiority and places emphasis on suggestions and planned discussions among the employees.

There is no precise delimitation for job responsibilities and employees are encouraged to participate in making decisions concerning production, quality, maintenance and planning (Olivella et al., 2008:804; Chase et al., 2006:474; Forza, 1996:44). As a useful strategy, Forza (1996:53) recommends that decentralisation of authority should be more reactive, thereby making it possible to handle uncertainty and to improve efficiency of the decision-making process. In a similar abstract, ReVelle (2002:190) establishes that the consensus decision-making puts horizontal control on the decentralised decision-making process to ensure that all the elements work together to make the lean manufacturing system effective. As an interesting and important point, Olivella et al. (2008:804) argue that employees should have real influence and power when they participate in decision making instead of serving as consultants only.

According to Summers and Scherpereel (2008:1302), the Kanban system automatically requires employees to co-ordinate production and manage the flow of work and inventory. Furthermore, Comm (2005:65) reflects that decentralising responsibilities to employees reduces time wasted in processing documents. Similarly, Fullerton and Wempe (2009:216) propose that since there is no excess inventory or other buffers available to counter production or quality failures in lean manufacturing settings, employees should have the ability and authority to make responsible decisions. Apart from being given more responsibilities, Comm and Mathaisel (2005:136) suggest that when employees are given permission and tools to make changes in processes, they should also be appropriately recognised for their initiatives. Employees that are given ownership of their own work area are able to make significant decisions about their workplace (Bateman, 2005:269). However, decisions that affect the cell should be done by the entire team.

By delegating functions intuitively, respectfully and appropriately, Olivella et al. (2008:804) claim that it empowers teams and employees to take considerable responsibilities. Under these circumstances, Marsh and Blau (2007:204) and Heizer and Render (2004:609) believe that empowerment means giving employees greater control over the process and respecting their opinions. Finally, Wallace (2004:812) contends that the amount of responsibility an organisation will decentralise onto employees or work teams depends on the strength and knowledge of the team.

A review of the above section shows that there is significant evidence indicating that lean manufacturing places more responsibility on to employees on the shop floor. Due to the critical aspect of leadership, the views of Wallace (2004:812) indicate that responsibilities cannot be allocated to employees if they are not capable. Therefore, it can be suggested that organisations should provide the necessary training to ensure employees are capable of taking on more responsibilities. The concept of integrated functions is presented in the following section of the literature review.

2.10 INTEGRATED FUNCTIONS

This section explains the principle of employees, who are able to perform many different tasks in production. The lean philosophy makes optimal use of employees' skills, thereby reducing indirect departments. According to Comm (2005:64), Karlsson and Ahlstrom (1996:37) and Forza (1996:48), tasks previously performed by indirect departments are integrated into the functions of multifunctional teams. Support functions such as the quality department in traditional production systems are reduced as lean manufacturing systems revolutionalise these functions through the integration of job responsibilities to employees on the shop floor. Forza (1996:46) broadens the debate that integrating functions enable positions to be exchanged within the work group and drive employees within the group to assist each other in moments of difficulty. Most commonly in application, Niepce and Molleman (1996:82) contest that employees are not limited to be rotated within the teams only; they can also be moved to different departments when required.

The work content of multifunctional teams increases substantially and results in job enlargement for the production line employees. Tasks such as procurement, material handling, planning, maintenance and quality control are integrated into the team's tasks (Schroeder, 2007:403; Lee and Allwood, 2003:1379; Karlsson and Ahlstrom, 1996:37). Related to this, the following authors (Lee and Peccei, 2008:10; Summers and Scherpereel, 2008:1302; Chase et al., 2006:474) believe that task autonomy enables employees to apply their skills in quality improvement and stops production when problems are encountered. Lee and Peccei (2008:9) expand on their view and mention that employees are also able to perform tasks that are challenging and fulfilling collaborately. The different levels of integrated functions, according to Bhuiyan and Baghel (2005:767), promote the culture of continuous improvement into daily activities of employees.

Schroeder (2007:404) stipulates that increased job responsibility and job enlargement should be compensated for accordingly by means of a proper remuneration system. In a similar contribution to Schroeder (2007:404), Forza (1996:49) postulates that employee loyalty and commitment is significantly influenced by the salary structure, reward system and appraisal schemes.

Sufficient training should be provided for the additional tasks and at the same time the potential employees should overcome resistance for the number of tasks they would perform (Sanchez and Perez, 2001:1433). As long as organisations provide proper training, Comm and Mathaisel (2005:136) and Bicheno (2004:55) articulate that it allows employees to understand their process as well as the processes before and after in the product flow. Similarly, Olivella et al. (2008:804) advocate that by multi-skilling employees, it enables more flexibility between operations and facilitates, learning and continuous improvement. Training should be well structured and documented on a relevant skills matrix. The skills matrix is a document that contains records of employees' training and skills. In practice, Khan et al. (2007:356) proclaim that the organisation should adhere to the skills matrix to ensure flexibility among employees.

As a matter of interest, Bicheno (2004:55) further alleges that employees at Toyota document their own work standards, learn a wider range of tasks and take greater responsibilities for supporting tasks. This eliminates employees' misconception of work standards and it also forces employees to think of the best way in which he or she should do the work within the "takt" time. Takt is a German word for rythym or meter and is best described as the rate of customer demand. It is a measure of the rate at which the customer purchases the product (Liker, 2004:94).

Olivella et al. (2008:800) do not agree with Bicheno (2004:55) and are adamant that employees' who perform tasks in their own way, as opposed to standardised methods, make it difficult for quality analysis, flow stabilisation calculations and task rotation. Virtually, standardised work methods ensure more flexibility and uniformity for each operation. Employees will consistently produce the same level of quality. It appears from the above literature that lean manufacturing aims to utilise the maximum capabilities of the employees.

The views of certain authors in this section concur that increased job responsibilities promote job enrichment which could benefit the organisation in response to problems of low motivation and absenteeism. The positive views also highlight improved job satisfaction and dedication of employees. In contending the success of this principle, the various authors indicate that sufficient training should be provided to achieve maximum benefits for the employees and the organisation. The last principle, "pull instead of push", is presented in the following section of the literature review.

2.11 PULL INSTEAD OF PUSH

This section presents the production planning system that is required to maintain costs at a minimum. It also includes a subsection that discusses the main tool that is used for the "pull" approach to function accordingly.

A "pull system", according to Womack and Jones (1996:67), means that no one upstream should produce a part or service until the customer downstream requests for it. In this approach, Zylstra (2006:186) contends that the "pull" method synchronises the upstream flow to actual demand and initiates replenishments to the consumption point.

In comparison to the traditional “push system”, Liker (2004:105-108) highlights that the purest form of “pull” is one-piece flow and is the ideal state of JIT manufacturing. Since the “pull system” corresponds with actual usage or consumption, lean organisations should constantly work towards achieving JIT replenishment. Furthermore, Zylstra (2006:86-87) states that lean manufacturing focuses on replenishing based on actual demand or consumption which allows a customer order shipment to “pull” its replenishment behind it. The inventory level in the warehouse is determined by the replenishment frequency and customer demand variation. Fixing and shortening replenishment cycles reduces inventory and simplifies replenishment orders.

According to ReVelle (2002:179), a proper management structure should first define the value system and then support the employees (value-adding agents) in order for a “pull system” to function successfully. A well-functioning “pull system” should work in tandem with several other lean manufacturing strategies. For example, small lot quantities is a key technique used in “pull systems” to ensure that quality problems are detected well before large batches of defective parts are produced. Dahlgaard and Dahlgaard-Park (2006:274) insist that an organisation needs to have profound knowledge about systems and manufacturing psychology to successfully implement flow and “pull”. This is needed to optimise the production system correctly and to build efficient partnerships which can survive in the long term.

The “pull” strategy should be extended to all production processes that are linked within the organisation and the value chain. Zylstra (2006:86) considers that applying lean to the entire distribution environment results in lower total costs, lower working capital and improves customer service. It simplifies the critical aspects of the distribution chain such that the entire network operates more effectively.

The “push” scheduling system still has its place in lean organisations, especially where suppliers need sufficient lead time. In that respect, Liker (2004:110) argues that the goal is to make lead times as short as possible; for example, ordering parts daily instead of monthly. Although lean manufacturing systems moves operations away from relying on forecasts to make actual demands, forecasts are still a critical component of lean planning processes, but are leveraged for longer terms and requires more aggregate planning (Zylstra, 2006:85). According to Summers and Scherpereel (2008:1302), a traditional “push system” plans the behaviour of the production system whereas a “pull system” responds to the behaviour of the production system. In its simplest term, Taj (2005:632) states that “pull” means “make to order” while “push” means “make to stock”.

The “pull” approach completes the linkage by leveraging operating capabilities to meet customer demand and is the final link between customer requirements, internal operations and suppliers. Zylstra (2006:185) stresses that the information which is required for “pull” is demand and should not be confused with sales and shipments since demand data relates to actual consumption of product rather than interim shipment or transfer. In its original form, Schroeder (2007:399) and Bhasin and Burcher (2006:57) detail a prerequisite for “pull” in JIT production to perform smoothly is the Kanban system. An explanation of the Kanban system is provided in the next sub-section.

2.11.1 KANBAN

“Kanban” is a Japanese term that refers to signal card. It is a system that triggers production and service processes such that employees have the correct part, when it is required, and in the correct quantity. This is accomplished by using an array of simple visual signals, such as the presence or absence of a part on a shelf, colour coded bins, cards and flags. Noting the factors mentioned, the views of Papadopoulou and Ozbayrak (2005:786) and Bicheno (2004:107) concur with Schroeder (2007:399) and Bhasin and Burcher (2006:57) in that the Kanban concept is the classical signalling device for production “pull systems”.

Information such as product name, part code, card number, batch number, lot size and due date are displayed on Kanban cards for specific WIP containers or batches. The Kanban card signals when to refill goods that are removed from a stocking location, or when a sub-assembly has been used. After a certain quantity is used, the Kanban signal is returned upstream to the supplying process, thereby signalling replenishment.

According to ReVelle (2002:180), there are three types of Kanban cards that are used in a Kanban system. These are:

- "Withdrawal Kanban" – Authorises a process to get parts from the previous process
- "Production Kanban" – Authorises the previous process to produce more parts
- "Supplier Kanban" – Authorises an outside supplier to deliver more parts

A single card Kanban operates between each pair of workstations. In most applications, Bicheno (2004:107) specifies that although there may be several single card Kanbans in a loop between a pair of workstations, each Kanban is the authorisation to both make a part or container of parts and to move it to a specified location. It works as a "push system" for production coupled with a "pull system" for deliveries. The dual card Kanban uses both production and withdrawal Kanban cards. It should be emphasised that Chase et al. (2006:477) and Bicheno (2004:109) maintain that production Kanbans usually stay at a particular work centre and alternate from Kanban board to finished goods container.

An organisation that produces parts using common processes benefits most from Kanban systems. Ideally, Kanban systems are used mainly for repetitive manufacturing and are not applicable to once-off production based on non-frequent and unpredictable orders (Schroeder, 2007:394). According to Lee-Mortimer (2008:104), the benefits of Kanban provides opportunities such as visibility and control; operator empowerment regarding production-related decisions; improvement of communication across the work centres; reduction in manufacturing lead time; faster response to changing demand; and analysis of production history regarding capacity constraints, over-production and delivery failures.

Overall, Zylstra (2006:196) is of the opinion that a "pull system" requires sufficient inventory to meet customer service lead times and buffer against variation. Typically, this means that Kanban systems are used to control inventory by having the correct amount of stock, ready to be shipped when the customer needs the product.

There is consensus from the various authors where organisations that manufacture towards customer demands eliminate the need for forecasting. Due to the fact that it is impossible to determine accurate customer orders, production based on forecasts regulates the inventory level. The goal is to manufacture products only when an actual order is received from the customer. The views of Liker (2004:105) indicate that "pull systems" are required to achieve JIT production. Similarly, the views of Schroeder (2007:399), Bhasin and Burcher (2006:57), Papadopoulou and Ozbayrak (2005:786) and Bicheno (2004:107) substantiate that Kanban systems are necessary to achieve optimum "pull" production.

In the previous sections, the background and main principles of lean manufacturing were presented. The literature review now moves on to show some criticisms, success factors and current state of organisations that claim to have adopted lean manufacturing in the following sections.

2.12 STRENGTHS AND WEAKNESSES OF LEAN

Cooney (2002:1144) declares that lean manufacturing cannot be viewed as a universal applicable system as there are inherent limitations of the model that cannot account for the range of circumstances faced by organisations. Since lean manufacturing is dependent upon a range of conditions being met and if these conditions cannot be achieved due to business conditions, then batch or mass flow may be a more practical form of manufacturing.

According to Andersson, Eriksson and Tortensson (2006:289), lean principles are not effective or cannot be applied when customer demand is unstable and unpredictable. The central focus on perfection for particular market demands cannot work in highly dynamic conditions. To a great extent, Sanchez and Perez (2001:1449) broaden the debate where smaller organisations find it difficult and expensive to implement some of the lean manufacturing practices such as flexible information systems or JIT production. The views of Andersson et al. (2006:290) concur with Sanchez and Perez (2001:1449) and state that lean manufacturing reduces flexibility, causes congestion in the supply chain and is not applicable to all industries. Hines, Holweg and Rich (2004:999) draw on previous research to cite the following criticisms of lean manufacturing over the years as exemplified in Figure 2.8:

	1980-1990	1990-mid 1990	Mid 1990-1999	2000+
Key gaps	Outside shop-floor Inter-company aspects Systemic thinking Auto assembly only	Mainly auto Human resources, exploitation of workers Supply chain aspects System dynamics aspects	Coping with variability Integration of processes Inter-company relationships Still mainly auto Integrating industries	Global aspects Understanding customer value Low volume industries Strategic integration E-business
Main critics	Carlisle and Parker (1989) Fucini and Fucini (1990)	Williams *et al.* (1992) Garrahan and Stewart (1992) Rineheart *et al.* (1993)	Davidow and Malone (1992) Cusumano (1994) Goldman *et al.* (1995) Harrison *et al.* (1999) Suri (1999) Schonberger and Knod (1997)	Bateman (2000) Christopher and Towill (2001) van Hoek *et al.* (2001)

Figure 2.8 – The main gaps and criticisms of lean thinking (Adapted from Hines et al., 2004:999)

Although the majority of the literature in the previous sections focus on the strengths of lean manufacturing, it is evident from Figure 2.8 that there are significant weaknesses in the system. These weaknesses were identified by the various authors over the years. Pettersen (2009:134) argues that all the existing literature on Autonomation and Poka-Yoke indicates that employees cannot be trusted to produce quality goods. There is a need to remove the possibility of human error from the system. In addition to the human aspect, Hines et al. (2004:998) contest that lean manufacturing could be viewed through a Marxist lens as being exploitive and inducing high pressure to employees on the shop floor.

It can be inferred from the above observations that lean manufacturing is not applicable to all industries. At the same time, the views of Pettersen (2009:134) indicate that lean manufacturing questions the levels of trust in employees. On the contrary, research findings in the previous sections highlight that lean manufacturing considers employees as the most valuable asset in the organisation. As mentioned previously in section 2.5, the views of Santos et al. (2006:76) and Chase et al. (2006:333) are that the concept of Poka-Yoke was created so that the focus of inspection moves away from detection to prevention. The following section discusses the critical factors that are needed for becoming a successful lean manufacturing organisation.

2.13 LEAN SUCCESS FACTORS

This section examines the methods of developing a successful lean manufacturing organisation. This is followed by the two critical success factors, namely, cultural transformation and value stream mapping, in the following subsections.

The first step, as highlighted by Lee-Mortimer (2006:265) and Meier and Forrester (2002:108) is to understand that the benefits of lean manufacturing are only noticeable in the long term and do not solve short-term competitive problems. The core of this concept, according to Bhasin and Burcher (2006:56), is that lean manufacturing should be viewed as a philosophy rather than a set of tools and techniques. Taken together, Bendell (2006:257), Papadopoulou and Ozbayrak (2005:784) and Emiliani and Stec (2005:377) claim that lean manufacturing is constantly undergoing a process of continuous and never-ending evolution which has been the focal point for organisations over the years.

2.13.1 CULTURAL TRANSFORMATION

Successful lean manufacturing implementations involve cultural changes in organisations, new approaches to product, satisfying customer requirements, and a high degree of training and education of employees from upper management to the shop floor (Sim and Rogers, 2009:39; Bhasin and Burcher, 2006:58; Comm, 2005:71; Emiliani and Stec, 2005:384; Emiliani and Stec, 2004:630; Lee and Allwood, 2003:1379). In addition, Hines et al. (2004:1006-1007) describe the existence of lean manufacturing at a strategic and operational level. The strategic level revolves around the customer while the techniques and tools apply to the operational level. Lean thinking at a strategic level and lean production at an operational level are crucial to understand the entire lean manufacturing concept of providing customer value.

Fullerton and Wempe (2009:231) conclude that shop floor employee involvement is critical to the successful adoption of lean manufacturing which requires management support and communication (Worley and Doolen, 2006:243). Dahlgaard and Dahlgaard-Park (2006:279) argue that many lean manufacturing implementations focus primarily in training employees in tools and techniques rather than understanding the human factor and building the correct culture. Lee and Allwood (2003:1379), Emiliani (2006:178) and Emiliani and Stec (2005:374) concur with Dahlgaard and Dahlgaard-Park (2006:279) and believe that the “respect for people” principle is commonly ignored. Perhaps this is the underlying reason that organisations sometimes find it difficult to successfully adopt lean manufacturing transformation.

2.13.2 VALUE STREAM MAPPING

Comm (2005:71) believes that lean manufacturing requires a total transformation which includes scrapping of existing inefficient processes and transforming them into value-added activities to deliver to customers. Sharing similar views, Bendell (2006:260) and Hines et al. (2006:873) contend that a natural starting point for any business process improvement in any organisation includes simple process thinking and mapping. The value stream mapping tool is a network of steps from the beginning to the end of the entire production process. Schroeder (2007:409) and Chase et al. (2006:473) claim that it represents material and information flow by identifying waste in the current production process and specifies methods for improving the entire value stream processes from the customers’ perspective. Essentially, analysis of the current state value maps depicts the existing way in which material and information is processed. According to Emiliani and Stec (2004:623), a future state value map depicts an upgraded condition that incorporates planned improvements for the entire value stream processes.

Lasa, Laburu and Vila (2008:50) demonstrate how value stream mapping proved to be a suitable tool for redesigning production systems from their study conducted at a plastic manufacturing organisation. Similarly, Taj and Berro (2006:344) report in their study at an automotive manufacturer that simply applying streamlining principles and organising teams with authority to improve local workflows produces results within three weeks to two months.

In practice, Chase et al. (2006:473) highlight that the main drivers for the success of value stream principles are: keeping the value streams moving at maximum speed; eliminating waste that stops, slows down, or diverts the value stream; concentrating on removing waste rather than speeding up value-adding operations and looking for waste in the factory, office, physical, procedural, and technical operations. Finally, Santos et al. (2006:4) report that the key to Japanese success over the years can be attributed to simple improvement methodologies, employee involvement, respect and teamwork.

During the review of existing literature, it appears that the main barriers to lean manufacturing are management support, communication, long term strategy, sustainability and organisational culture. The views of Fullerton and Wempe (2009:231) and Santos et al. (2006:4) reveal, in particular, that employee involvement at all levels in an organisation ensures success in lean manufacturing. In conclusion, since lean implementation involves a total business process change, organisations cannot implement lean manufacturing directly to their system by simply practicing lean activities (Motwani, 2003:340). It is a system that requires a total change of the employee's mindset in the organisation. The point is that organisations should understand that employees are the key success to any business process change. The last section of the literature review presents the current status of organisations that claim to have adopted lean manufacturing, followed by the summary of this chapter.

2.14 CURRENT LEAN ORGANISATIONS

Despite the wide knowledge and available resources, many organisations are struggling to reap the maximum benefit of staying lean. Several authors have posited that lean manufacturing requires the organisation's management's total commitment to constantly invest in its employees and to promote a culture of continuous improvement.

Many organisations that have implemented lean manufacturing have mistaken a particular set of lean tools and techniques for deep "lean thinking". Liker (2004:12) reports that many organisations have a persistent trend in their inability to implement lean manufacturing where the lean production line degrades rather than improves over time. Lean manufacturing organisations have generally embraced lean tools but do not understand what makes them work together in a system. Furthermore, Liker (2004: 12) purports that his "4P model" in Figure 2.9 illustrates most organisations operating at the "Process" level.

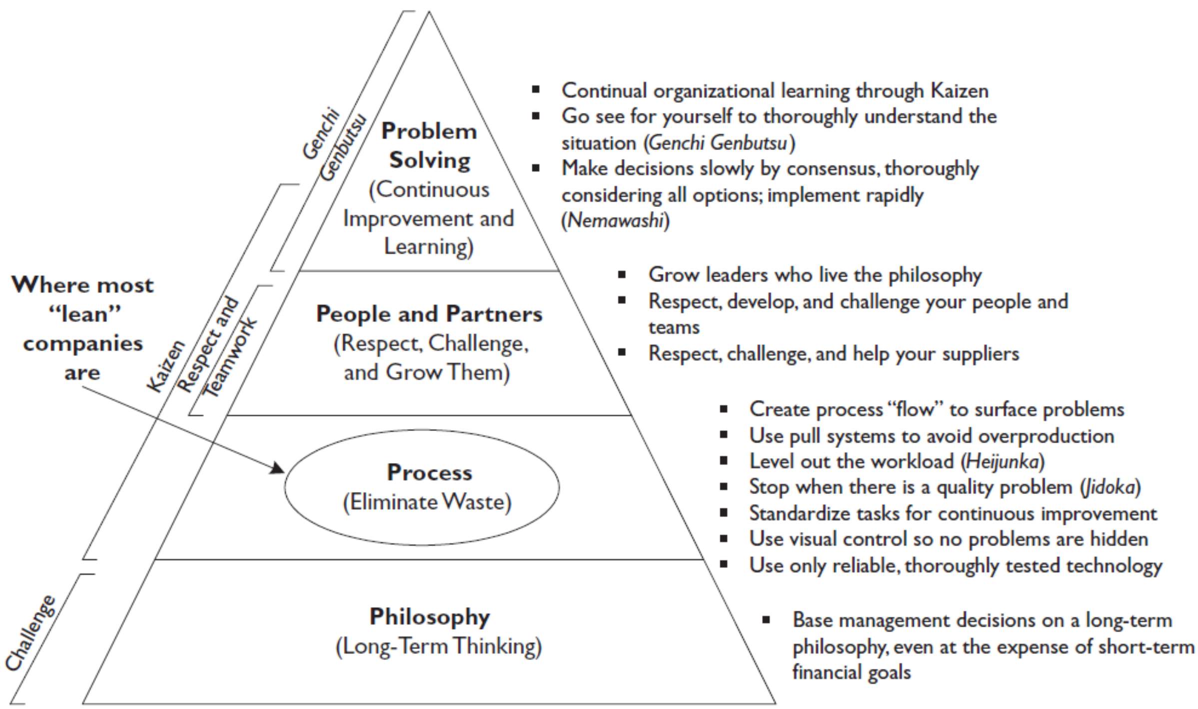


Figure 2.9 – The "4P" model and where most companies are (Adapted from Liker, 2004:13)

The failure of organisations to proceed beyond the process level signifies that the improvements they make will not have the heart and intelligence behind them to make them sustainable throughout the organisation. The other 3Ps in Figure 2.9 (Problem Solving, People and Partners, and Philosophy) are as equally important as the process level (Liker, 2004:13). According to Emiliani and Stec (2005:371) and Liker (2004:13) the performance level of lean organisations depends on the adoption of a true culture of continuous improvement. Emiliani (2006:178) postulates that it is imperative for managers to make greater efforts to understanding continuous improvement and respecting employees in order to achieve favourable financial and non-financial outcomes that benefit all key stakeholders.

In contrast to these findings, it is important to note that with a wide practice in many organisations and with the substantial benefits achieved, lean manufacturing has set the benchmark in production systems.

2.15 SUMMARY OF THE CHAPTER

From the literature, it is evident as to which elements should be included in simulations in order to make them valid in their characterisation of lean manufacturing. This chapter outlined the main determinants of lean manufacturing, followed by the critical success factors for achieving total lean transformation. It also dealt with various authors' perspectives on each of the determinants presented in this chapter. The concluding remarks reveal that lean manufacturing requires a total cultural change to achieve maximum benefits. The next chapter will outline the design of the research and the methodology used during this study.

CHAPTER 3

DESIGN OF RESEARCH AND METHODOLOGY

3.1 INTRODUCTION

This chapter illustrates, with the aid of a flow diagram, the research design and methodology followed in this project. The chapter presents the options and techniques available for conducting research and also demonstrates those selected for this study. It includes details of the questionnaire design, data collection techniques, target population group, sample size and credibility. The preliminary work and findings are also discussed, followed by the introduction of the main study.

3.2 RESEARCH DESIGN

The most common and useful purpose of research, according to Babbie and Mouton (2001:74-79), is characterised as exploring, describing or explaining a situation under investigation. The key differences are that exploratory research entails investigating unknown areas of research, while descriptive research is focused on describing phenomena without providing causal explanations and explanatory research provides causal explanations of phenomena. Furthermore, they postulate that the research design outlines the entire plan or structured framework that is intended to conduct the research. Terre Blanche, Durrheim and Painter (2006:57) share similar views as Babbie and Mouton (2001:74) and indicate that the research paradigm, the purpose of the study, the techniques employed and the situation within which the observation takes place are the four critical aspects of the research design. Viewed in this light, the researcher analysed the full content of the set of circumstances at the organisation before designing the present study.

The outline of this research project is presented in Figure 3.1.

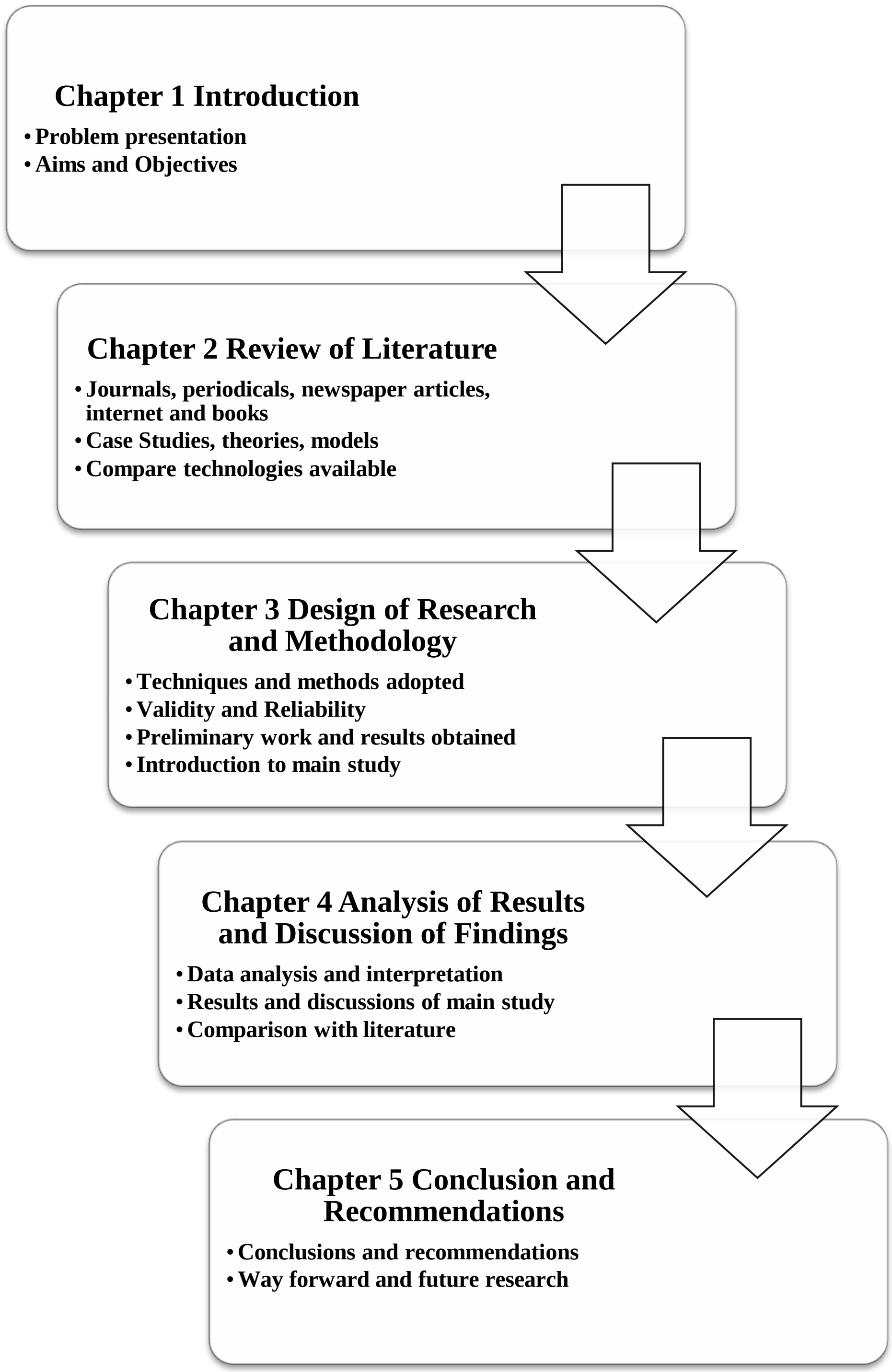


Figure 3.1 – Research Design

As can be seen in the graphical representation in Figure 3.1, the research starts by identifying the problem, followed by a detailed literature survey, thereafter appropriate methodology is adopted and the results and discussions are presented, followed finally by conclusions and recommendations.

3.3 METHODOLOGY

Terre Blanche et al. (2006:561) define methodology as the study of procedures or methods used in research to create new knowledge. On further examination, Sekaran (2006:5) and Cooper and Schindler (2006:198) advocate that qualitative and quantitative techniques are commonly used to conduct research. In most cases, qualitative research is focused on understanding and interpreting data while providing a detailed description of events, situations and interaction between people and things, thus providing depth and detail. The views of Terre Blanche et al. (2006:47) and Babbie and Mouton (2001:53) concur with Cooper and Schindler (2006:198) in that qualitative research aims to study human interaction from the insider's perspective as they identify, examine and reflect on perceptions. In summary, qualitative techniques are used to study phenomena that do not fit into particular theories.

Cooper and Schindler (2006:198) articulate that quantitative research is often used for testing a theory and focuses on describing, explaining and predicting data with the use of statistical and mathematical methods. The most distinguishing feature based on the opinion of Terre Blanche et al. (2006:272) is that the researcher generally knows in advance the important variables prior to designing a quantitative study. In essence, quantitative research is most commonly encountered as part of formal or conclusive research and the aim of this technique is to determine the relationship between an independent variable and a dependent or outcome variable in a population. In addition, Welman and Kruger (2001:84) point out that the two common types of quantitative research designs are characterised as non-experimental (descriptive) or experimental.

Considering the above, Terre Blanche et al. (2006:44), Sekaran (2006:121) and Babbie and Mouton (2001:80) contend that non-experimental research is used when the objective is to provide a systematic description that is as factual and accurate as possible. On the other hand, experimental research establishes causality between variables. In essence, experimental research allows the researcher to manipulate a specific independent variable in order to determine what effect it would have on other dependent variables. Under these circumstances, Terre Blanche et al. (2006:172), Sekaran (2006:145) and Welman and Kruger (2001:69) claim that intervention is common in experimental research. In summary, quantitative techniques allows the researcher to study facts and test hypotheses.

After providing some basic points about qualitative and quantitative research techniques, it is important to examine and demonstrate how these techniques are applied in practice. To this end, the author collated some ideas of other researchers who used the different techniques in their respective articles and will now present this to conclude the section.

Doolen et al. (2008:637) used both quantitative and qualitative techniques to conduct their field study. Quantitative analysis was used for surveys and qualitative analysis was used for interviews and organisational documents. Worley and Doolen (2006:228), applied qualitative techniques in their exploratory case study since it allowed them to fully explore relationships between variables in their natural settings. Meier and Forrester (2002:104), Comm and Mathaisel (2005:138) and Lasa et al. (2008:44) used case studies by means of quantitative analysis to conduct their formal and conclusive research findings. This study incorporated the quantitative research approach owing to its high reliability. The questionnaire survey method was used as the data collection tool. The reason in deploying the questionnaire survey technique was to explore the organisational content of lean manufacturing and measure the participants' opinions against the evaluator.

3.4 QUESTIONNAIRE DESIGN

Due to the critical aspect of questionnaire designs, Sekaran (2006:237) highlights three focus areas on which the researcher should concentrate. These include the actual wording of the questionnaire, the planning of categorising and coding the response variables and the general appearance of the questionnaire. Cooper and Schindler (2006:366) share a similar view as Sekaran (2006:237) on the importance of the actual wording of questionnaires; however, they indicate that the questionnaire content and the response strategy choice is also important.

Another preparatory step includes selecting the appropriate questioning technique. In particular, Sekaran (2006:239) outlines open-ended and close-ended questions as the two common types of questioning techniques used for developing and constructing questionnaires. Open-ended questions are used when participants have to formulate their own opinion and responses in the questionnaire. Close-ended questions are generally used when participants do not have to express themselves verbally but rather make choices among a set of alternatives given by the researcher. It also helps the participants to make quick decisions and the results are much easier to interpret since they are standardised and therefore can be analysed statistically. Another point pertaining to common errors made in questionnaires as highlighted by the authors (Sekaran, 2006:240-241; Babbie and Mouton, 2001:234-237; Welman and Kruger, 2001:168-170) includes ambiguous or vague questions, double-barrelled questions, loaded or leading questions, incorrect length or sequencing of questions and irrelevant or sensitive questions.

To try and avoid some of these cumbersome constraints and difficulties, the researcher developed a draft questionnaire based on the theoretical framework conducted in chapter two. Survey-type questionnaires developed by other researchers (Yen, 2003:1359; Meier and Forrester, 2002:105; Sanchez and Perez, 2001:1434; Karlsson and Ahlstrom, 1996:26) in lean manufacturing were also consulted to inform the design instrument of the questionnaire in this study. The content of the questionnaire was based on the nine lean manufacturing principles developed by Karlsson and Ahlstrom (1996:26) in their lean production model. To avoid any misconception or ambiguity by the participants, the researcher provided a short explanation of each principle, followed by the underlying questions that included words which were familiar to the participants. In addition, the questionnaire was kept as short as possible since the research included the majority of employees in the production environment that have limited time to participate in the survey.

Having been through the questionnaire design checklist, close-ended questions were adopted since they were easy to quantify through fixed alternatives and it also increased the possibility of the participants wanting to partake in the survey. The questionnaire was structured into two parts. The first part of the questionnaire required general details of the participants. This was to ensure that the results could be categorised in terms of departmental roles and job description in the organisation. The second part of the questionnaire was a list of the nine lean manufacturing principles, where the participants were required to rank the possibility of their adoption in the BPS. In addition, the covering letter of the questionnaire presented the purpose of the survey, including assurance of confidentiality. Finally, the questionnaire was pilot tested within the quality department to gain feedback from the employees regarding their understanding of lean manufacturing, the “length” of questionnaire and the application of lean manufacturing in the BPS.

3.5 MEASURING INSTRUMENT

The objective of a measuring instrument is to gather data that represents quantities of what is being measured. Cooper and Schindler (2006:309) point out that measurement in research consists of assigning numbers to empirical events, objects or properties with a set of rules that incorporates a three part process. This process includes selecting the empirical events, followed by developing mapping rules of assigning numbers that represent what is being measured and finally applying the mapping rules to each event that is measured.

Several authors (Cooper and Schindler, 2006:311; Sekaran, 2006:185; Babbie and Mouton, 2001:131) have noted that measurement scales can be classified as nominal, ordinal, interval and ratio. In addition, there are many different types of measurement scales that are available to collect data. In order to fulfil the purpose of this study, the five point Likert scale was selected since it was appropriate to construct interval measurements. This means that the questionnaire will contain a series of statements in which the participant is asked to agree or disagree with each statement. The objective of a Likert scale, according to Cooper and Schindler (2006:339), is used to classify scaled ratings such as: 1 – strongly disagree, 2 – disagree, 3 - not sure, 4 – agree, 5 – strongly agree.

The essential features of the five point Likert scale will indicate the extent to which the employees “agree” or “disagree” with the application of lean manufacturing in the BPS. Essentially, the participants’ responses will be evaluated based on these scaled ratings. The questionnaire will be marked individually and then analysed statistically. Each question will be analysed individually in terms of validity, content and the frequency of responses.

3.6 DATA TYPES, ANALYSES AND COLLECTION

It is important to stipulate that data are the basic material with which researchers work. The two types of data are namely primary or secondary data sources which can be further classified as qualitative or quantitative. According to Sekaran (2006:219) and Cooper and Schindler (2006:77) primary data refers to the collection of new data whereas secondary data is obtained by reviewing existing available data. As mentioned above, the key difference between qualitative and quantitative data is that qualitative data is textual while quantitative data is numerical in nature.

Since this report was based on an empirical study, quantitative data collection methods accompanied by primary data sources were employed to achieve the purpose of this study. This method is in line with the description of empirical studies as highlighted by Babbie and Mouton (2001:104-105).

Due to the importance of information gathered through data, Sekaran (2006:223-224) proposes the following methods for collecting data, namely, interviews, questionnaires, observation and projective tests. The data collection method applicable in this survey study entails the administering of a questionnaire. The reason for selecting this method is that questionnaires have the advantage of obtaining data more efficiently in terms of researcher time, energy and costs.

In an attempt to get an insight into the participants' response rates, the researcher initially interviewed some employees on the production floor. Positive feedback indicated that most employees were keen to participate in this survey; however, there were some that did not show interest. Another finding was that those employees who were keen to participate in this survey, had some basic knowledge on the practical benefits of lean manufacturing and the effect it had on employees. It can be perceived that those employees who were not keen to participate in the survey were not familiar with the lean manufacturing terminology and the actual BPS.

This prompted the researcher to spend some time on the production floor and interact with the employees to provide them with some general knowledge on lean manufacturing before administering the questionnaires. In addition, the researcher decided to be present when the production floor employees participated in the survey to clarify any questions that were unclear. The remainder of the questionnaires were distributed to employees within the different departments who contribute to the daily operational activities that impact on productivity, quality and customers.

3.7 SCOPE AND SAMPLE SIZES

Sampling is the process of selecting a sufficient number of elements from a population. In terms of theory, the two basic types of sampling techniques available are probability and non-probability sampling. The key difference, according to Welman and Kruger (2001:47), is that probability sampling includes all members of the population whereas in non-probability sampling, some members of the population are not included in the sample. Furthermore, owing to the uniqueness of its nature, Babbie and Mouton (2001:139) contend that non-probability sampling includes convenient, purposive and snowball sampling procedures as opposed to the statistical principal of randomness in probability sampling.

In planning this investigation, the target population selected for the study were the employees at Behr and the purposive sampling method was adopted. It was preferable to use this technique since the study concentrated only on one Behr location. Employees at other Behr locations will not serve as sample members since permission to conduct the study was obtained specifically from Behr Durban. The method of purposive sampling is a type of non-probability sampling where researchers rely on their experience, ingenuity or previous research findings to collect information from sample members that is representative of the relevant population (Welman and Kruger, 2001:63).

Following the decision in selecting the appropriate sampling method is the formulation of the correct sample size. Sekaran (2006:293-294) cite specific cases conducted by Krejcie and Morgan (1970) where they document representative predefined sample sizes for population ranges to ensure a good decision model. Upon examining this documented sampling table, the appropriate sample size that represents a population of 600 equates to 234 and 650 equates to 242, respectively. In relation to this, the total population group at Behr is 625 which is the midpoint of 600 and 650. Therefore, through interpolation, the author calculated a sample size of 238 participants to fulfil the purpose of this study. As a result, it was decided to distribute 300 questionnaires to employees within the different departments. A total of 254 questionnaires were returned answered which indicated a good response rate of 85%. This was more than the planned sample size of 238 participants.

3.8 VALIDITY AND RELIABILITY

In general, the primary objective of research is to investigate a problem area and present findings based on data collected. To be effective, Cooper and Schindler (2006:318) acclaim that the characteristics of good measurement are the validity, reliability and practicality of the measurement tool. Thus, achieving the three outputs determines how well the data will be collected and analysed to achieve sound measurement.

Cooper and Schindler (2006:325) postulate that the validity of the questionnaire determines how well the measuring instrument assists the researcher in solving the research problem. This means that the questionnaire should measure what it is set out to achieve. In the context of an empirical study, Babbie and Mouton (2001:122) describe validity as the extent to which an empirical measure adequately reflects the real meaning of the concept under consideration. Along similar lines, Yin (2009:40) stresses the necessity of four commonly used tests to establish the quality of an empirical study. These can be classified as, construct validity which identifies correct operational measures for the concepts being studied; internal validity that is used mainly for explanatory or causal studies to establish casual relationship where certain conditions lead to other conditions; external validity which identifies if a study’s findings are generalised beyond the immediate case study and reliability for testing the consistency and repeatability of results. For the purpose of this study, construct validity and internal validity were employed to verify the measuring instrument.

In a similar contribution to Yin (2009:40), Sekaran (2006:203) contends that the reliability of the measuring instrument removes bias and ensures consistent measurement across time and across the various items in the instrument. This is aptly summarised by the following authors (Yin, 2009:45; Cooper and Schindler, 2006:321;

Sekaran, 2006:203; Babbie and Mouton, 2001:125) who maintain the measurement must yield similar results if repeated.

Cooper and Schindler (2006:323) describe the operational requirements where the practical value of the research must be economical, convenient and interpretable. In view of the validity and reliability tests, the pilot test ensured that the questionnaire was adequately edited to accomplish the purpose of the main study. The Cronbach’s Alpha reliability test was employed for this study.

3.9 PRELIMINARY WORK

In order to test the feasibility of the study, preliminary work in the form of a pilot test was conducted to determine if the methodology adopted would meet the objectives of this project. Babbie and Mouton (2001:244) are of the opinion that studies usually undertaken in South Africa neglects the pre-testing phase of the questionnaire construction. Pre-testing is important especially where more than one cultural group is included in the study. The benefit of pre-testing questionnaires, according to Sekaran (2006:249), identifies ambiguity and problems commonly encountered with wording or measurements.

Acknowledging the above, a pilot test was conducted within the quality department. Though the employees selected within the quality department may have been effective for the pilot test, there was still a concern of the employees not understanding the lean manufacturing terminology. Therefore, as a useful strategy, the researcher decided to be present for the pilot test to clarify any doubts. The pilot questionnaire was administered to twenty employees within the quality department over two weeks consisting of two managers, two engineers, six technicians and ten auditors.

The nine principles of lean manufacturing are documented in the BPS. As a result, the structure of the questionnaire consisted of each lean manufacturing principle followed by questions relating to the actual application of each principle as viewed by the employees at Behr.

3.9.1 QUESTIONNAIRE: PRE-INTERVENTION

On the basis of statistically analysing data, it is important that emphasis is placed on understanding and interpreting the results obtained. Therefore, to gain a clear understanding of the responses from the pilot test, a statistician assisted with the use of the SPSS to analyse and interpret the data. The questionnaire was administered pre-intervention (actual application of lean manufacturing at Behr) and post-intervention to the employees within the quality department at Behr.

The statistical technique applied to the pilot study included Cronbach's Alpha reliability test. As a reference source, Pallant (2005:90) claims that the Cronbach’s Alpha reliability analysis is commonly used to test the internal consistency of the measurement scale. Thus achieving a value off greater than 0.7 indicates higher reliability. It was found that the Cronbach’s Alpha value for the total set of 62 questions administered was 0.877. This value indicates that the overall reliability score is very good for the present study. The pilot questionnaire can be viewed in appendix A.

3.9.2 QUESTIONNAIRE: POST-INTERVENTION

During the questionnaire administration, a discussion was held with the participants regarding the content of the questionnaire. There were three common errors identified by the twenty participants: namely, the questionnaire was too long, the content of questions was not clearly structured and many did not understand some of the terminology used. Furthermore, the participants also reported that the questions needed to be designed such that the operators were able to understand the terminology used. In an attempt to amend the errors identified, the results from the Cronbach’s Alpha reliability analysis indicated that 11 questions were strongly negative and 18 questions were incorrectly answered or could have probably been misinterpreted. In addition, 10 questions were identified as inappropriate and could be eliminated.

Following the feedback given by the participants and the results of the reliability analysis, the questionnaire was edited to reduce the number of questions and reformulated with the help of the quality manager and the BPS manager. Through this approach and from a methodological standpoint, the corrections thus made will hope to enhance the accuracy of the results. The final questionnaire consisted of 41 questions and this can be viewed in appendix B.

All participants were in agreement that lean manufacturing is not properly adhered to at Behr. It is evident that the correct application of lean manufacturing will assist Behr to reduce defects, increase delivery lead times and produce quality goods without waste. The main study will follow the same format as the pilot study; however, the questionnaires will be administered throughout the organisation over a three month period.

3.10 METHOD OF DATA ANALYSIS

The methods employed for analysing the data collected will include descriptive statistics such as frequencies and means, and inferential statistics such as factor analysis, communalities and hypotheses testing.

3.10.1 DESCRIPTIVE STATISTICS

According to Gaur and Gaur (2009:37), descriptive statistics are frequently used to summarise and categorise data such that conclusions can be drawn from the different variables. The most common types of descriptive analysis include measures of central tendency and measures of variability. Pallant (2005:49-50) further details them as mean scores, mode, standard deviations, skewness, kurtosis and frequencies. For the purpose of this study, means scores and frequencies will be used to evaluate the data and will be presented as tables and figures in chapter 4. In addition, pie graphs and cross tabulations will be presented in appendix C to outline the profile of the survey participants.

3.10.2 INFERENTIAL STATISTICS

Factor analysis is a statistical technique with the main goal of data reduction. A typical use of factor analysis, according to Gaur and Gaur (2009:131-132) and Pallant (2005:172), is in survey research where a researcher wishes to represent a number of questions with a small number of hypothetical factors. The result of the factor analysis conducted in this research is presented in a rotated component matrix which can be viewed in appendix D. Certain components are divided into finer components. With reference to the factor analysis table in appendix D:

- The principle component analysis was used as the extraction method, and the rotation method was Varimax with Kaiser Normalization. This is an orthogonal rotation method that minimises the number of variables that have high loadings on each factor. It simplifies the interpretation of the factors.
- Factor analysis/loading show inter-correlations between variables.

An examination of the content of items loading at or above 0.5 effectively measured along the nine components. It is noted that it was only for the components of Just-in-time and Vertical Information Systems that the variables, which constituted the components, loaded perfectly in one factor. This means that the questions (variables) which constituted these components perfectly measured the component. However, all of the other components have factors that overlap, indicating a mixing of the factors. This means that the questions in the overlapping components did not specifically measure what it set out to measure. This could be with respect to interpretation or inability to distinguish what the questions were measuring.

The communality for a given variable, according to Gaur and Gaur (2009:133) and Kinnear and Gray (2009:568), can be interpreted as the total proportion of its variation that is accounted by the extracted factors. An assessment of how well the questionnaire model is doing can be obtained from the communalities. The ideal, according to Kinnear and Gray (2009:573), is to obtain values that are close to one. This would indicate that the model explains most of the variation for those variables. In the case of this study, the model is acceptable as it explains approximately 64% of the variation for the 41 variables. The individual communalities and average scores of the components are discussed in the results (chapter 4).

3.10.3 HYPOTHESIS TESTING

The traditional approach to reporting a result requires a statement of statistical significance. According to Gaur and Gaur (2009:33), hypothesis testing is commonly used to test significant relationships such as the assumption of some characteristic that could be supported or rejected by empirical evidence. The Pearson's Chi-square test will be performed to determine whether there was a statistically significant relationship between the variables (rows vs. columns). As suggested by Kinnear and Gray (2009:409) and Pallant (2005:290), a p-value is generated from a test statistic with a significant result indicated by "$p < 0.05$".

The null hypothesis states that there is no association between the variables. The alternate hypothesis indicates that there is an association. The results in the main study indicate that there are differences between each statement and the respective category. All significant Chi Square values are highlighted and are discussed in chapter 4.

3.11 SUMMARY OF THE CHAPTER

This chapter outlined the research design of the present study through detailed information sources and explanations of existing research philosophies and methodologies. The research was a quantitative empirical study that used a questionnaire for the method of analysis to conduct the investigation. Furthermore, the questionnaire was validated prior to being administered, which included some changes, and the results were verified and deemed reliable with the assistance of a statistician. The main objective of the questionnaire was to elicit the employees' views on lean manufacturing application at Behr. Twenty employees within the quality department were subjected to pilot the questionnaire administration accompanied by the researcher over a two week period. Results showed that Behr does not practice the complete set of lean manufacturing principles as specified in the BPS. The main study was also introduced and followed the same format as the preliminary work. In terms of the gaps identified in the pilot test, the main study incorporated the updated questionnaire, consisting of 41 questions and included 254 employees from the different departments over a three month period. The next chapter will present the results and discussion of the main study.

CHAPTER 4

ANALYSIS OF RESULTS AND DISCUSSION OF FINDINGS

4.1 INTRODUCTION

This chapter will present the results and discuss the findings of the main study. The data collected from the participants will be analysed using the SPSS version 17.0. The results will be presented in the form of bar graphs, tables and figures. The layout of the chapter will consist of nine sections that include the statistical results (mean scores, gaps, communality, p-value and reliability) of questions pertaining to each lean manufacturing principle. The sections are as follows: elimination of waste, continuous improvement, zero defects, just-in-time, multifunctional teams, decentralised responsibilities, integrated functions, vertical information systems and pull instead of push.

The mean scores are independent of department and position. In an attempt to understand the variation in responses for each principle, results within departments and positions will be presented as percentages. The responses of “disagree” will be combined with “strongly disagree” whilst the responses of “agree” will be combined with “strongly agree”. In this manner, only three categories of results in percentage form will be presented as “agree”, “unsure” and “disagree”. The reason for combining the responses will be to allow the analysis to be clearly presented and to create a better understanding of the results. A detailed summary of this chapter will be presented at the end.

4.2 ELIMINATION OF WASTE

It is evident from literature in chapter 2 that any activity in the product flow which does not add value to the customer is classified as waste. Therefore, the first principle of lean adoption seeks to establish how the respondent’s rate the extent to which the eight non-value-added waste, namely: overproduction of work in progress inventory, warehouse inventory, transportation of components, waiting for preceding processes, motion of unnecessary operations, inappropriate processing, correction of defects and unused employee creativity identified in production, is managed within the organisation. The initiatives reported by the participants could provide opportunities for reducing non-value-added activities in production. The overall results from the survey data pertaining to this principle is demonstrated in Table 4.1. These include mean scores, gaps, communalities, p-values and reliability. The reasons for selecting the aforementioned statistical data to evaluate the results are explained in chapter 3.

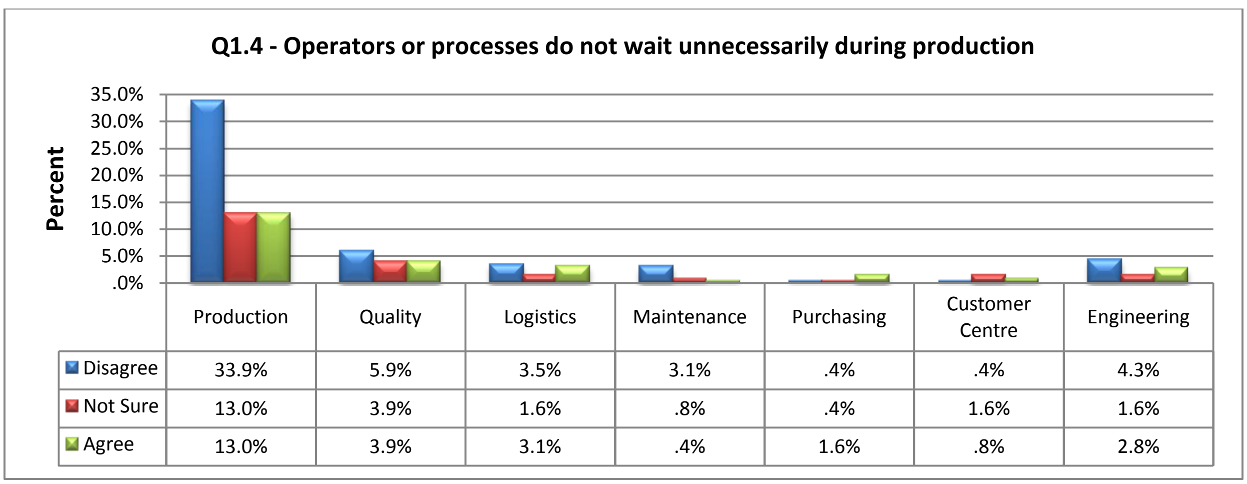
Question	Mean	Gap	Communality	p-value for Department	p-value for Position	Cronbach's Alpha
1.1) Products are manufactured only when required	3.1	-1.9	0.635	0.000	0.034	
1.2) Inventory in stores is kept to a minimum	2.9	-2.1	0.684	0.004	0.008	
1.3) The movement of material within the organisation is kept to a minimum	3.0	-2.0	0.637	0.261	0.547	
1.4) Operators or processes do not wait unnecessarily during production	2.6	-2.4	0.579	0.052	0.022	
1.5) Operators do not move excessively to complete a task	3.0	-2.0	0.614	0.000	0.168	
1.6) There are no unnecessary processing steps in production	3.1	-1.9	0.681	0.006	0.405	
1.7) Defects and scrap are constantly monitored	3.2	-1.8	0.640	0.002	0.239	
1.8) Employees are motivated to be more creative	3.2	-1.8	0.556	0.000	0.001	
Overall	3	-2.0	0.628			0.844

Table 4.1 Results pertaining to the principle of waste elimination

It can be noted from Table 4.1 that the average score per question is close to 3. This indicates a degree of “uncertainty” since the five point Likert scale represents 3 as “not sure”. A closer inspection of the scoring indicates that there were as many participants who “agreed” with the statements as there were those who did not. It is observed that the focal gaps were identified in question 1.4, 1.7 and 1.8 from the combined value of responses grouped as percentages. The overall communality value of 0.628 in Table 4.1 indicates that the model is explaining variations 63 percent of the time. In addition, the Cronbach’s Coefficient Alpha of 0.844 maintains the high reliability for the established scales. Chi-square test per question confirms the gap scores were not random, but are systematic of the response type. For these questions, there is a significant relationship within departments and within position ($p<0.05$). This means that participants within departments and within positions share different views on the questions. However, it is noted that for the department category of question 1.4 and the position category of question 1.7 there are no significant differences ($p>0.05$).

Within the department category, production scored in the region of slight overall “disagreement” with the statements. On the other hand, by position it is observed that operators scored the lowest across all of the questions in this category. The scoring pattern from the frequencies by department and position indicate, for example, that for question 1.1, there are differences in the scoring patterns, but not as much for question 1.2. Therefore, further analysis of the gaps identified is required to establish why the above results differ within departments and within positions.

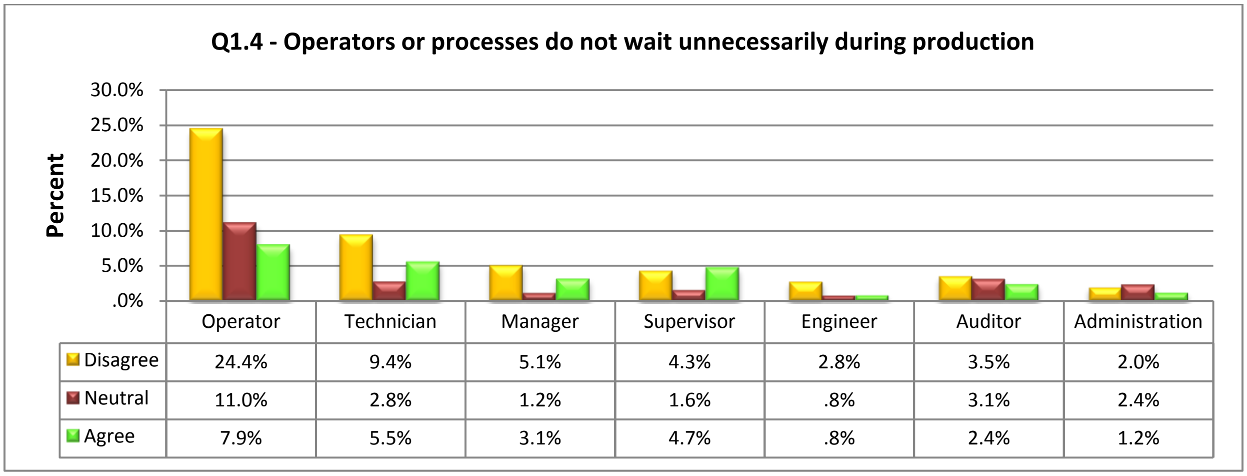
By department and position, the results in percentages for question 1.4 are represented by Figures 4.1 and 4.2 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	33.9%	5.9%	3.5%	3.1%	.4%	.4%	4.3%
Not Sure	13.0%	3.9%	1.6%	.8%	.4%	1.6%	1.6%
Agree	13.0%	3.9%	3.1%	.4%	1.6%	.8%	2.8%

Figure 4.1 – Department response for question 1.4

As presented in Figure 4.1, five out of the seven categories of departments which comprise of 50.7 percent of the total sample show a trend of “disagreement”, whilst only purchasing shows a high level of “agreement”. It is understandable that customer centre would show a high level of “uncertainty” as they are not directly involved in the production process. The majority of “agreement” within the purchasing department could mean that since expediters are responsible to ensure components are readily available for operations, they do not believe that operators wait unnecessarily in production.



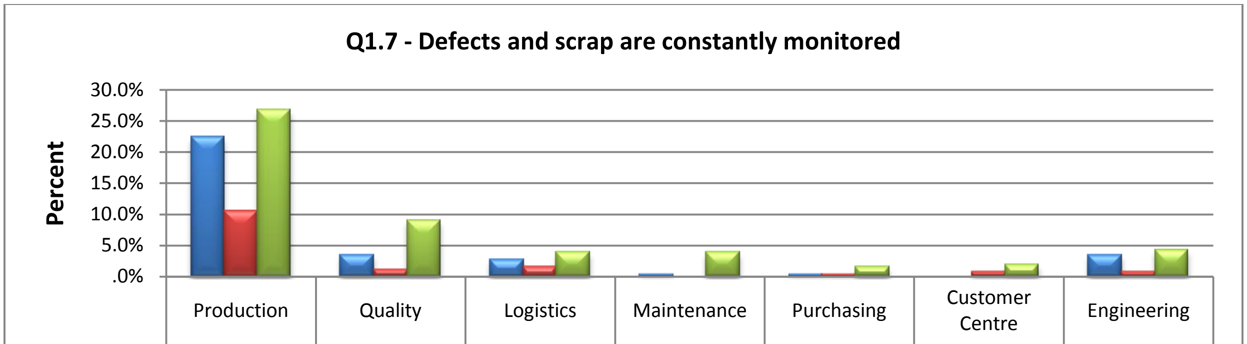
	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	24.4%	9.4%	5.1%	4.3%	2.8%	3.5%	2.0%
Neutral	11.0%	2.8%	1.2%	1.6%	.8%	3.1%	2.4%
Agree	7.9%	5.5%	3.1%	4.7%	.8%	2.4%	1.2%

Figure 4.2 – Position response for question 1.4

In the position category represented in Figure 4.2, 51.5 percent of the total participants "disagree" with this statement. Only supervisors show a marginal positive difference in "agreement". This may be due to supervisors wanting to indicate that processes are running smoothly under their watch. Twenty four percent of the total 43.3 percent operators, who are on the frontline of the processes, show the largest and strongest sentiment for "disagreement". A combination of the responses by position and department validate the strong overall negative response for question 1.4.

The results obtained in Figure 4.1 and 4.2 highlight significant improvement opportunities for unnecessary waiting time which is aligned with Bicheno (2004:16) who surmises that waiting for parts in production affects lead time. Therefore, it can be inferred that decreasing waiting time will result in increased productivity and, in addition, this time may be used as a benefit to the organisation in terms of training and other activities. In an attempt to identify the various reasons employees wait during production, ReVelle (2002:174) highlights some causes which are explained in detail under section 2.3.4 of the literature review.

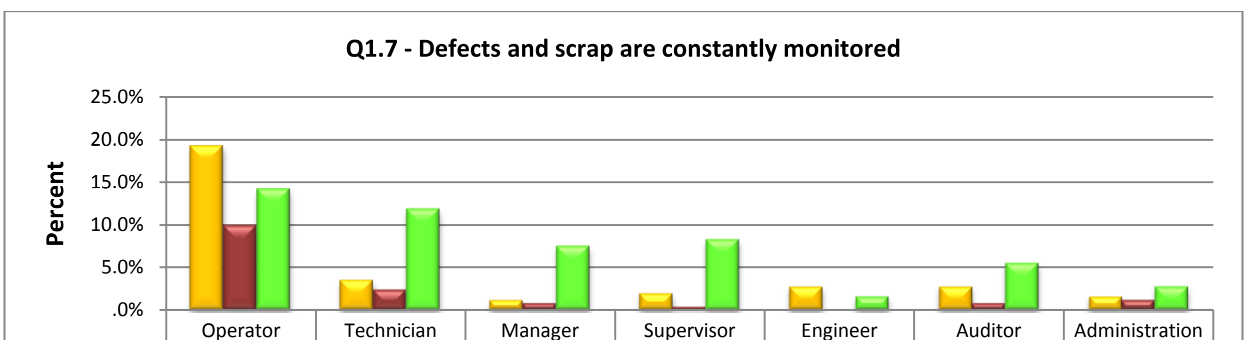
By department and position, the results in percentages for question 1.7 are represented by Figures 4.3 and 4.4 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	22.4%	3.5%	2.8%	.4%	.4%	.0%	3.5%
Not Sure	10.6%	1.2%	1.6%	.0%	.4%	.8%	.8%
Agree	26.8%	9.1%	3.9%	3.9%	1.6%	2.0%	4.3%

Figure 4.3 – Department response for question 1.7

All departments in Figure 4.3 show a general trend of “agreement” in response to this statement. With more than 50 percent of the participants “agreeing” with the statement, it can be deduced that these findings are beneficial to the organisation. To ensure significant control across all manufacturing operations, it is important to know that defects and scrap are constantly monitored. However, according to Forza (1996:47), to be effective, it is also important that immediate corrective action is adequately taken. There is substantial evidence by the various authors such as Bendell (2006:258), Rawabdeh (2005:806), Carreira (2005:62) and Liker (2004:29) to confirm that monitoring of defects and scrap reduces financial losses and customer dissatisfaction. It can be suggested that through employee involvement and continuous improvement, there is significant opportunity to reduce defects and scrap in an organisation.



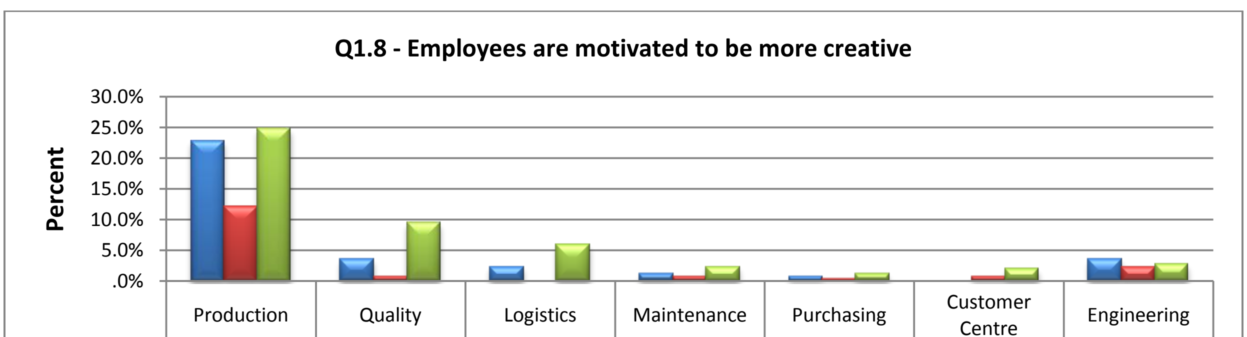
	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	19.3%	3.5%	1.2%	2.0%	2.8%	2.8%	1.6%
Neutral	9.8%	2.4%	.8%	.4%	.0%	.8%	1.2%
Agree	14.2%	11.8%	7.5%	8.3%	1.6%	5.5%	2.8%

Figure 4.4 – Position response for question 1.7

Of all the participants represented in Figure 4.4, 2.8 percent of the engineers and 19.3 percent of the operators, which comprise 22.1 percent of the total sample, indicate the highest “disagreement” for this statement. The engineers’ responses could possibly be related to their personal views when conducting trials and for which there are no reconciliation of the samples. On the other hand, the operators could possibly be relating their responses to defects that are identified at the source and reworked immediately, for which there is no record. There is evidence to suggest that in response to identifying defects at the source, these perceptions align significantly with Liker (2004:130) and Bicheno (2004:153) who substantiate that inspection at the source reduces rework costs and the waste of defects.

Again, a combination of the responses by department and position indicate overall agreement. Another argument identified from the objectives in chapter one is that if defects and scrap are constantly monitored the organisation should be supplying their customers with defect-free products. However, this is not the case as the concern of defective products being supplied to customers is one of the challenges that the organisation is currently experiencing. This is an important point as the views of ReVelle (2002:176) indicate low customer confidence and in some instances loss of future business due to defective products.

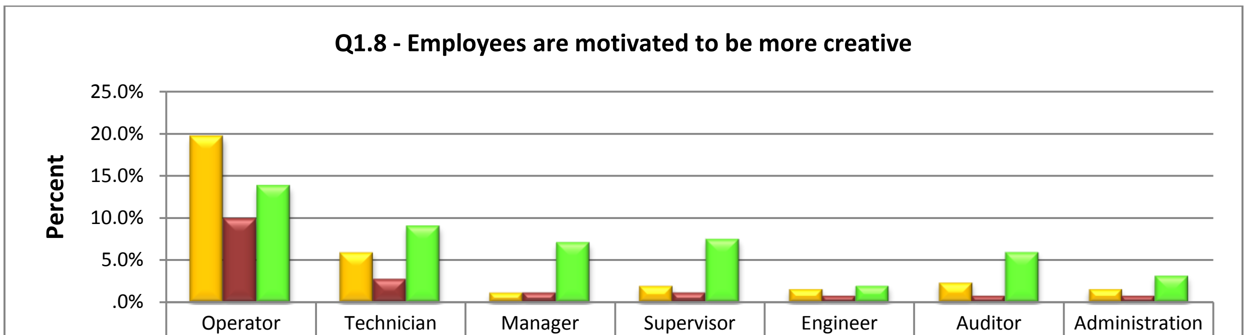
By department and position, the results in percentages for question 1.8 are represented by Figures 4.5 and 4.6 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	22.8%	3.5%	2.4%	1.2%	.8%	.0%	3.5%
Not Sure	12.2%	.8%	.0%	.8%	.4%	.8%	2.4%
Agree	24.8%	9.4%	5.9%	2.4%	1.2%	2.0%	2.8%

Figure 4.5 – Department response for question 1.8

Figure 4.5 indicates that only the engineering department (3.5 percent of total 8.7 percent by department type) “disagreed” with this statement. Most of the other departments showed strong positive differences with a total of 48.5 percent in “agreement”. These differences could perhaps be attributed to the different departmental management styles and the manner in which these managers motivate their teams. The positive initiatives reported for motivating employees to be more creative should portray true management support and encouragement instead of just compliance. This is supported by Emiliani and Stec (2005:372) who claim that employees will realise their full potential and actual innate desires to make positive contributions in the workplace. In this manner, the organisation will be able to make better use of employees’ time.



	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	19.7%	5.9%	1.2%	2.0%	1.6%	2.4%	1.6%
Neutral	9.8%	2.8%	1.2%	1.2%	.8%	.8%	.8%
Agree	13.8%	9.1%	7.1%	7.5%	2.0%	5.9%	3.1%

Figure 4.6 – Position response for question 1.8

From Figure 4.6, it is evident that 19.7 percent of the total 43.3 percent operators were the majority of the employees who “disagreed” with the statement. It could be perceived from these findings that the operators’ responses could possibly reflect that they are not motivated enough by management or could have been shown disrespect at some point for improvement opportunities which they had previously identified. A combination of the department and position again show an overall pattern of agreement.

The high negativity in responses from operators is consistent with the findings of Sim and Rogers (2009:37-46) who found in their study that shop floor employees (referred to as operators) do not believe that the organisation views them as the most important asset, requiring constant motivation. Similarly, the opinions of Worley and Doolen

(2006:231) and Dahlgaard and Dahlgaard-Park (2006:275) indicate major discouragement in the lean effort when employees' views are not respected. The authors (Lee and Peccei, 2008:9; Emiliani and Stec, 2005:372; Emiliani and Stec, 2004:636) in section 2.3.8 highlight that organisations which have the correct respect and culture generally motivate employees to be more creative. Therefore, it appears that managers should review their ability to inspire and motivate employees as a means of uncapping their full potential.

4.3 CONTINUOUS IMPROVEMENT

The continuous improvement methodology ensures that better ways are discovered to complete production tasks. Therefore, the second principle on continuous improvement links questions of innovation and employee participation in response to evaluating the effectiveness within the organisation. The overall mean scores, gaps, p-values and Cronbach's Alpha for each of the six questions representing the continuous improvement principle are illustrated in Table 4.2.

Question	Mean	Gap	Communality	p-value for Department	p-value for Position	Cronbach's Alpha
2.1) All employees are asked to assist in solving problems	2.9	-2.1	0.638	0.005	0.001	
2.2) Training is provided for all employees on continuous improvement	2.9	-2.1	0.603	0.144	0.003	
2.3) Employees are motivated to come up with suggestions	3.5	-1.5	0.729	0.056	0.000	
2.4) Kaizen workshops are held to assist in improving operations	3.1	-1.9	0.613	0.191	0.002	
2.5) The Plan Do Check Act (PDCA) cycle is used to address problems	3.0	-2.0	0.564	0.009	0.000	
2.6) There is order and cleanliness in the organisation	3.4	-1.6	0.678	0.094	0.000	
Overall	3.1	-1.9	0.637			0.845

Table 4.2 Results pertaining to the principle of continuous improvement

The average score for this section as depicted in Table 4.2 is 3.1(since all of the questions are positive). Questions 2.3, 2.4 and 2.6 indicate stronger patterns of “agreement” and have the largest gaps in this category compared to the others. As can be seen in Table 4.2, 64 percent of the variation is explained by the model and the value 0.845 indicates a high level of reliability for this section. It is noted that only for the departmental responses are there not much differences for the gaps identified as p>0.05. The concept of cleanliness also seems to resonate with the employees. An investigation of the variation in responses for the gaps identified (questions 2.3, 2.4 and 2.6) by department and position follow.

By department and position, the results in percentages for question 2.3 are represented by Figures 4.7 and 4.8 respectively.

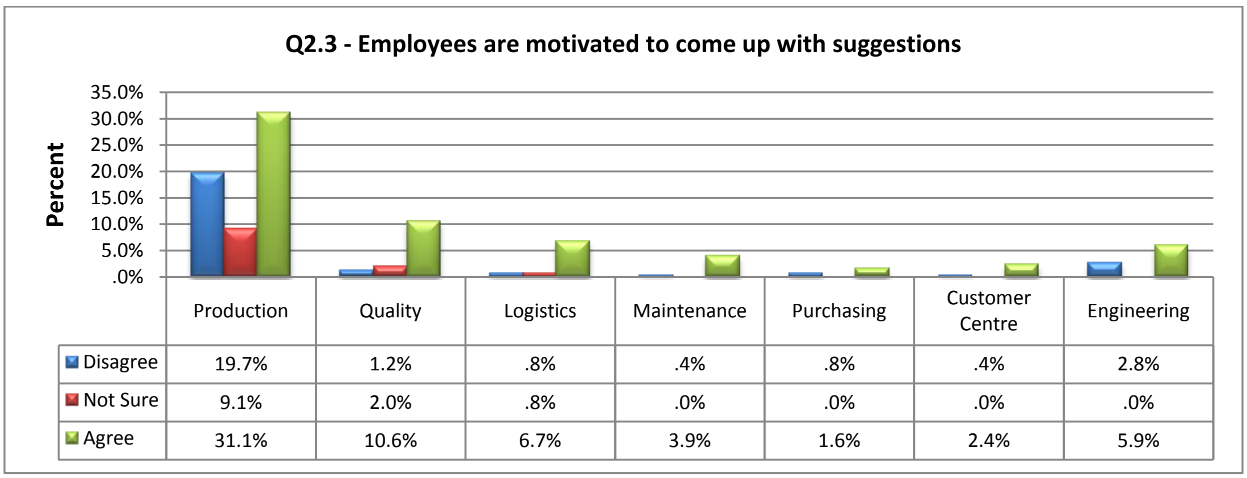
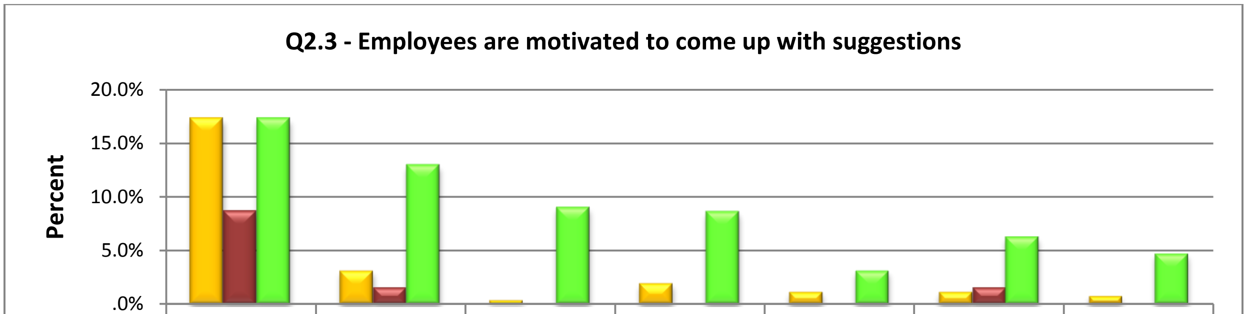


Figure 4.7 – Department response for question 2.3

The results presented in Figure 4.7 indicate that 62.2 percent of participants within departments “agree” with this statement. There is evidence to suggest that the existing suggestion scheme programme within the organisation is effective. These findings align with the views of Chase et al. (2006:327) and Karlsson and Ahlstrom (1996:29) who allege that the suggestion scheme programme is commonly used as a method of motivating employees to develop continuous improvement suggestions. Since the suggestion scheme programme usually provides intrinsic cash awards, the positive responses coincide with the views of Olivella et al. (2008:807) and Bhuiyan and Baghel (2005:766), claiming that rewards are generally used as a motivator for participation. On the other hand, the results could be in contradiction with the views of Bicheno

(2004:146) who is adamant that the suggestion scheme programme does not always pay but should create a culture of continuous improvement. The overall results of this study are similar to the findings of Lee and Peccei (2008:22) of two Korean organisations which identified that rewards generally motivates employees as opposed to the job itself.

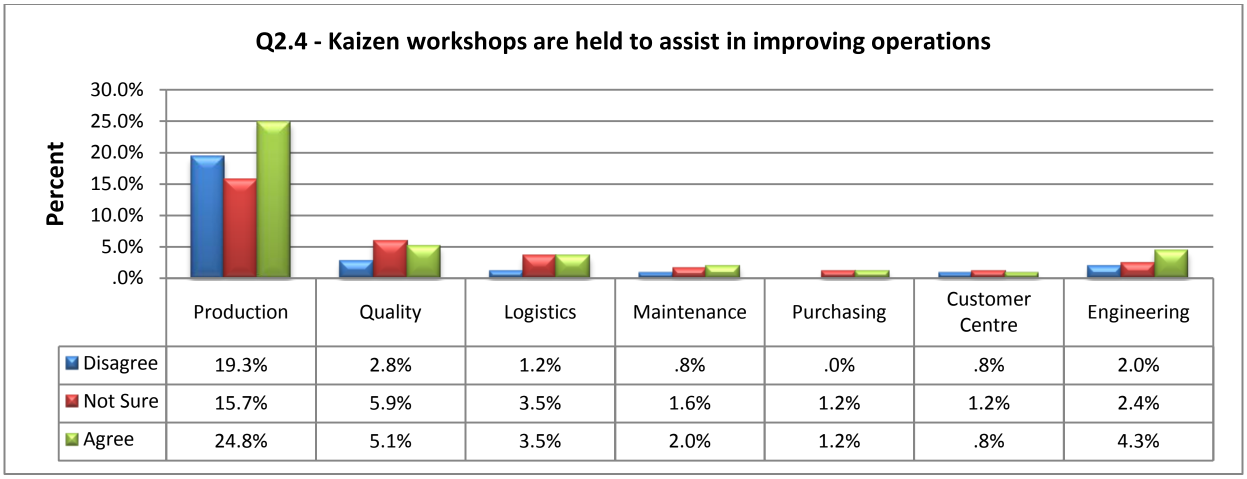


	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	17.3%	3.1%	.4%	2.0%	1.2%	1.2%	.8%
Neutral	8.7%	1.6%	.0%	.0%	.0%	1.6%	.0%
Agree	17.3%	13.0%	9.1%	8.7%	3.1%	6.3%	4.7%

Figure 4.8 – Position response for question 2.3

By position as well, it is observed in Figure 4.8 that all categories of employees “agree” with the statement. However, there were as many as 17.3 percent of operators who agreed with the statement as there were those who did not. As a natural consequence of suggestions that are not implemented, it could validate the 26 percent of “disagreement” indicated in Figure 4.8. The findings highlighted for “disagreement” are in contradiction with the views of Bhuiyan and Baghel (2005:766) who contend that employees are generally given explanations for suggestions that are rejected. Another possible interpretation could be that a reward programme will have no motivational effect if there is no trust between employees and leaders. Ideally, the suggestion scheme programme should encourage employees’ participation and provide opportunities for self development.

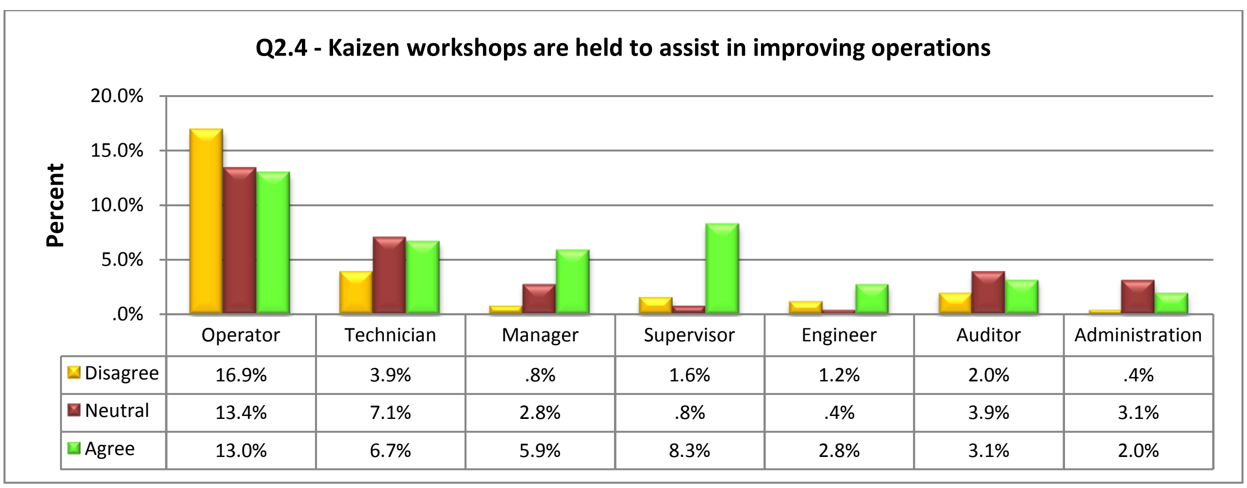
By department and position, the results in percentages for question 2.4 are represented by Figures 4.9 and 4.10 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	19.3%	2.8%	1.2%	.8%	.0%	.8%	2.0%
Not Sure	15.7%	5.9%	3.5%	1.6%	1.2%	1.2%	2.4%
Agree	24.8%	5.1%	3.5%	2.0%	1.2%	.8%	4.3%

Figure 4.9 – Department response for question 2.4

As can be seen in Figure 4.9, there is a consistent trend of “agreement” between departments which comprise 41.7 percent of the total sample, for this question. In comparing the results, one aspect of concern is highlighted by the quality department. It indicates a high level of “uncertainty” (5.9 percent of total 13.8 percent by department type). This is a continuous improvement tool and it is expected that the quality department should have extensive knowledge of it. The overall 31.5 percent responses of “uncertainty” within departments appears to be in contradiction with the views of Khan et al. (2007:349-350) who indicate that Kaizen is used to identify better ways of working and is not restricted to any department in particular.



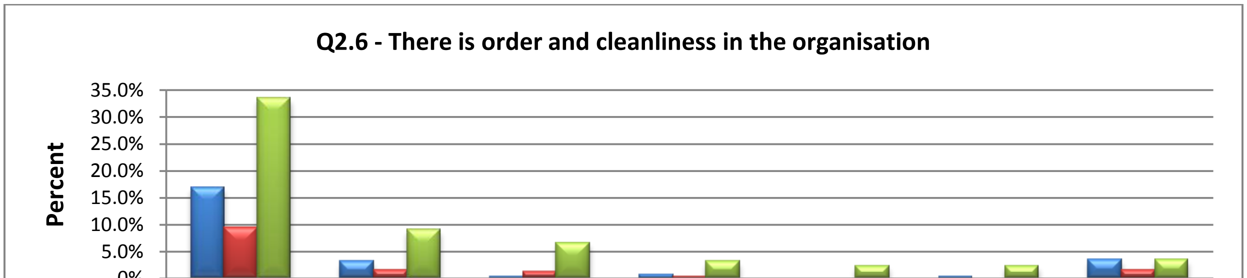
	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	16.9%	3.9%	.8%	1.6%	1.2%	2.0%	.4%
Neutral	13.4%	7.1%	2.8%	.8%	.4%	3.9%	3.1%
Agree	13.0%	6.7%	5.9%	8.3%	2.8%	3.1%	2.0%

Figure 4.10 – Position response for question 2.4

By the position category it can be observed in Figure 4.10 that 5.9 percent of managers, 8.3 percent of supervisors and 2.8 percent of engineers “agree” with the statement.

However, positions such as auditors, administration and technicians showed a high level of "uncertainty" (14.1 percent in total). The major trend of "disagreement", which accounts for 16.9 percent of the sample, lies within the operators. In retrospect therefore, it would appear that the different positions are not restricted to the operators only and are not included in Kaizen activities. Perhaps this was the reason for the responses of "disagreement" and "uncertainty". These responses are in contradiction with the views of Forza (1996:52) and Bhuiyan and Baghel (2005:766) who indicate that Kaizen activities involve the collective effort of employees at every level of the organisation. Therefore, from an operative point of view, adopting this approach will strengthen employee involvement in the improvement process and all future Kaizen activities.

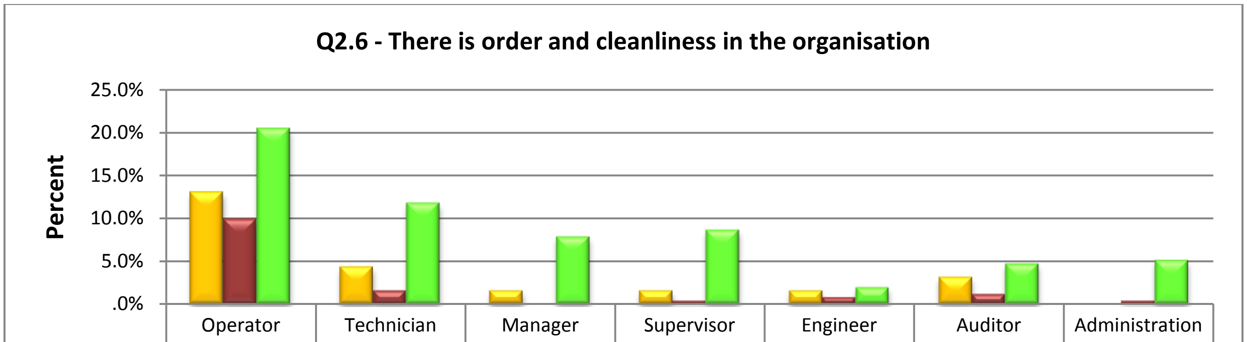
By department and position, the results in percentages for question 2.6 are represented by Figures 4.11 and 4.12 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	16.9%	3.1%	.4%	.8%	.0%	.4%	3.5%
Not Sure	9.4%	1.6%	1.2%	.4%	.0%	.0%	1.6%
Agree	33.5%	9.1%	6.7%	3.1%	2.4%	2.4%	3.5%

Figure 4.11 – Department response for question 2.6

With the exception of the engineering department in particular, the results in Figure 4.11 indicates consensus in "agreement" (60.7 percent in total) within departments. The positive responses reveal that the "5S" tool is correctly used in the organisation to maintain a clean and organised work environment. These results are consistent with the views of Motwani (2003:345) who contends that a clean and organised working environment lays the foundation for all other improvements.



	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	13.0%	4.3%	1.6%	1.6%	1.6%	3.1%	.0%
Neutral	9.8%	1.6%	.0%	.4%	.8%	1.2%	.4%
Agree	20.5%	11.8%	7.9%	8.7%	2.0%	4.7%	5.1%

Figure 4.12 – Position response for question 2.6

By position as well, as being observed in Figure 4.12, all categories of employees “agree” with the statement. In convergence, another significant finding is that approximately 25.2 percent of the majority of participants do not believe that there is order and cleanliness in the organisation. Since the primary aim of maintaining a clean organisation, according to the various authors (Bicheno, 2004:52; Liker, 2004:142; Motwani, 2003:345), is to lay the foundation for improvement, the resulting analysis from the proportion of negative responses highlights an important area of concern for the organisation. A combination of the results by department and position verifies the overall results. Therefore, to be effective, the organisation should set order and cleanliness as a goal and determinant for all productivity and quality improvements.

4.4 ZERO DEFECTS

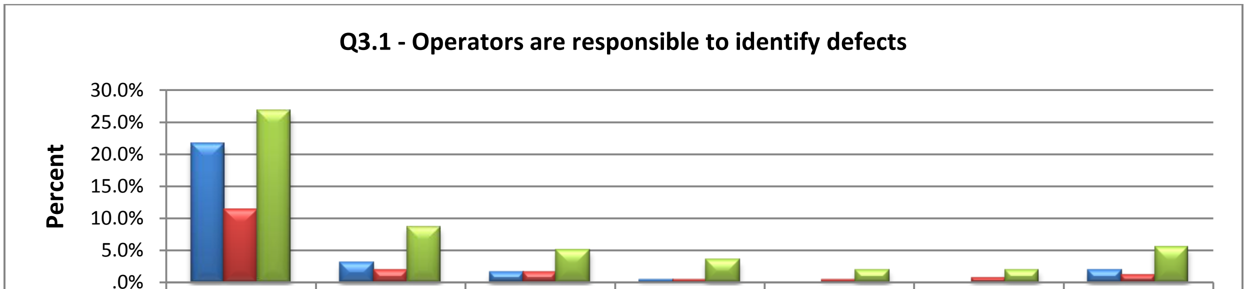
The concept of zero defects pertains to ensuring that production tasks are done correctly the first time without manufacturing defects. The third principle on zero defects deals with the operator’s ability to identify defects and to use the correct tools to rectify them. This section evaluates employees’ responses regarding responsibility in decision making, for example, in terms of stopping the production line. In responding to this principle, the results of the associated questions are presented in Table 4.3.

Question	Mean	Gap	Communality	p-value for Department	p-value for Position	Cronbach's Alpha
3.1) Operators are responsible to identify defects	3.3	-1.7	0.690	0.165	0.000	
3.2) Operators are encouraged to stop the line should a defect occur	3.0	-2.0	0.602	0.162	0.000	
3.3) Operators are responsible to correct defects	2.9	-2.1	0.582	0.010	0.000	
3.4) Poka-Yoke devices are used to prevent defects	3.2	-1.8	0.653	0.011	0.000	
Overall	3.1	-1.9	0.632			0.832

Table 4.3 Results pertaining to the principle of zero defects

It is evident in Table 4.3 that questions 3.1 and 3.4 scores are high in terms of "agreement". The variation in percentage also confirms this gap. Therefore, 69 percent of the variation for question 3.1 and 65 percent of the variation for question 3.4 is explained by the model. In addition, the reliability value of 0.832 indicates high accuracy. For the department category of question 3.1, there is no significant differences as p>0.05. An investigation of the gaps identified for question 3.1 and 3.4 by department and position follow.

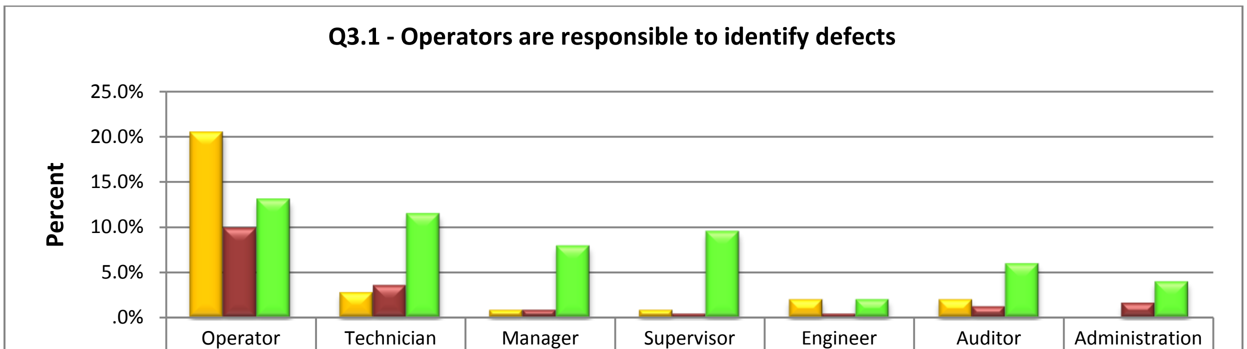
By department and position, the results in percentages for question 3.1 are represented by Figures 4.13 and 4.14 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	21.7%	3.1%	1.6%	.4%	.0%	.0%	2.0%
Not Sure	11.4%	2.0%	1.6%	.4%	.4%	.8%	1.2%
Agree	26.8%	8.7%	5.1%	3.5%	2.0%	2.0%	5.5%

Figure 4.13 – Department response for question 3.1

The results in Figure 4.13 depict a strong relationship of “agreement” within departments which account for 53.6 percent of the total sample. Indeed, there is also a high level of “disagreement” (21.7 percent) within the production department. In attempting to understand the negative responses from production, it can be concluded that since the actual operations take place within the production department, these employees should have the best knowledge as to whether the operators have the ability to identify defects or not. It can therefore be surmised that the overall consensus in “agreement” concurs with the findings of Lee and Peccei (2008:5), who declare that the entire organisation should be responsible for the quality of products. Therefore, by adopting this approach, all employees should maintain this responsibility and operators will not feel restricted as part of their function only.

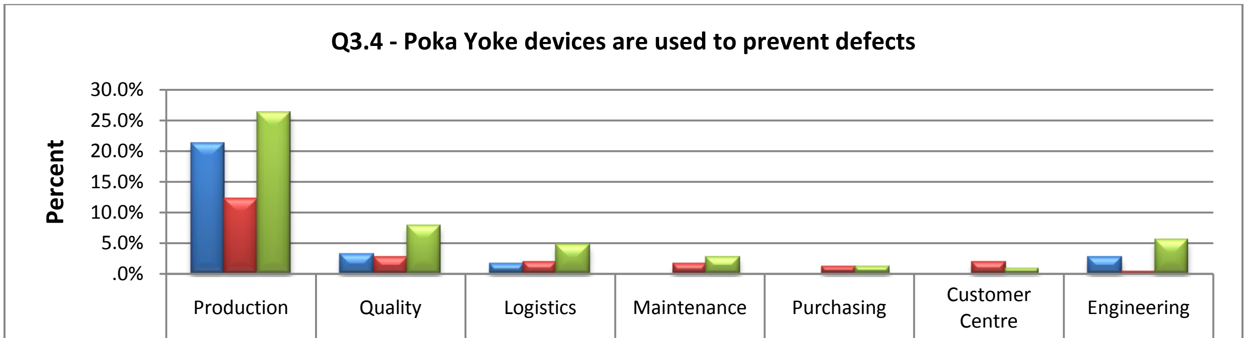


	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	20.5%	2.8%	.8%	.8%	2.0%	2.0%	.0%
Neutral	9.8%	3.5%	.8%	.4%	.4%	1.2%	1.6%
Agree	13.0%	11.4%	7.9%	9.4%	2.0%	5.9%	3.9%

Figure 4.14 – Position response for question 3.1

From the analysis in Figure 4.14, the majority of operators show the highest contention of “disagreement” (20.5 percent of total 43.3 percent by position type) as compared to the remaining positions that “agree” (40.5 percent). This is also confirmed in the departmental analysis as operators are mainly involved within the production department. The analysis reveals that operators do not believe they are responsible for identifying defects. This belief is contradictory to the views of the authors (Lee and Peccei, 2008:11; Chase et al., 2006:474; Liker, 2004:129; ReVelle, 2002:183; Sanchez and Perez, 2001:1436; Karlsson and Ahlstrom, 1996:30) who contend they should. It is possible that the results of “agreement” could be reflecting the perceptions of operators identifying defects during immediate work stoppages only. On the other hand, the results of “disagreement” could verify the views of Santos et al. (2006:78) who are adamant that operators are able to make unintentional errors during inspection and therefore would not like to be held responsible.

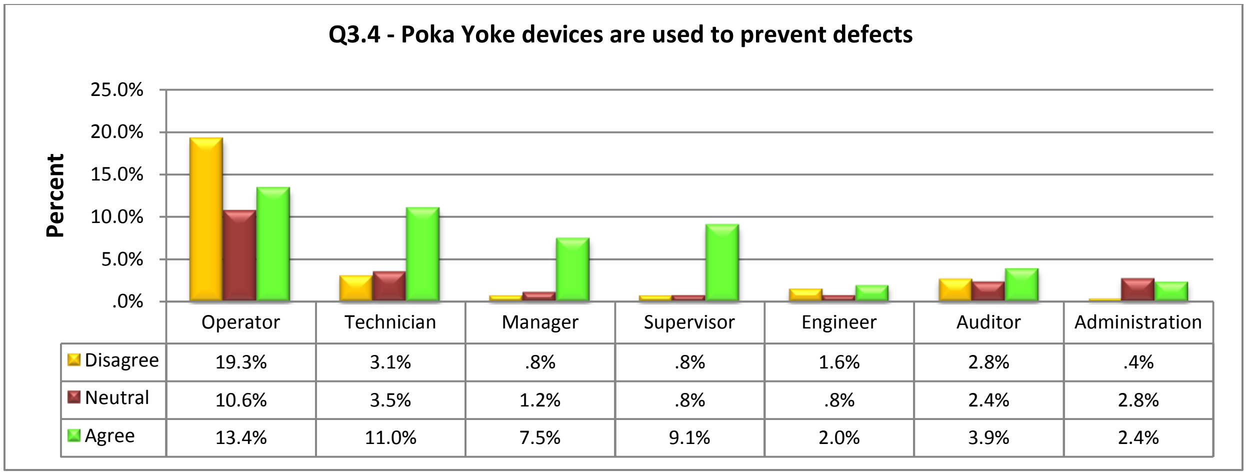
By department and position, the results in percentages for question 3.4 are represented by Figures 4.15 and 4.16 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	21.3%	3.1%	1.6%	.0%	.0%	.0%	2.8%
Not Sure	12.2%	2.8%	2.0%	1.6%	1.2%	2.0%	.4%
Agree	26.4%	7.9%	4.7%	2.8%	1.2%	.8%	5.5%

Figure 4.15 – Department response for question 3.4

The results in Figure 4.15 demonstrate a high contention of “agreement” (49.3 percent in total) between departments. Within the production (21.3 percent), quality (3.1 percent), logistics (1.6 percent) and engineering (2.8 percent) departments, there are also some levels of “disagreement” that exists for this statement. In such circumstances, the contributing factors of “disagreement” could possibly be related to those departments that have immediate interaction with defects when they surface and for which there is no Poka-Yoke devices available to prevent them. Another contemporary issue that affects the use of Poka-Yoke devices could probably result from technology being expensive. However, this view contradicts Santos et al. (2006:81) who suggest that Poka-Yoke devices should be designed such that they are ingenious, simple and cheap.



	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	19.3%	3.1%	.8%	.8%	1.6%	2.8%	.4%
Neutral	10.6%	3.5%	1.2%	.8%	.8%	2.4%	2.8%
Agree	13.4%	11.0%	7.5%	9.1%	2.0%	3.9%	2.4%

Figure 4.16 – Position response for question 3.4

In Figure 4.16, it is evident that the operators (19.3 percent) share the highest content of “disagreement”. Although there are positive responses from other positions, there is also a fair amount of disagreement between the technicians and auditors (5.9 percent in total). Taken together, these positions are directly involved in production, which confirms that not enough Poka-Yoke devices exist within the organisation to prevent defects. This finding is interesting and supported by Santos et al. (2006:76) and Chase et al. (2006:333) who declare that Poka-Yoke devices are commonly used to maintain the zero defects principle. In every sense, therefore, the organisation should evaluate all existing operations and immediate processes that rely on human inspection to be converted such that Poka-Yoke devices can be used. Even if not the prime purpose of this study, Poka-Yoke devices should always be investigated for any process that could result in something going wrong.

4.5 JUST-IN-TIME

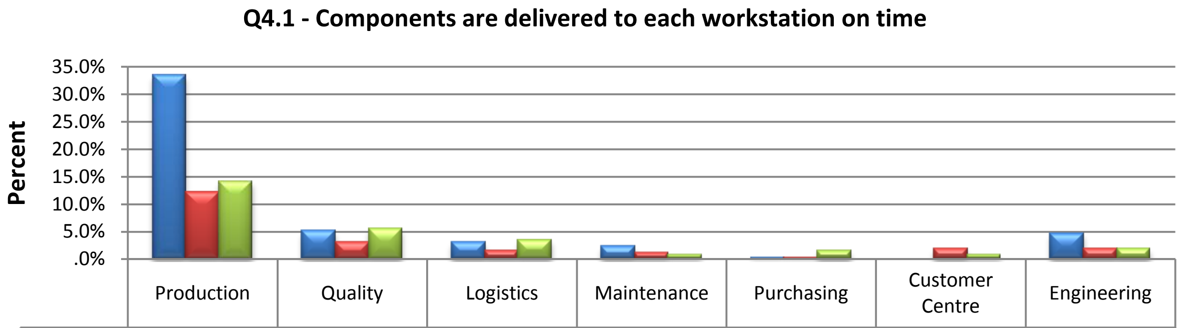
The JIT concept is to maintain a smooth flow in production by providing the required part, in the correct quantity, at the exact point in time, when needed (Bayraktar et al., 2007:849; Chase et al., 2006:474; Sanchez and Perez, 2001:1437; Karlsson and Ahlstrom, 1996:32). Therefore, the fourth principle of JIT is to measure the responses of material movement in production. The statistical scores for each of the three questions representing the JIT principle are illustrated in Table 4.4.

Question	Mean	Gap	Communality	p-value for Department	p-value for Position	Cronbach's Alpha
4.1) Components are delivered to each workstation on time	2.7	-2.3	0.691	0.011	0.004	
4.2) Components are delivered to each workstation in the correct quantities	2.7	-2.3	0.747	0.130	0.047	
4.3) Correct components are delivered to each workstation	2.9	-2.1	0.709	0.018	0.001	
Overall	2.8	-2.2	0.716			0.821

Table 4.4 Results pertaining to the principle of just-in-time

It can be concluded from Table 4.4 that questions 4.1 and 4.2 indicate an approximate 2:1 ratio of “disagreement” to “agreement”. In fact, all statements show overall “disagreement”; however, the most significant variation was identified through percentage evaluation and are pronounced in question 4.1 and 4.2. The communality value for question 4.1 indicates that the model accounts for 69 percent of the variation. Similarly, 75 percent of the variation is explained by the model for question 4.2. The overall reliability score of 0.821 highlights the accuracy of this section. For question 4.1, there is a significant relationship within departments and positions ($p<0.05$). On the other hand, for question 4.2 there is no significant relationship within departments ($p>0.05$); however, there is variation in responses within the position category ($p<0.05$). Therefore, an investigation of the gaps identified for question 4.1 and 4.2 by department and position, follow.

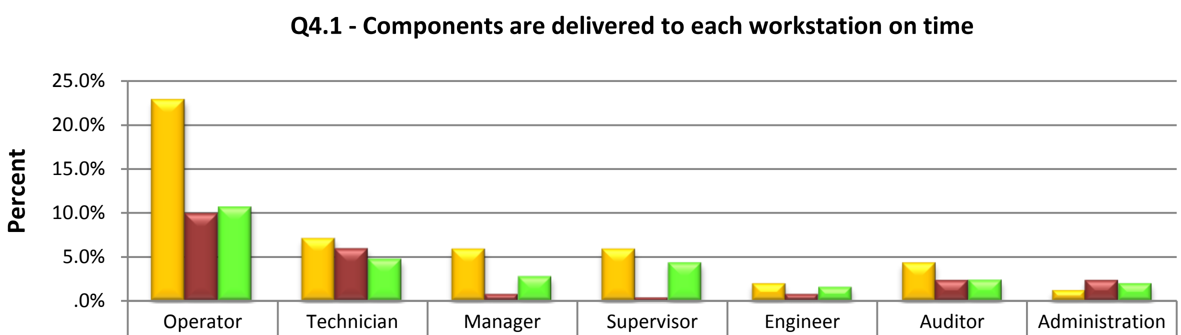
By department and position, the results in percentages for question 4.1 are represented by Figures 4.17 and 4.18 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	33.5%	5.1%	3.1%	2.4%	0.4%	0.0%	4.7%
Not Sure	12.2%	3.1%	1.6%	1.2%	0.4%	2.0%	2.0%
Agree	14.2%	5.5%	3.5%	.8%	1.6%	0.8%	2.0%

Figure 4.17 – Department response for question 4.1

It can be deduced from Figure 4.17 that the results within departments indicate a trend of "disagreement" (49.2 percent of total sample) for components being delivered to each workstation on time. As can be seen, the customer centre department is not directly involved in production and therefore has a high response of "uncertainty". In convergence, it is ironic that the purchasing and logistics departments indicate some level of "agreement" (5.1 percent of total sample). This could be the case since these departments are responsible to ensure that material is always available for production. These findings coincide with Zylstra (2006:198) who contends that planners, normally within the logistics department, should spend more time updating and managing methods used in triggering replenishment to ensure components are delivered to each workstation on time.

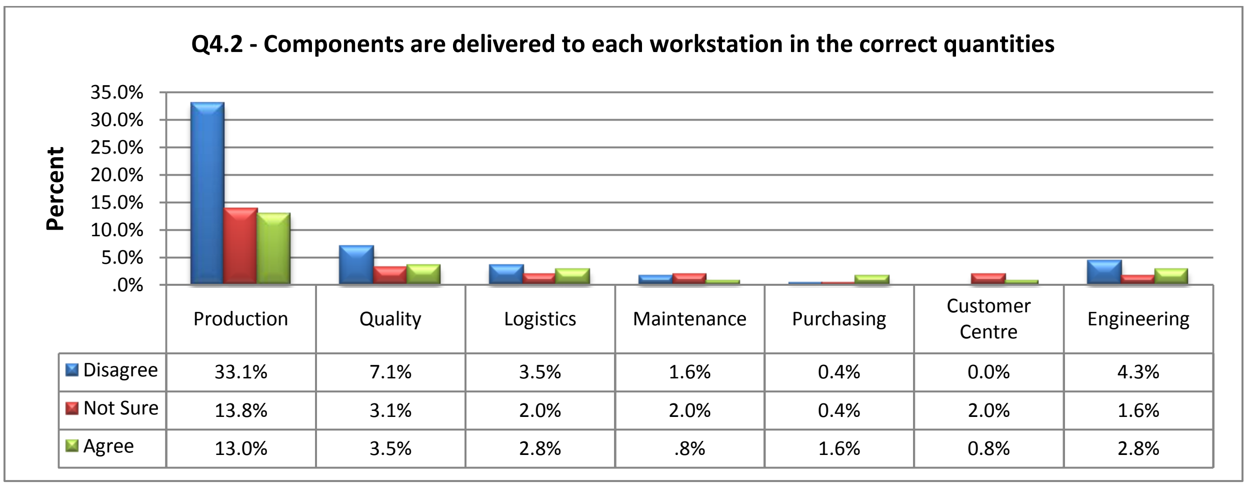


	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	22.8%	7.1%	5.9%	5.9%	2.0%	4.3%	1.2%
Neutral	9.8%	5.9%	.8%	.4%	.8%	2.4%	2.4%
Agree	10.6%	4.7%	2.8%	4.3%	1.6%	2.4%	2.0%

Figure 4.18 – Position response for question 4.1

It is evident from Figure 4.18 that with the exception of the administration category, all other positions (48 percent in total) do not believe that components are delivered to each workstation on time. The results obtained could possibly mean that processes constantly wait for parts during production. Apart from the difficulty of trying to eliminate this problem, it is important to first identify the different contributing factors. For the purpose of this study, these are highlighted by ReVelle (2002:174) in chapter 2 under section 2.3.4. Perhaps a more realistic middle path would be for the organisation to focus on facilitating a smooth flow in production by carefully planning and scheduling the flow of resources throughout all processes.

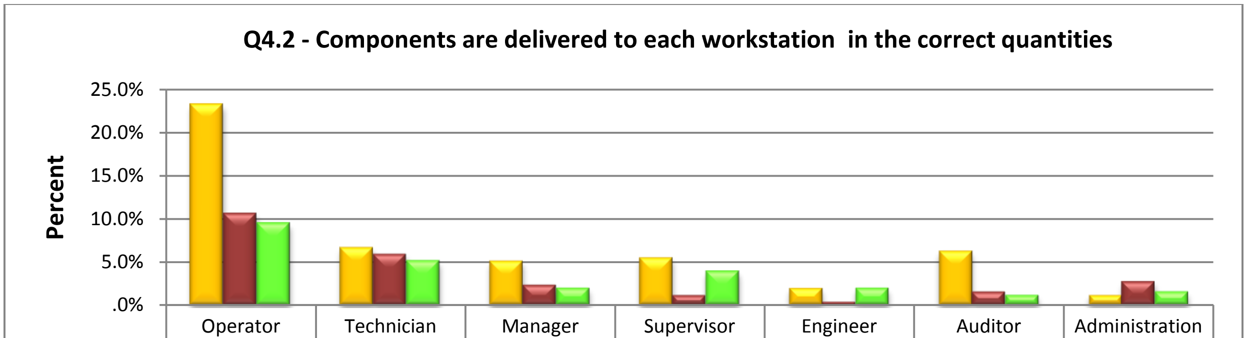
By department and position, the results in percentages for question 4.2 are represented by Figures 4.19 and 4.20 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	33.1%	7.1%	3.5%	1.6%	0.4%	0.0%	4.3%
Not Sure	13.8%	3.1%	2.0%	2.0%	0.4%	2.0%	1.6%
Agree	13.0%	3.5%	2.8%	.8%	1.6%	0.8%	2.8%

Figure 4.19 – Department response for question 4.2

Figure 4.19 reveals that the responses to this statement are similar to those highlighted in question 4.1 above; which indicates strong “disagreement” within departments. The highest contention of “disagreement” was within the production department (33.1 percent) itself. As such, it is not uncommon that since the production department works with these components they should have actual knowledge of the delivery of the correct quantities of components. In most cases, Santos et al. (2006:5) contend that delivering the correct quantity of components is strongly correlated with delivering components on time. Such a result could be attributed to the significant work of the Japanese, who specify that this is the basic idea of the JIT concept. Altogether, it can be inferred from the results in this study that there is very little control of material supplied to production.



	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	23.2%	6.7%	5.1%	5.5%	2.0%	6.3%	1.2%
Neutral	10.6%	5.9%	2.4%	1.2%	.4%	1.6%	2.8%
Agree	9.4%	5.1%	2.0%	3.9%	2.0%	1.2%	1.6%

Figure 4.20 – Position response for question 4.2

As highlighted in Figure 4.20, there is a general trend of "disagreement" by the position category as well (50 percent of total sample). These results also support the notion that there is a causal relationship between quantity and timeliness of components being delivered to workstations. The ranking of these factors is consistent with the principles of JIT and are aligned with the authors (Bayraktar et al., 2007:849; Chase et al., 2006:474; Sanchez and Perez, 2001:1437; Karlsson and Ahlstrom, 1996:32) proclaiming that it involves providing the required part, in the correct quantity, at the exact point in time during production. It has been observed that pressure upon an organisation from customers can sometimes affect the entire production flow. This implies that changing customer demands affects planned schedules; however, organisations in general should have counter measures in place to overcome such situations.

4.6 MULTIFUNCTIONAL TEAMS

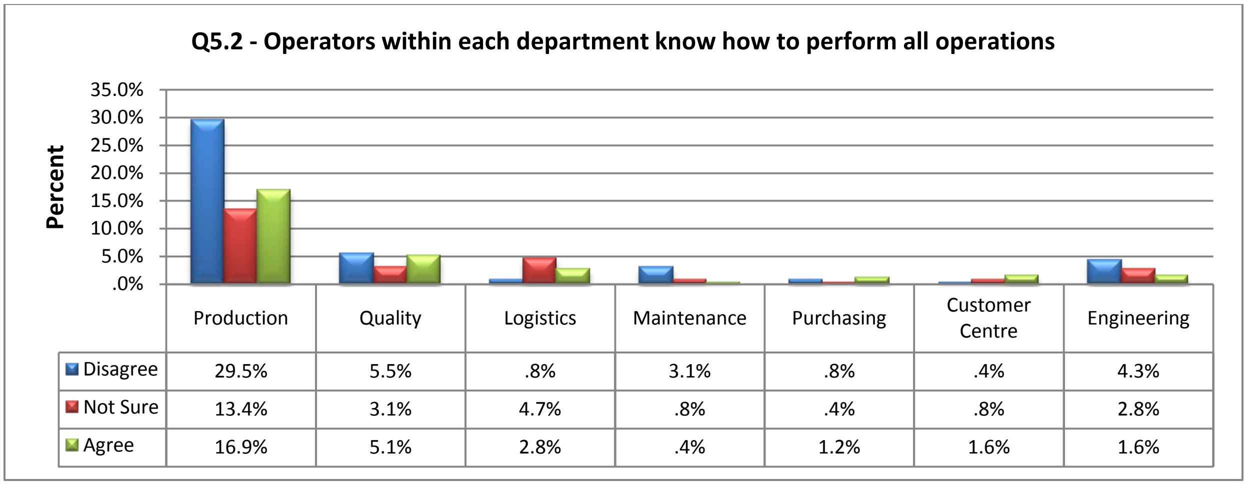
The concept of multifunctional teams is to ensure employees work together and accept more responsibility to perform a wider range of tasks. The questions structured around this principle aims to evaluate the responses on teamwork and multitasking. The individual scores for each question and overall ratings for the principle on multifunctional teams are presented in Table 4.5.

Question	Mean	Gap	Communality	p-value for Department	p-value for Position	Cronbach's Alpha
5.1) Multifunctional teams exist within the organisation	2.9	-2.1	0.598	0.128	0.000	
5.2) Operators within each department know how to perform all operations	2.8	-2.2	0.543	0.008	0.009	
5.3) The organisation does not rely on designated employees to perform specific tasks	2.7	-2.3	0.458	0.819	0.078	
5.4) Tasks are rotated between operators within a department	3.0	-2.0	0.566	0.097	0.001	
5.5) Teamwork promotes trust, support, respect and collaboration	4.1	-0.9	0.795	0.480	0.680	
Overall	3.1	-1.9	0.592			0.593

Table 4.5 Results pertaining to the principle of multifunctional teams

Questions 5.2 and 5.3 show a relatively strong “disagreement”, whilst question 5.5 indicates strong “agreement”. The first two questions also relate to the independence that is given to employees, as seen by operators in question 3, under the principle of zero defects. Looking at the overall score for question 5.5, there is significant evidence to declare that employees see the benefit of working together. From the percentage analysis, it can be established that the largest gaps exist for question 5.2, 5.3 and 5.5. It can be inferred from Table 4.5 that 80 percent of the variation for question 5.5 is explained by the model. However, there is a relatively low explanation by the model for questions 5.2 and 5.3 with a variation of 54 percent and 46 percent respectively. This section also indicates a relatively low accuracy from the overall reliability score of 0.593. There is a significant relationship within department and within position for question 5.2 ($p<0.05$). However, for questions 5.3 and 5.5, the model indicates insignificant relationship within departments and positions ($p>0.05$). An investigation of the gaps identified for question 5.2, 5.3 and 5.5 by department and position follow.

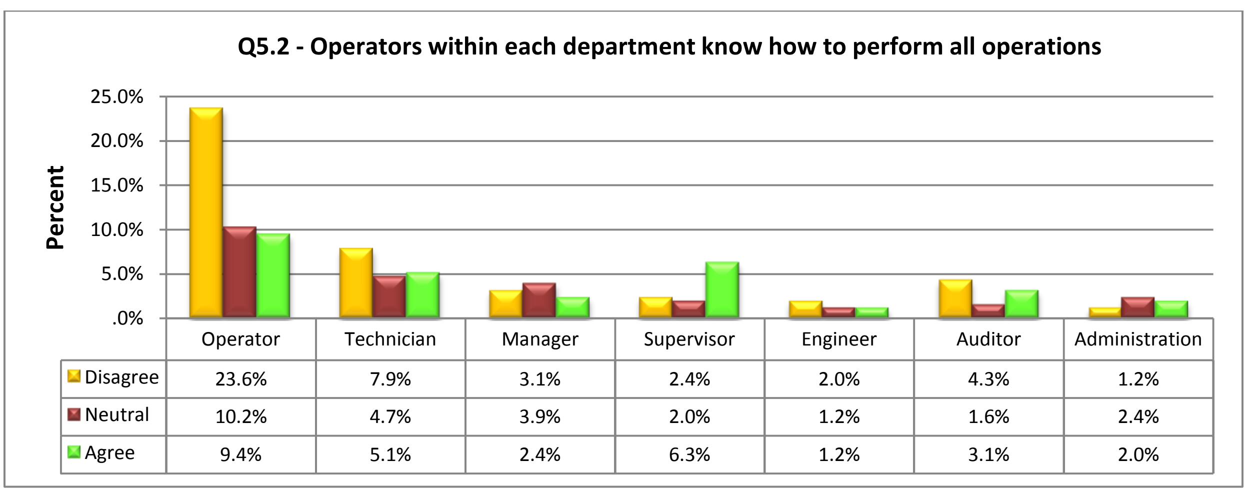
By department and position, the results in percentages for question 5.2 are represented by Figures 4.21 and 4.22 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	29.5%	5.5%	.8%	3.1%	.8%	.4%	4.3%
Not Sure	13.4%	3.1%	4.7%	.8%	.4%	.8%	2.8%
Agree	16.9%	5.1%	2.8%	.4%	1.2%	1.6%	1.6%

Figure 4.21 – Department response for question 5.2

As presented in Figure 4.21, 29.5 percent of production, 5.5 percent of quality, 3.1 percent of maintenance and 4.3 percent of engineering “disagree” with this statement. There is a high level of “uncertainty” within the logistics department. By comparison, therefore, it can be seen that operators are designated to perform only their specific job functions and are not able to multitask. Within the context of the lean manufacturing concept, these results are in contradiction with the authors (Olivella et al., 2008:803; Santos et al., 2006:68; Karlsson and Ahlstrom, 1996:34) positing that this principle allows employees to perform many different tasks. The results strongly suggest that operators should be exposed to frequent job rotation as a means of multitasking.

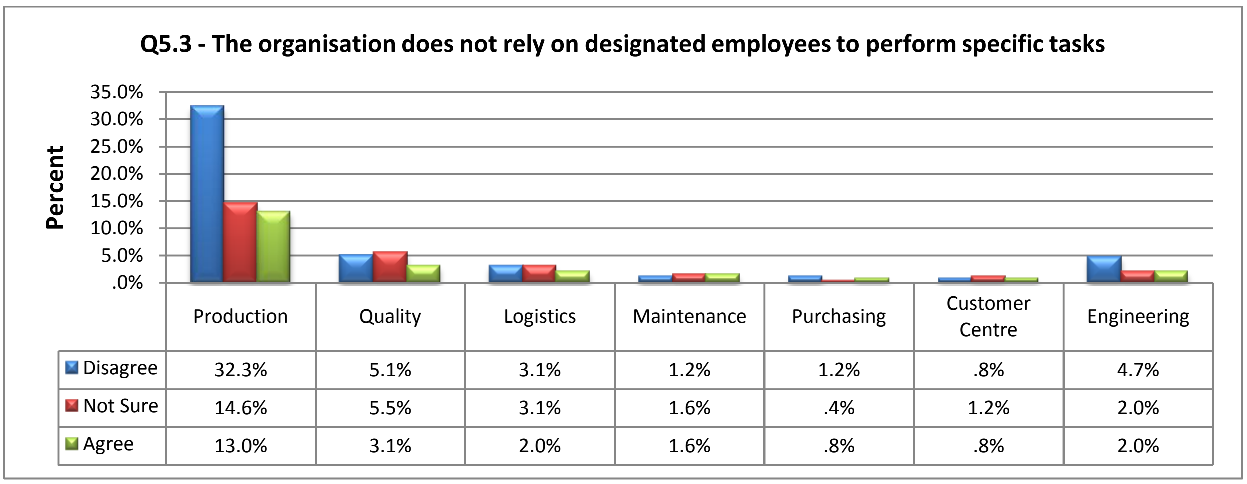


	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	23.6%	7.9%	3.1%	2.4%	2.0%	4.3%	1.2%
Neutral	10.2%	4.7%	3.9%	2.0%	1.2%	1.6%	2.4%
Agree	9.4%	5.1%	2.4%	6.3%	1.2%	3.1%	2.0%

Figure 4.22 – Position response for question 5.2

From the range of positions, the supervisors (6.3 percent of total 10.7 percent by position type) mainly “agree” with this statement as represented in Figure 4.22. This may be due to the supervisors' wanting to indicate that their immediate subordinates are expected to perform all operations in their particular section. The operators, technicians and auditors combined (35.8 percent of total sample) share similar views of "disagreement" whilst the remainder of positions are evenly spread with their responses. These findings contradict the views of Chase et al. (2006:435) and Womack and Jones (1996:122) who maintain that multitasking employees and conducting frequent job rotation allows the organisation to make full use of employees' skills. One of the key benefits of multi-tasking employees, according to authors (Comm, 2005:64; Karlsson and Ahlstrom, 1996:37; Forza, 1996:48), is that it enables the organisation to reduce indirect departments and costs.

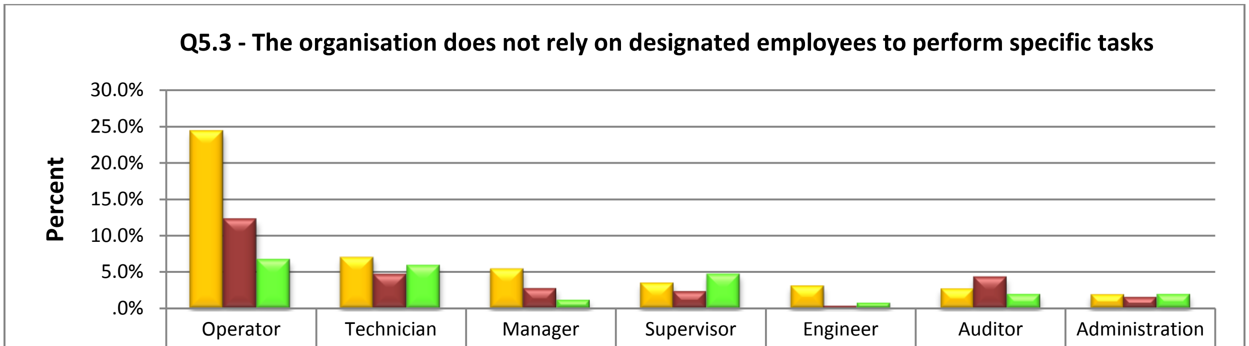
By department and position, the results in percentages for question 5.3 are represented by Figures 4.23 and 4.24 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	32.3%	5.1%	3.1%	1.2%	1.2%	.8%	4.7%
Not Sure	14.6%	5.5%	3.1%	1.6%	.4%	1.2%	2.0%
Agree	13.0%	3.1%	2.0%	1.6%	.8%	.8%	2.0%

Figure 4.23 – Department response for question 5.3

From the results presented in Figure 4.23, it can be deduced that the production and engineering department (37 percent in total) have a high response rate of "disagreement" to this statement. This could mean that within these departments there is strong reliance on designated employees to perform specific tasks. It also confirms another significant finding which indicates that there is no workforce flexibility in the organisation. Within the quality and logistics department there were many who "disagreed" with the statement as there were those who were "uncertain". To a certain extent, the functions within the production department should not be vulnerable to designated employees as this could lead the organisation to production downtime and losses. This is supported by the findings of Wallace (2004:803) who reported that multi-skilling employees was used as a strategy in response to the high levels of absenteeism experienced in Swedish organisations.

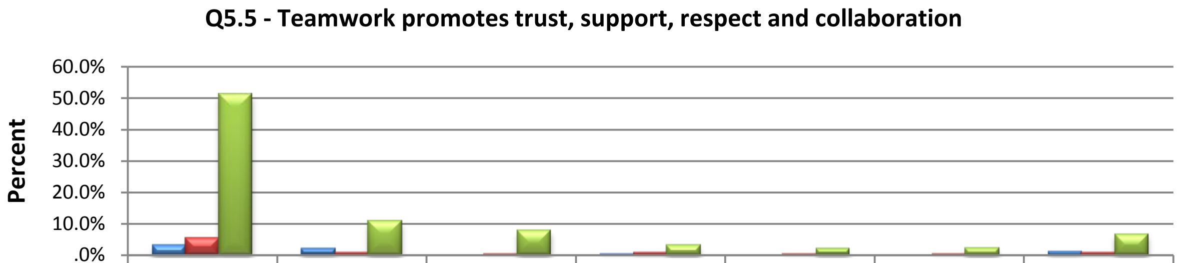


	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	24.4%	7.1%	5.5%	3.5%	3.1%	2.8%	2.0%
Neutral	12.2%	4.7%	2.8%	2.4%	.4%	4.3%	1.6%
Agree	6.7%	5.9%	1.2%	4.7%	.8%	2.0%	2.0%

Figure 4.24 – Position response for question 5.3

Figure 4.24 indicates that by position as well, all categories of employees “disagree” with the statement (48.4 percent of total sample). It is noted that within the auditor position there is a high level of uncertainty (4.3 percent). However, supervisors indicate a fair amount of “agreement” which could possibly mean that they ensure employees within their teams are able to multitask. This could be attributed mainly to absenteeism that affects production targets and therefore indicates no reliance on designated employees to perform specific operations. This finding is in consensus with the authors (Comm 2005:65; Sanchez and Perez, 2001:1447; Forza, 1996:53; Womack and Jones, 1996:60) who believe that the production system will be sensitive to absenteeism if functions are dependent on designated employees.

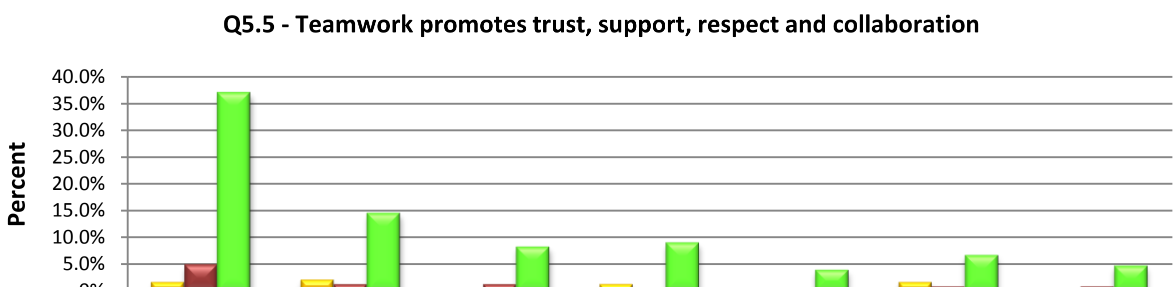
By department and position, the results in percentages for question 5.5 are represented by Figures 4.25 and 4.26 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	3.1%	2.0%	.0%	.4%	.0%	.0%	1.2%
Not Sure	5.5%	.8%	.4%	.8%	.4%	.4%	.8%
Agree	51.2%	11.0%	7.9%	3.1%	2.0%	2.4%	6.7%

Figure 4.25 – Department response for question 5.5

As it can be seen in Figure 4.25, all responses within departments "agree" that team work is effective within an organisation (84.3 percent of total sample). Another possible interpretation could mean that the employees view teamwork as an important competitive strategy. This result is consistent with findings from the literature (Bicheno, 2004:144; Heizer and Render, 2004:375) that teamwork promotes trust, support, respect and collaboration within the organisation. A necessary suggestion would be to establish if team work is currently practised within the organisation as the results reveal that employees find teamwork effective and beneficial. It can be argued that employees should also have an abundance of self confidence in their area of expertise to be successful in a team. However, it can be inferred that organisational support is also necessary to achieve effective teamwork.



	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	1.6%	2.0%	.0%	1.2%	.4%	1.6%	.0%
Neutral	4.7%	1.2%	1.2%	.4%	.0%	.8%	.8%
Agree	37.0%	14.6%	8.3%	9.1%	3.9%	6.7%	4.7%

Figure 4.26 – Position response for question 5.5

The entire position category in Figure 4.26 shows a high level of “agreement” with this statement. For all participants, it appears that team work is beneficial to their working environment. It is important to highlight the views of Wallace (2004:803) who contends that teamwork is influenced by a variety of factors and that it is imperative for employees to have the correct skills to form multifunctional teams. Therefore, it can be deemed important that the organisation provides training for employees in developing the appropriate skills needed to work in teams. It has been broadly embraced by Wallace (2004:803) that an important aspect of achieving effective teamwork involves team members being comfortable enough to admit when they are wrong without fear of embarrassment. The overall concept of teamwork definitely supports the organisation in maintaining the lean manufacturing philosophy. For example, authors such as Olivella et al. (2008:803); Santos et al. (2006:68); Karlsson and Ahlstrom (1996:34), comment that multifunctional teams are a salient feature of lean manufacturing.

4.7 DECENTRALISED RESPONSIBILITIES

The concept behind decentralising responsibilities involves the transfer of decision-making roles to employees on the production floor. Therefore, the principle of decentralisation seeks to establish how the participants rate the extent to which responsibilities are controlled and maintained within the organisation. All significant results pertaining to this principle are presented in Table 4.6.

Question	Mean	Gap	Communality	p-value for Department	p-value for Position	Cronbach's Alpha
6.1) Operators are given more responsibilities in production	2.8	-2.2	0.650	0.003	0.001	
6.2) The hierarchical level in the organisation is kept to a minimum	2.9	-2.1	0.531	0.000	0.000	
6.3) Operators are encouraged to make decisions concerning production and quality	2.7	-2.3	0.666	0.018	0.000	
6.4) Operators have real influence and power when they participate in decision making instead of serving as consultants	2.7	-2.3	0.631	0.067	0.000	
Overall	2.8	-2.2	0.619			0.745

Table 4.6 Results pertaining to the principle of decentralised responsibilities

There seems to be overall “disagreement” in this category. As this relates particularly to operators, it again supplements the pattern of scoring by operators. The analysis of communality scores in Table 4.6 indicates that the model explains approximately above 60% of the variations for all questions with the exception of question 6.2, which has a communality value of 0.531. However, the reliability score of 0.745 for this section confirms that the instrument measured what it purports to measure. Further statistical analysis of Chi-Square testing indicates significant relationships within departments and positions for all questions ($p<0.05$) except for question 6.4 (within department) which has a score of $p>0.05$.

Even though independence and contributions by employees are encouraged, the marginal majority of employees do not believe that this takes place. This leads to the question of who should be given responsibility. From the literature, there is consensus among the authors (Olivella et al., 2008:804; Chase et al., 2006:474; Forza, 1996:44) that employees should be assigned responsibilities for production, quality, maintenance and planning. The significant amount of evidence highlighted in chapter 2 proceeds to suggest that empowering employees encourages work performance and willingness to take added responsibility.

According to the results presented in Table 4.6, it can be inferred that question 6.1 indicates that the organisation does not have sufficient trust in the employees to allocate more responsibilities to them. Question 6.2 reveals that the organisation currently has a large range of positions in the hierarchical structure. Question 6.3 highlights that operators are not encouraged to participate in quality and productivity activities. Question 6.4 suggests that employees are not respected for their opinions. There is no further analysis performed to investigate responses within departments and positions as there is overall disagreement for all questions. One insight into decentralising responsibilities onto employees ensures that talent is spread throughout the organisation and not restricted to specific positions.

4.8 INTEGRATED FUNCTIONS

The principle of integrating functions in production is to create an environment in which employees are able to perform many different tasks. The objective of questions pertaining to integrated functions is to establish whether employees are given opportunities to multitask. The rated scores of responses for each of the questions representing the principle of integrated functions are illustrated in Table 4.7.

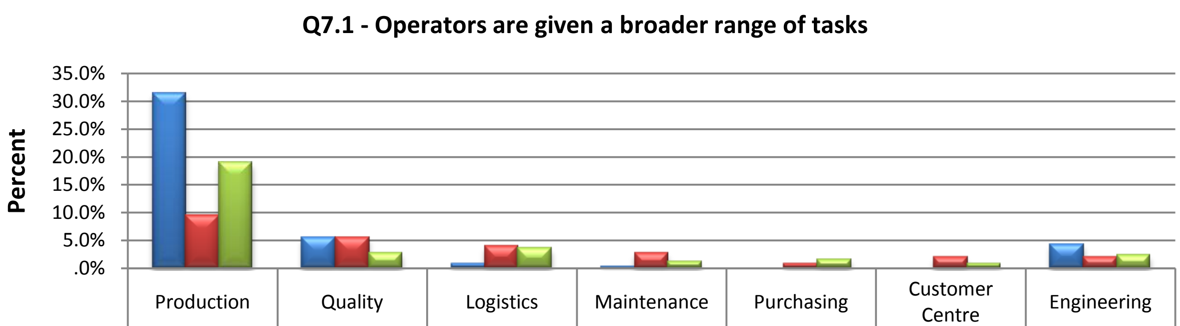
Question	Mean	Gap	Communality	p-value for Department	p-value for Position	Cronbach's Alpha
7.1) Operators are given a broader range of tasks	2.8	-2.2	0.591	0.000	0.001	
7.2) Sufficient training is provided to multi-skill employees	3.1	-1.9	0.576	0.712	0.013	
7.3) Employees are rewarded for learning new skills	2.6	-2.4	0.569	0.005	0.136	
Overall	2.8	-2.2	0.579			0.607

Table 4.7 Results pertaining to the principle of integrated functions

The most significant gaps evident in Table 4.7 exists for question 7.1 and 7.3 since it shows stronger “disagreement”. These questions pertain to the variety of tasks that are allocated to operators and whether rewards are provided for learning new skills. Participants do not “strongly agree” with the statement that operators are given a broader range of tasks. Almost half (48 percent) of the participants are dissatisfied that they are not rewarded for learning new skills. Even though there is some dissatisfaction, employees recognise that opportunities are provided for them to improve their skills. The overall communality value for all factors taken together explains 58 percent of the total variation for this section.

In terms of accuracy, the Cronbach's Alpha value of 0.607 indicates low reliability as compared to the remainder of the sections. On the other hand, there is a statistically significant relationship within department and position for question 7.1 ($p<0.05$). For question 7.2, there is a significant relationship within departments ($p<0.05$) but not within positions ($p>0.05$). Therefore, further investigation of the gaps identified for question 7.1 and 7.3 by department and position follow. This section links questions of innovation and employee participation in response to evaluating the effectiveness within the organisation.

By department and position, the results in percentages for question 7.1 are represented by Figures 4.27 and 4.28 respectively.

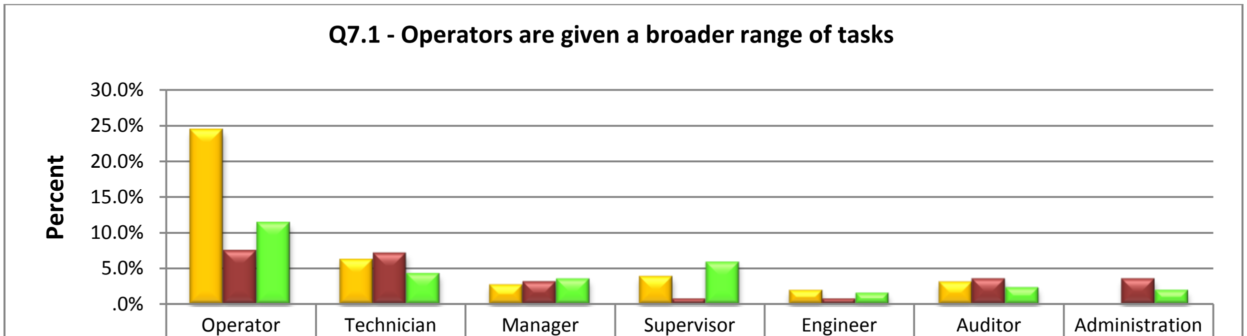


	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	31.5%	5.5%	.8%	.4%	.0%	.0%	4.3%
Not Sure	9.4%	5.5%	3.9%	2.8%	.8%	2.0%	2.0%
Agree	18.9%	2.8%	3.5%	1.2%	1.6%	.8%	2.4%

Figure 4.27 – Department response for question 7.1

Figure 4.27 illustrates that the production, quality and engineering department (total of 41.3 percent) "disagrees" with this statement. Within the quality department there is an equal response of "uncertainty" and "disagreement" whilst the logistics, maintenance and customer centre departments indicate a higher level of "uncertainty". For the production department specifically, the results indicate that operators are restricted and are not given opportunities to multitask.

It can be suggested from the results that employees should be multi-skilled so that they are able to perform many different functions effectively and which could also enhance their career opportunities. Therefore, the organisation should invest in providing the appropriate training and present more opportunities for operators to grow within the organisation. However, within certain departments, it is difficult to multi-skill as there could be special requirements for a particular position that needs sophisticated knowledge and experience.



	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	24.4%	6.3%	2.8%	3.9%	2.0%	3.1%	.0%
Neutral	7.5%	7.1%	3.1%	.8%	.8%	3.5%	3.5%
Agree	11.4%	4.3%	3.5%	5.9%	1.6%	2.4%	2.0%

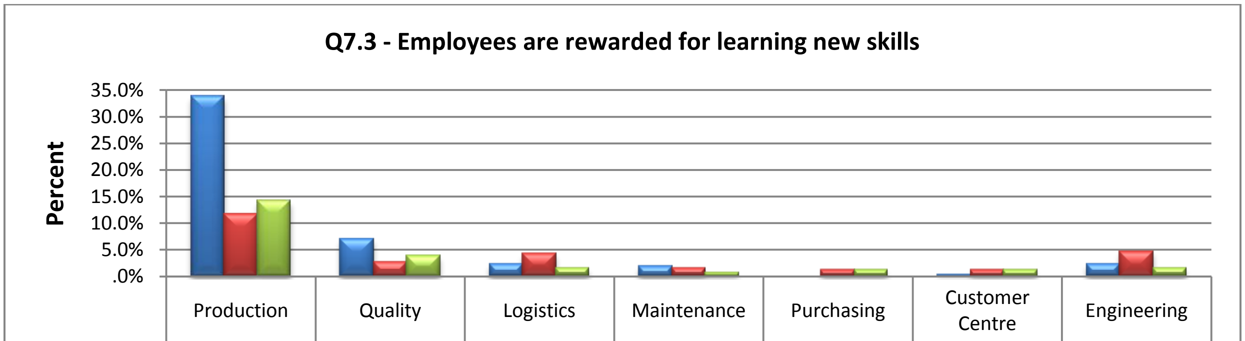
Figure 4.28 – Position response for question 7.1

As highlighted in Figure 4.28, it is interesting to note how operators significantly indicate the highest responses of “disagreement” (24.4 percent of total 43.3 percent by position type). This could be the result of their physical involvement in production and for which they are not given opportunities to perform a broader range of tasks. From this viewpoint, there is contradiction with the findings of the lean manufacturing experts (Comm, 2005:64; Karlsson and Ahlstrom, 1996:37; Forza, 1996:48) who stress that operators performing a broader range of tasks reduce indirect departments such as quality. Managers and supervisors, on the other hand, “agree” with this statement (9.4 percent of total sample).

In comparing the results, it makes sense for managers and supervisors to agree with the statement as they delegate and allocate tasks to the operators and expect results.

As found by Forza (1996:46), integrating functions allow operators to help each other in moments of difficulty which stresses another possible argument on the importance of allowing operators to perform a broader range of tasks.

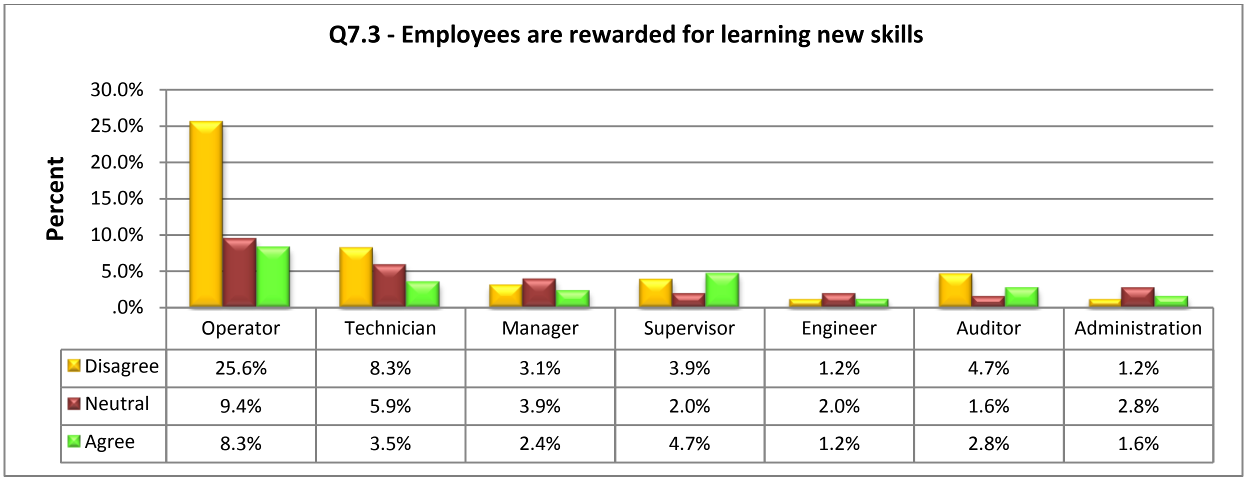
By department and position, the results in percentages for question 7.3 are represented by Figures 4.29 and 4.30 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	33.9%	7.1%	2.4%	2.0%	.0%	.4%	2.4%
Not Sure	11.8%	2.8%	4.3%	1.6%	1.2%	1.2%	4.7%
Agree	14.2%	3.9%	1.6%	.8%	1.2%	1.2%	1.6%

Figure 4.29 – Department response for question 7.3

It is evident in Figure 4.29 that production, quality and maintenance "disagree" with this statement (43 percent in total), whilst the logistics and engineering departments are "uncertain" (9 percent of sample). The findings are consistent with Schroeder (2007:404) and Forza (1996:49) who believe that employees' loyalty and commitment is significantly influenced by appraisal schemes. In general, employees tend to be sceptical and do not feel valued when they learn new skills and are not compensated by an appropriate remuneration system. Therefore, to remove the disillusionment that may occur as a result of training, the organisation should attempt to make the existing internal training policy more structured so that employees can be rewarded adequately for learning new skills.



	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	25.6%	8.3%	3.1%	3.9%	1.2%	4.7%	1.2%
Neutral	9.4%	5.9%	3.9%	2.0%	2.0%	1.6%	2.8%
Agree	8.3%	3.5%	2.4%	4.7%	1.2%	2.8%	1.6%

Figure 4.30 – Position response for question 7.3

The results presented in Figure 4.30 for question 7.3 reveal that operators, technicians and auditors “disagree” with this statement (a combined total of 38.6 percent). The supervisory positions indicate an almost equal ratio of “agreement” to “disagreement”. Of particular interest, managers (3.9 percent of sample) indicate a high level of uncertainty although they are responsible for deciding employees’ rewards. The tendency of employees not being rewarded for learning new skills is in contradiction with Schroeder (2007:404) who believes that increased job responsibility and enlargement should be compensated for accordingly. The interpretation of these findings suggests that human nature is such that employees will respond to whatever incentives and rewards are in place.

4.9 VERTICAL INFORMATION SYSTEMS

The concept of vertical information systems is to ensure that all types of information are continuously communicated to employees and displayed throughout the organisation. This section links questions of transparency within the organisation in order to evaluate how and what type of important information is communicated to employees. The results of the four questions representing the principle of vertical information systems is summarised in Table 4.8.

Question	Mean	Gap	Communality	p-value for Department	p-value for Position	Cronbach's Alpha
8.1) The organisation is transparent in all aspects of the business	2.8	-2.2	0.663	0.016	0.008	
8.2) Strategic information such as the organisations market plans, and financial performance is communicated to all employees	3.0	-2.0	0.721	0.090	0.013	
8.3) Operational information such as productivity, timeliness and quality is communicated to all employees	3.2	-1.8	0.678	0.585	0.000	
8.4) Information is continually displayed in dedicated spaces throughout the organisation	3.3	-1.7	0.660	0.143	0.000	
Overall	3.1	-1.9	0.680			0.831

Table 4.8 Results pertaining to the principle of vertical information systems

The majority of the participants do not believe that the organisation is transparent in all aspects of the business (43 percent). Therefore, an investigation of the gaps identified for question 8.1 within departments and positions is required. The overall reliability score of 0.831 may be viewed as relative lack of error for this section. The total variation of 68 percent is explained by the model while there is a significant relationship for question 8.1 within departments and positions ($p<0.05$).

Altogether, there is consensus in agreement for questions 8.2, 8.3 and 8.4 as depicted in Table 4.8. It can be inferred that necessary information relative to organisation performance, market plans and operational information is made available through various channels such as notice boards. For question 8.2, the primary effect of providing strategic information to all employees creates an atmosphere of trust within the organisation, as suggested by Motwani (2003:342). In relation to question 8.3, the effect of providing operational information is validated by the findings of Forza (1996:47) who asserts that continuously providing operational information, allows employees to immediately acknowledge the problems identified. Lastly for question 8.4, the overall positive findings are in consensus with the views of Bicheno (2004:61) who documents that visual management allows employees to be responsive for day to day operations.

By department and position, the results in percentages for question 8.1 are represented by Figures 4.31 and 4.32 respectively.

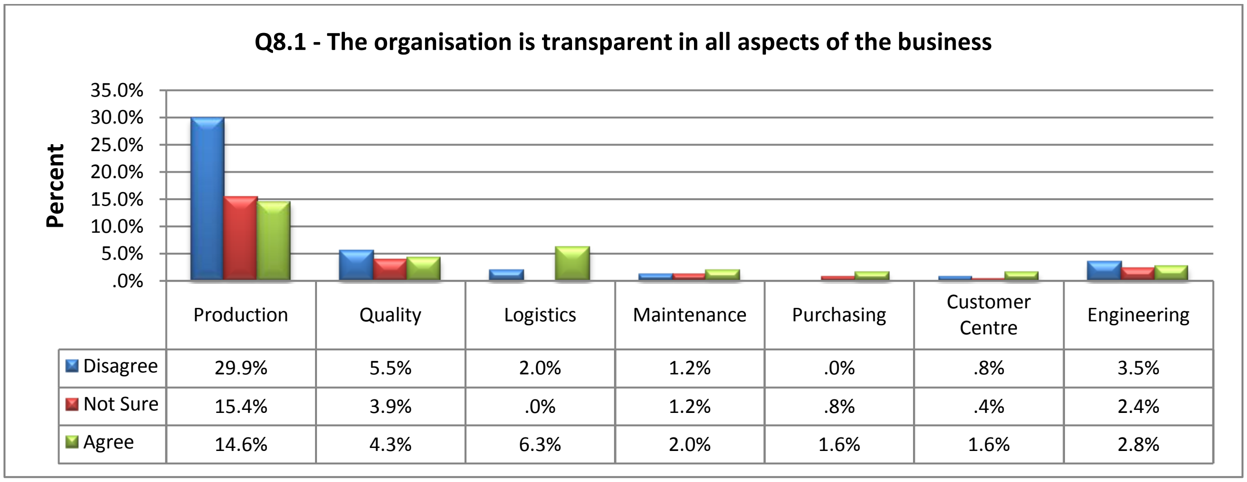


Figure 4.31 – Department response for question 8.1

The results in Figure 4.31 indicate that production, quality and engineering (combined total of 38.9 percent) do not believe that the organisation is transparent in all aspects of the business. Logistics, maintenance, purchasing and customer centre “agree” with this statement to some extent (11.5 percent in total). Therefore, it is possible that since there are some aspects of the business available only to certain departments, this could be the result of the contradicting views in responses. To get some idea of the appropriateness of the assumption, it could be attributable to the fact that different departments are exposed to a variety of levels and types of information. For example, the finance department would have full access to sales prices and manufacturing turnover costs.

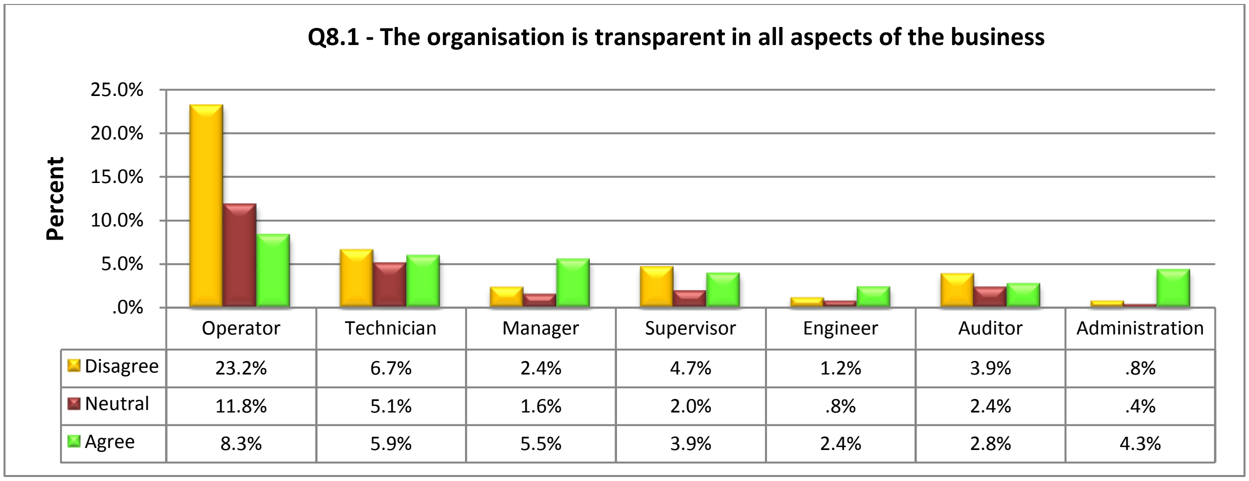


Figure 4.32 – Position response for question 8.1

Results shown in Figure 4.32 indicate that operators, technicians, supervisors and auditors (38.5 percent in total) “disagree” with the statement. The findings contradict the views of Womack and Jones (1996:26) who believe that transparency allows employees to discover better ways to create value. As far as positions are concerned, it could mean that different job categories have exposure to various aspects of the business. The implication here is that only the managers and administration employees “agree” that the organisation is transparent in all aspects of the business.

4.10 PULL INSTEAD OF PUSH

The concept of the pull instead of push is to manufacture products to actual customer order and not to stock (Taj, 2005:632). This section evaluates employees’ responses on questions pertaining to production planning. The statistical analyses of the responses are highlighted in Table 4.9.

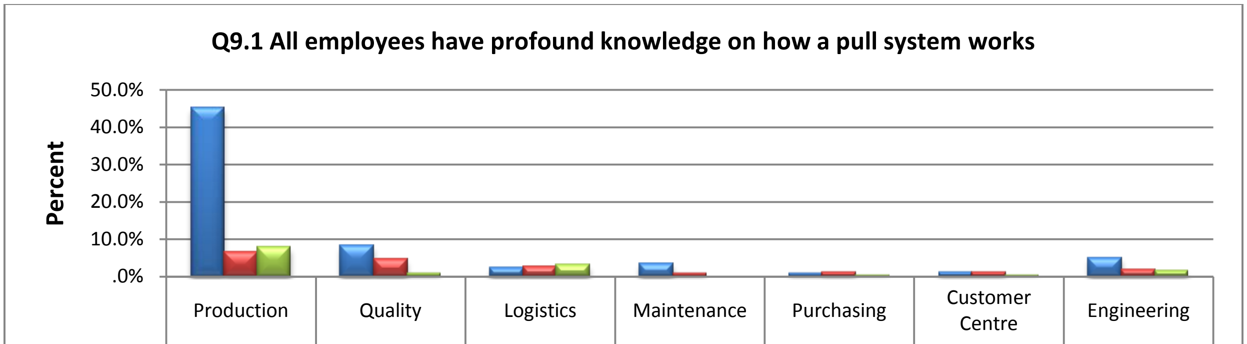
Question	Mean	Gap	Communality	p-value for Department	p-value for Position	Cronbach's Alpha
9.1) All employees have profound knowledge on how a pull system works	2.2	-2.8	0.627	0.003	0.036	
9.2) Production is made to actual customer demand rather than to forecasts	3.0	-2.0	0.696	0.437	0.004	
9.3) Each workstation pulls the output from the preceding process	2.9	-2.1	0.668	0.008	0.000	
9.4) A Kanban card system is used to signal when material is required	2.4	-2.6	0.697	0.001	0.004	
Overall	2.6	-2.4	0.672			0.773

Table 4.9 Results pertaining to the principle of pull instead of push

Some amount of training needs to be done with respect to questions 9.1 and 9.4, as most employees do not know what a “pull system” is or the functioning of the Kanban card system. However, these may be department or position specific responses. The overall variance of 67 percent is explained by the model. Since Cronbach’s Alpha value for this section was significantly higher than 0.7, this indicates high reliability.

The Chi-Square test reveals a significant relationship within departments and positions for question 9.1 and 9.4 ($p<0.05$). Therefore, an investigation of the gaps identified for question 9.1 and 9.4 by department and position follow.

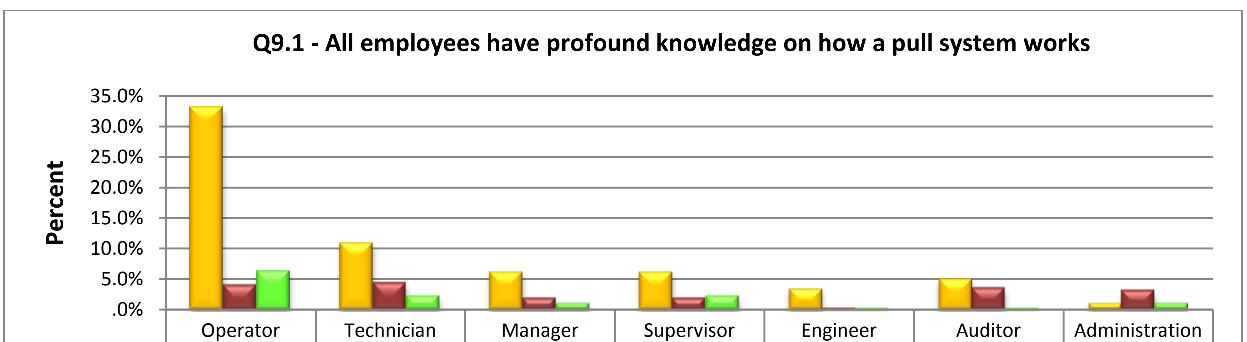
By department and position, the results in percentages for question 9.1 are represented by Figures 4.33 and 4.34 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	45.3%	8.3%	2.4%	3.5%	.8%	1.2%	5.1%
Not Sure	6.7%	4.7%	2.8%	.8%	1.2%	1.2%	2.0%
Agree	7.9%	.8%	3.1%	.0%	.4%	.4%	1.6%

Figure 4.33 – Department response for question 9.1

The results obtained in Figure 4.33 show that a total of 66.6 percent of participants within departments "disagree" with the statement. The consensus in "disagreement" indicates that all employees need to be trained on the application of a "pull system". These findings are important and supported by Dahlgaard and Dahlgaard-Park (2006:274) who strongly contend that employees should have profound knowledge on the "pull system" in order for it to work. Another key implication barrier would be a proper management structure to support the employees. This reveals the significance of organisations developing structured training programmes for employees on "pull systems" before implementing the tool.

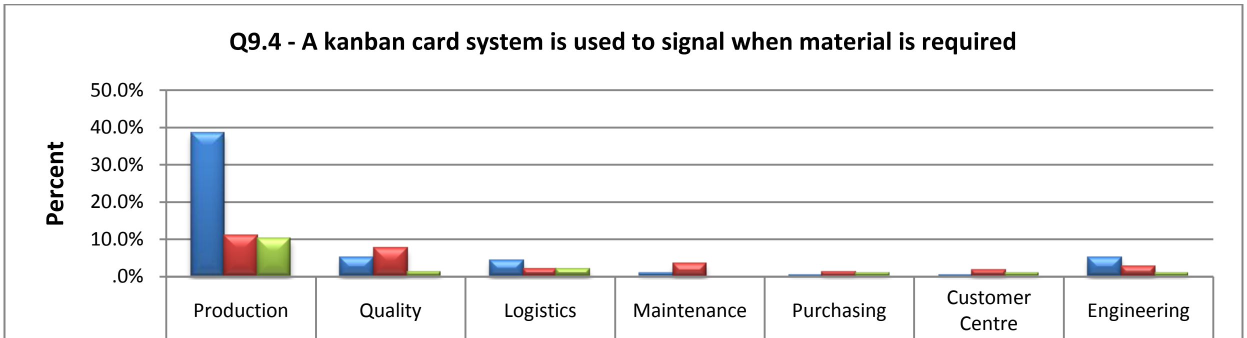


	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	33.1%	11.0%	6.3%	6.3%	3.5%	5.1%	1.2%
Neutral	3.9%	4.3%	2.0%	2.0%	.4%	3.5%	3.1%
Agree	6.3%	2.4%	1.2%	2.4%	.4%	.4%	1.2%

Figure 4.34 – Position response for question 9.1

As Figure 4.34 shows, all positions, with the exception of the administration function, do not believe that employees have profound knowledge on how a "pull system" works. It makes sense for the administration functions to indicate "uncertainty" as they are not directly involved in operational activities. An evaluation of the results could possibly mean that no training has been provided on the concept of "pull" to employees. The goal is for all employees to know how the "pull system" works before it can be implemented and applied successfully. The findings are significant and reveal that although the organisation has a documented procedure to use the "pull system"; it does not practise it accordingly, as employees who are the main drivers do not understand how the system works.

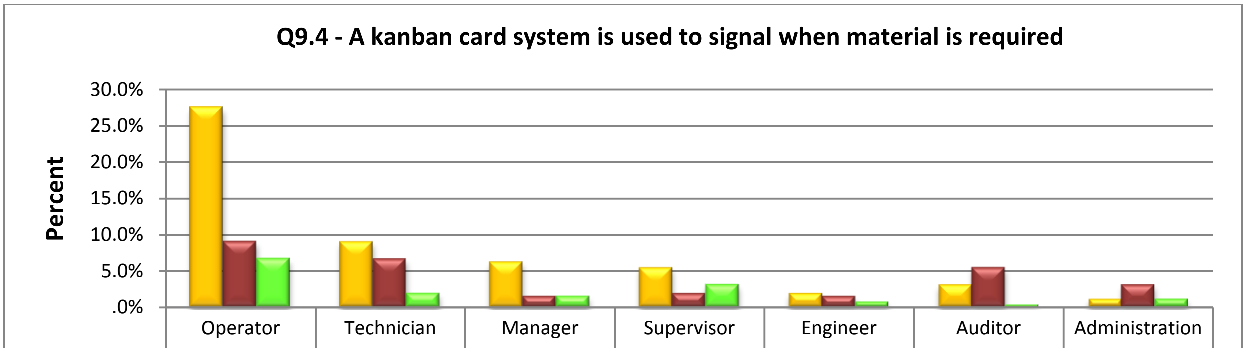
By department and position, the results in percentages for question 9.4 are represented by Figures 4.35 and 4.36 respectively.



	Production	Quality	Logistics	Maintenance	Purchasing	Customer Centre	Engineering
Disagree	38.6%	5.1%	4.3%	.8%	.4%	.4%	5.1%
Not Sure	11.0%	7.5%	2.0%	3.5%	1.2%	1.6%	2.8%
Agree	10.2%	1.2%	2.0%	.0%	.8%	.8%	.8%

Figure 4.35 – Department response for question 9.4

The extent of "disagreement" depicted in Figure 4.35 for Kanban application (54.7 percent in total) is similar to those of "pull" instead of "push" and mirror each other closely. This makes sense, since a Kanban system is the classical signalling device for "pull" production as highlighted by the authors (Schroeder, 2007:399; Bhasin and Burcher, 2006:57; Papadopoulou and Ozbayrak, 2005:786; Bicheno, 2004:107). From the results presented in Figure 4.35, it is evident that production, logistics and engineering share the highest content of "disagreement", which constitutes 48 percent of the total sample. Within the quality, maintenance, purchasing and customer centre department, there is a high level of "uncertainty". This could be because employees in these departments do not understand the Kanban concept.



	Operator	Technician	Manager	Supervisor	Engineer	Auditor	Administration
Disagree	27.6%	9.1%	6.3%	5.5%	2.0%	3.1%	1.2%
Neutral	9.1%	6.7%	1.6%	2.0%	1.6%	5.5%	3.1%
Agree	6.7%	2.0%	1.6%	3.1%	.8%	.4%	1.2%

Figure 4.36 – Position response for question 9.4

Five of the position categories represented in Figure 4.36 show a consistent trend of “disagreement” which consists of 50.5 percent of the total sample. The auditors and administration employees show a high level of “uncertainty”. Since the organisation has common processes there is consensus with the views of Schroeder (2007:394) who concludes that Kanban systems are mainly used for repetitive manufacturing. These rankings are consistent with the objectives of maintaining a lean and sustainable organisation because all other factors are closely related to it. The analysis of the initiatives reported reveal that the Kanban concept is not used within the organisation although it is documented in the current production system. A combination of the responses by position and department validate the strong overall negative response to the “pull” instead of “push” concept.

4.11 SUMMARY OF THE CHAPTER

This chapter presented the results of the empirical study. Results of the study revealed that the difference in opinion between positions and departments indicate that there is a large gap in terms of understanding the actual production system. The appropriate responses are quantitatively identified and the nature of these relationships and the differences are revealed. The results of the survey identified 16 significant areas that require improvement and two overall lean manufacturing principles that are not completely adopted within the organisation. Therefore, only questions that had statistically significant relationships were discussed. There were also opportunities for improvement highlighted in this chapter for each of the significant findings. Although lean manufacturing has been broadly embraced to eliminate waste and to improve quality and productivity, these benefits cannot be affirmed by the employees. Based on the analysis and presentation of the results obtained, the following chapter will present the conclusion and recommendations for the project.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter will present an overview of the investigation accomplished through the theoretical study and the empirical study. The findings and conclusions are based on theories studied to ascertain the contributions of lean manufacturing initiatives for enhancing manufacturing performance. The first part of this chapter summarises the theoretical and empirical study, followed by discussions on significant findings highlighted in chapter 4. Thereafter, the chapter explains the conclusions to validate the research objectives. The limitation of the study, along with recommendations deduced from the investigation, is also presented in this chapter. The chapter ends with suggestions for future research opportunities.

5.2 SUMMARY OF THEORETICAL STUDY

It was established in chapter one that lean manufacturing encapsulated the manufacturing world as a strategic methodology to improve an organisation's performance in terms of cost, quality and productivity. Therefore, the first step of the theoretical study investigated the history of lean manufacturing and explained how it evolved over the years. Thereafter, an in-depth research on the significant contributions of lean manufacturing highlighted the different tools, techniques, success stories and theoretical models. Since the primary focus of this study was confined to the production environment, only relevant sources pertaining to the production environment were investigated.

Analyses of all the views of authors show that there are nine lean manufacturing principles applicable to the production environment. The nine principles were identified in a model that was developed by Karlsson and Ahlstrom (1996:26) which was intended to measure the adoption of lean practices in the production and operation function. Based on the nine principles presented in chapter two, a reliable and valid lean assessment survey instrument was developed in measurable format to evaluate the existing lean manufacturing process at the organisation in this case study. The organisational components of lean manufacturing which contribute to production were tested and the results show the measurement was effective.

5.3 SUMMARY OF EMPIRICAL STUDY

The empirical part of this study was intended to test the hypothesis for improving organisational performance through lean manufacturing. Important constructs of evidence were presented to support relationships between lean techniques that affect quality and productivity. In comparing the results, the study found significant differences in responses between departments and positions. A relationship was established between operators and all other positions. For the identified areas of concerns, operators showed the highest amount of negativity. The results within departments highlighted significant findings in production. Taken together, the findings are consistent with the theoretical background. All findings that had a statistically significant result were compared to theory and discussed in detail. The study reveals that there are some lean techniques that are not carried out effectively but also identifies opportunities for improvement in those key areas of lean manufacturing.

5.4 ACHIEVEMENT OF RESEARCH AIMS AND OBJECTIVES

The objective of this study was based on the researcher’s intention to create a framework that could evaluate the interrelationship of lean manufacturing in the existing production system as viewed by the employees. Under these circumstances, the study provided empirical evidence of a significant relationship between lean success factors and manufacturing performance. The factors that contributed to quality and productivity were identified through extensive literature review and the responses from the study that measured the application of lean techniques.

The results obtained in chapter 4 have provided support to the three objectives of the study. Firstly, the findings show the existing strengths and weaknesses of the current lean manufacturing process. Secondly, there is a significant, positive relationship between the findings highlighted in comparison to excessive scrap, process defects, inaccurate inventory levels and defective products supplied to customers. Thirdly, all the areas identified for improvement opportunities prevail that additional work is necessary to enhance the current lean manufacturing process in the organisation.

5.5 RESTRICTIONS AND LIMITATIONS

The inherent limitations of the study could present as opportunities for future research. The first limitation based on the perception of the author is that the study was conducted in a single manufacturing organisation in Durban and does not include other organisations that practice lean manufacturing. Findings are valid for the organisation in question and cannot be generalised across all organisations in South Africa. The second limitation is that the focus of the study is restricted to the production environment. Another limitation was the imposed time frame when embarking on such a project. The most significant limitation was that there was no opportunity for the researcher to work with the recommended solutions for the problem areas identified in the lean manufacturing process.

5.6 CONCLUSION

The organisation in which this research was undertaken has a well documented production system and is a good practitioner of lean manufacturing, yet significant improvement opportunities were highlighted from the study for certain techniques. It should be noted that even if an organisation claims to manufacture lean it may be possible to improve performance very significantly. Hence, it can be deduced that organisations only practice certain tools and techniques but do not understand what makes them work together as a system. It can also be inferred that despite the wide knowledge and resources available, organisations fail to complete the transition from theory to practice. Both the above conclusions are consistent with Liker (2004:12) from the review of literature. It can therefore be surmised that organisations which claim to successfully manufacture lean are very few. This study demonstrated that the research hypothesis is correct that there are certain lean manufacturing principles that are not adequately applied. The hypothesis is supported by the results of insufficient lean adoption, which reveal the extent and nature of the differences between the idealised prescription in the organisation and the reality on the shop floor. The most significant conclusion is what the organisation is currently doing and not what it should be doing.

This research is intended to improve productivity and quality through lean manufacturing. It is hoped that the research carried out demonstrates to the organisation in which this study was undertaken and other organisations that documented procedures should have structured follow up mechanisms to ensure sustainability. The research has also presented a checklist for monitoring and measuring the current lean process on the shop floor. In conclusion, it should be emphasised that the study contributes to literature by increasing the understanding of lean processes and performance from a South African perspective.

5.7 RECOMMENDATIONS

This section highlights the recommendations based on the study pertaining specifically to the research undertaken on shop floor. Therefore, all perceptions for the following sections need to be contextualised within this regard.

5.7.1 RECOMMENDATIONS BASED ON FINDINGS

From the research findings it can be observed that organisations adopt lean manufacturing to enhance performance. However, there appears to be a significant gap pertaining to a follow up assessment tool that could be used to evaluate the transfer of theoretical knowledge to the existing practice on the shop floor. In attempting to understand the identified gap, the findings from the study presented in chapter 4 signify a relationship between the existing applications of lean adoption on the shop floor compared to the documented process. Therefore, on the basis of the relationship established, the empirical part of the study highlighted the following improvement opportunities for each of the nine lean manufacturing principles as represented in Table 5.1 and will represent the framework to improve the current lean manufacturing process within the organisation under study.

Lean Principle	Improvement Area
Elimination of Waste	• Operators or processes waiting unnecessarily in production • Taking immediate corrective action when defects and scrap appear • Encouraging employees to be more creative
Continuous Improvement	• Including more employees from the shop floor in Kaizen activities • Maintaining order and cleanliness in the organisation
Zero Defects	• Instilling that all employees are responsible for the quality of products • Increasing the use of Poka-Yoke devices
Just-in-time	• Ensuring the correct quantity of components are delivered to workstations on time
Multifunctional Teams	• Eliminating reliance of designated employees for certain processes
Decentralised Responsibilities	• Allocating responsibilities to employees on the shop floor
Integrated Functions	• Training employees to multi-task • Providing recognition or rewards for employees learning new skills
Vertical Information Systems	• Transparency in all aspects of the business
Pull instead of Push	• Training on “pull systems” • Training on Kanban

Table 5.1 – Improvement areas for lean principles (devised by researcher)

In response to improving the concerns identified in Table 5.1, the following benefits can be expected:

- product flow will balance and employees or processes will not wait unnecessarily in production
- process defects will be reduced and possibly eliminated if immediate corrective action is taken
- encouraging employees to be more creative ensures that they are able to make full use of their skills
- including more employees in Kaizen activities will promote the continuous improvement philosophy
- Poka-Yoke devices will eliminate biasness of employees and inspection
- the Kanban card concept will eliminate incorrect quantities or delays of material delivered to workstations

- multitasking employees will reduce reliance on designated specialists and indirect departments
- developing trust in employees and allocating more responsibilities will create a highly empowered workforce that improves overall performance
- increasing transparency, open sharing of information and reward systems will motivate employees
- providing training on “pull systems” and Kanban will ensure complete control of the entire production system.

All factors that significantly contribute to the aforementioned improvements are explained in detail in chapter 2. Techniques such as process mapping, value stream mapping and brainstorming sessions should be consistently maintained within the organisation in order to see the entire flow of material movement in production. This was highlighted by Schroeder (2007:409) and Chase et al. (2006:473) as a potential area to continuously improve existing workflows and to ensure that the organisation has a deeper understanding of the current production process. It should be emphasised that value stream mapping is a valuable tool in any lean organisation to link people and processes as recommended by Comm (2005:71).

It is recommended that a considerable amount of work is needed to transform the current production system into a “pull system”. However, it is envisaged that only when the production flow is smooth and organised, can a “pull system” be implemented. Another important avenue is for the organisation to provide training programs on “pull systems” for all employees before embarking on the transformation to a “pull system”.

More attention is required for productivity and quality functions in order to achieve better performance results such as throughput, lead time and reject rate. Effective corrective action should be taken for the problem areas identified to achieve superior business performance. This work suggests that it is necessary for organisations to understand the characteristics of the environment in which they operate and to ensure that the appropriate configuration for follow up processes that will make them most effective are maintained.

5.7.2 RECOMMENDATIONS BASED ON STUDY

The success of lean manufacturing was identified by practices that involve management support, employee involvement and a highly skilled workforce. The research demonstrates that the infrastructure and execution among these constituent elements, such as the employees, are critical to the success of lean manufacturing. It can be deduced that employees are the single most important resource for an organisation and by developing an open, honest and transparent culture it would ensure the system works effectively. This brings to light that lean manufacturing requires a complete transition of the entire organisation. It is important to note that all of the lean manufacturing techniques mentioned do not entail simply practising the tools but rather adopting a philosophy which the employees bring into reality. Perhaps management in general should pay much closer attention to using structured performance evaluators and follow up procedures to continually monitor the lean process and thereby ensure sustainability of the system.

5.7.3 RECOMMENDATIONS FOR THE AUTOMOTIVE INDUSTRY

A significant insight of an organisation's performance can be established by leveraging into the manufacturing system from an operator's point of view. Therefore, as a method of motivating employees when implementing new systems, it is vital to include them during the entire implementation process as this will motivate them to make the system a success. Under changing conditions, it can be inferred that managers should spend more time on the production floor to convince all employees that all operations are important. The results of the study provide some interesting and important insights such as cultural changes and follow up procedures that are necessary for organisations seeking to implement lean manufacturing.

5.7.4 RECOMMENDATIONS FOR FUTURE RESEARCH

This section presents several avenues that could be recommended for future research activities. These include:

- a more detailed study, through a larger population, with various types of industries that claim to practice lean manufacturing in South Africa.
- real life situations for optimal performance of lean manufacturing.
- refine and design a universal checklist that is able to track the conformance of processes and frameworks for lean such as International Organisation for Standardisation quality management systems
- further empirical studies of this nature in different industrial sectors should be performed to compare these findings with those of this study.
- learning more about other organisations that claim to practice lean manufacturing with studies from real life extent for ranking their existing state.

5.8 CONCLUDING REMARKS

This research has demonstrated how a well established and stable organisation in South Africa's manufacturing sector attempted to implement a successful management philosophy such as lean manufacturing but found it difficult to complete the transition from theory to practice. This was proven from an operator's perspective as to what prevails on the shop floor compared to what is documented and perceived to be working by management. The research has also established that more in-depth reviews can assist organisations to ensure that their production system remains sustainable.

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PILOT STUDY QUESTIONNAIRE **ANNEXURE A**

VOLUNTARY QUESTIONNAIRE FOR BEHR EMPLOYEES

Improving quality and productivity at an automotive manufacturing organisation in Durban

FOR OFFICE USE ONLY: Respondent Code: ___________

Dear Sir / Madam,

I am conducting research to critically review the effectiveness of Lean Manufacturing in the context of the Behr Production System (BPS). As BPS forms an integral part of the business, I believe that this survey will enable me to establish why excessive scrap, process defects, inaccurate inventory levels and defective products supplied to customers continue to surface at Behr.

Note to the respondent

- I need your help to understand how effective the application of Lean Manufacturing principles are carried out in the BPS
- Although I would like you to help me, you do not have to take part in this survey.
- If you do not want to take part, just hand in the blank questionnaire at the end of the survey session.
- What you say in this questionnaire will remain private and confidential. No one will be able to trace your opinions back to you as a person.
- Please note that there is no correct or incorrect answer and try to answer all questions even if the alternatives do not necessarily suit your opinion.

How to complete the questionnaire

- Please answer the questions as truthfully as you can. The questions are grouped into nine categories, and at the start of each category an explanation is provided to help you understand the relating questions of that category.
- I am only seeking for information that you and your fellow employees should feel comfortable telling me about. The information that I need is based on each individual's personal view on the application of lean manufacturing in the current BPS.
- You can mark each appropriate response with a tick or a cross.
- Please answer the questionnaire with a pen and not a pencil.

Part 1: Personal Profile

A. Indicate your Department	
Production	
Quality	
Logistics	
Maintenance	
Purchasing	
Customer Centre	
Engineering	

B. Indicate your Position	
Manager	
Supervisor	
Engineer	
Technician	
Inspector / Auditor	
Operator	
Administration	

Part 2: Lean Manufacturing Principles

1	**<u>Elimination of Waste</u> - Any activity in production that does not add value to the finished product, such as excess inventory, unnecessary movements of employees, scrap, rework or transportation.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
1.1	Work in progress Inventory is kept to a minimum					
1.2	Inventory levels are consistently monitored to prevent arbitrary buying of materials and the accumulation of excess inventory					
1.3	Lot sizes are continuously monitored and reduced to keep inventory down					
1.4	The number of times parts are transported within the different manufacturing cells are kept to a minimum					
1.5	The shortest distances are maintained to transport parts within the different manufacturing cells					
1.6	Manufacturing cycle times are kept to a minimum – Employees do not spend excessive time waiting for a cycle to be completed					
1.7	All production operations are standardised – Employees do not waste their motions in selecting or searching for tools that is not in immediate reach					
1.8	All tools and processes are capable of producing quality goods					
1.9	Defects resulting in scrap and rework are constantly monitored					
1.10	Employees are constantly motivated by management to be more creative and utilise their full potential to contribute to improvements					

2	**<u>Continuous Improvement</u> – Continuous improvement is an ongoing effort to improve products, services or processes. These efforts can seek “incremental” improvement over time or “breakthrough” improvement all at once.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
2.1	All employees are involved in continuous improvement activities					
2.2	Since employees have firsthand knowledge of their processes their views are never underestimated by management					
2.3	Appropriate feedback is consistently provided on continuous improvement initiatives					
2.4	All employees have been trained on continuous improvement					
2.5	Suggestions from the suggestion scheme program are continuously improving processes, quality and production.					
2.6	The number of suggestions per employee should increase					
2.7	Operators gather in groups to come up with suggestions on possible improvements					
2.8	Kaizen activities are frequently held in support of continuous improvement initiatives					
2.9	The PDCA methodology is consistently used to address problems and close them off consistently					
2.10	The 5S methodology is used to maintain a clean and organised working environment					
3	**<u>Zero Defects</u> - Zero defects is a way of thinking and doing production tasks right the first time without manufacturing defects. This philosophy increases the organisations profits by eliminating the cost of failure and increasing revenues through increased customer satisfaction.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
3.1	Operators are responsible to identify defective parts at the source of the operation					
3.2	Operators are permitted to stop the line in the event that defective parts are noticed					
3.3	Operators are entrusted with the task of adjusting defective parts to prevent the interruption of work flow					
3.4	Defective parts are reworked at the workstation where the defect was identified					
3.5	Process variables are frequently monitored and controlled instead of controlling the parts produced					
3.6	Measuring and inspection is carried out at the end of every process and after the product is fully assembled					
3.7	Autonomous defect control such as Poka-Yoke devices are used as a majority source of inspection methodology					
3.8	The number of people dedicated primarily to the quality control department is kept to a minimum					

4	**<u>Just-in-time</u> – It is a concept that controls inventory and material flow throughout the entire organisation. The philosophy involves providing the required part, in the correct quantity at the exact point in time.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
4.1	Each process is provided with the required part, in the correct quantity at the exact point in time					
4.2	Production lot sizes, buffer sizes and order lead time are continuously reduced to ensure just-in-time production					
4.3	The percentage of parts delivered just-in-time by suppliers is greater than normal deliveries					
4.4	The number of stages of material flow that uses pull (backward request) is greater in relation to push (forward scheduling)					
4.5	Inventory levels between work centres are maintained consistently					
5	**<u>Multifunctional teams</u> – A group of employees that are organised in a particular work area and are able to perform many different tasks. These teams are often organised along a cell based part of the product flow.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
5.1	Multifunctional teams exist within the organisation and are arranged at the different manufacturing processes					
5.2	The number of employees working in multifunctional teams should increase					
5.3	Employees within Multifunctional teams perform many different tasks in the product flow					
5.4	Tasks performed by indirect departments is the responsibility of the team					
5.5	Tasks are rotated amongst multifunctional team members					
5.6	There is no reliance or dependence on single employees performing a specific task					
5.7	Employees are trained in performing various tasks in the production process					
5.8	Teamwork promotes trust, support, respect and collaboration					
6	**<u>Decentralised responsibilities</u> - The process of transferring and assigning decision-making authority to lower level employees in an organisation hierarchy.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
6.1	Operators are responsible for planning, maintenance, inspection and quality to prevent the disruption of product flow					
6.2	Supervisory tasks are performed by multifunctional teams through rotating team leadership among employees especially trained for that specific task					
6.3	The number of hierarchical levels in the organisation is kept to a minimum					
6.4	Operators are encouraged to make decisions concerning production, quality and maintenance					
6.5	Employees have real influence and power when they participate in decision making instead of serving as consultants					

7	**<u>Integrated functions</u> – A philosophy that enables employees to perform many different tasks.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
7.1	Indirect tasks such as materials handling, planning, maintenance, and quality control, are performed by multifunctional teams.					
7.2	The number of tasks performed by multifunctional teams should increase, thus reducing the ratio of indirect employees to direct employees					
7.3	Employees are constantly rotated to perform many different tasks					
7.4	Sufficient training is provided to multi-skill employees					
7.5	Employees are rewarded for learning new skills					
7.6	Multi-skilled employees are given the opportunity to perform job rotation					
8	**<u>Vertical information systems</u> - The transfer of information to all employees within the organisation**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
8.1	The organisation is transparent in all aspects of the business					
8.2	Strategic information such as the organisations market plans, and financial performance is provided to all employees					
8.3	Operational information such as productivity, timeliness and quality is provided to all employees					
8.4	Information is continually displayed in dedicated spaces, directly in the production flow and this is discussed at regular meetings					
8.5	Visual communication is common throughout each process					
9	**<u>Pull Instead of Push</u> – A philosophy that emphasises production planning to manufacture to order instead of manufacturing to stock. No one upstream should produce a part until the customer downstream requests for it**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
9.1	All employees within the organisation have profound knowledge on how the pull system works					
9.2	The organisation manufactures products to actual customer demand rather than to forecasts					
9.3	Each workstation pulls the output from the preceding process as it is needed during production					
9.4	A Kanban card system is used to signal material replenishment					
9.4	Small lot quantities are used as a strategy to detect defects faster					

Thank you very much for participating and completing this questionnaire.

MAIN STUDY QUESTIONNAIRE **ANNEXURE B**

VOLUNTARY QUESTIONNAIRE FOR BEHR EMPLOYEES

Improving quality and productivity at an automotive manufacturing organisation in Durban

FOR OFFICE USE ONLY: Respondent Code: ___________

Dear Sir / Madam,

I am conducting research to critically review the effectiveness of Lean Manufacturing in the context of the Behr Production System (BPS). As BPS forms an integral part of the business, I believe that this survey will enable us to establish why excessive scrap, process defects, inaccurate inventory levels and defective products supplied to customers continue to surface at Behr.

Note to the respondent

- I need your help to understand how effective the application of Lean Manufacturing is carried out in the BPS.
- Although I would like you to help me, you do not have to take part in this survey.
- If you do not want to take part, just hand in the blank questionnaire at the end of the survey session.
- What you say in this questionnaire will remain private and confidential. No one will be able to trace your opinions back to you as a person.
- Please note that there is no correct or incorrect answer and try to answer all questions even if the alternatives do not necessarily suit your opinion.

How to complete the questionnaire

- Please answer the questions as truthfully as you can. The questions are grouped into nine categories, and at the start of each category a brief explanation is provided to help you understand the relating questions that follow.
- I am only seeking for information that you and your fellow employees should feel comfortable telling me about. The information that I need is based on each individual's personal view on the application of lean manufacturing in the current BPS.
- You can mark each appropriate response with a tick or a cross.
- Please answer the questionnaire with a pen and not a pencil.

Part 1: Personal Profile

A. Indicate your Department	
Production	
Quality	
Logistics	
Maintenance	
Purchasing	
Customer Centre	
Engineering	

B. Indicate your Position	
Manager	
Supervisor	
Engineer	
Technician	
Inspector / Auditor	
Operator	
Administration	

Part 2: Lean Manufacturing Principles

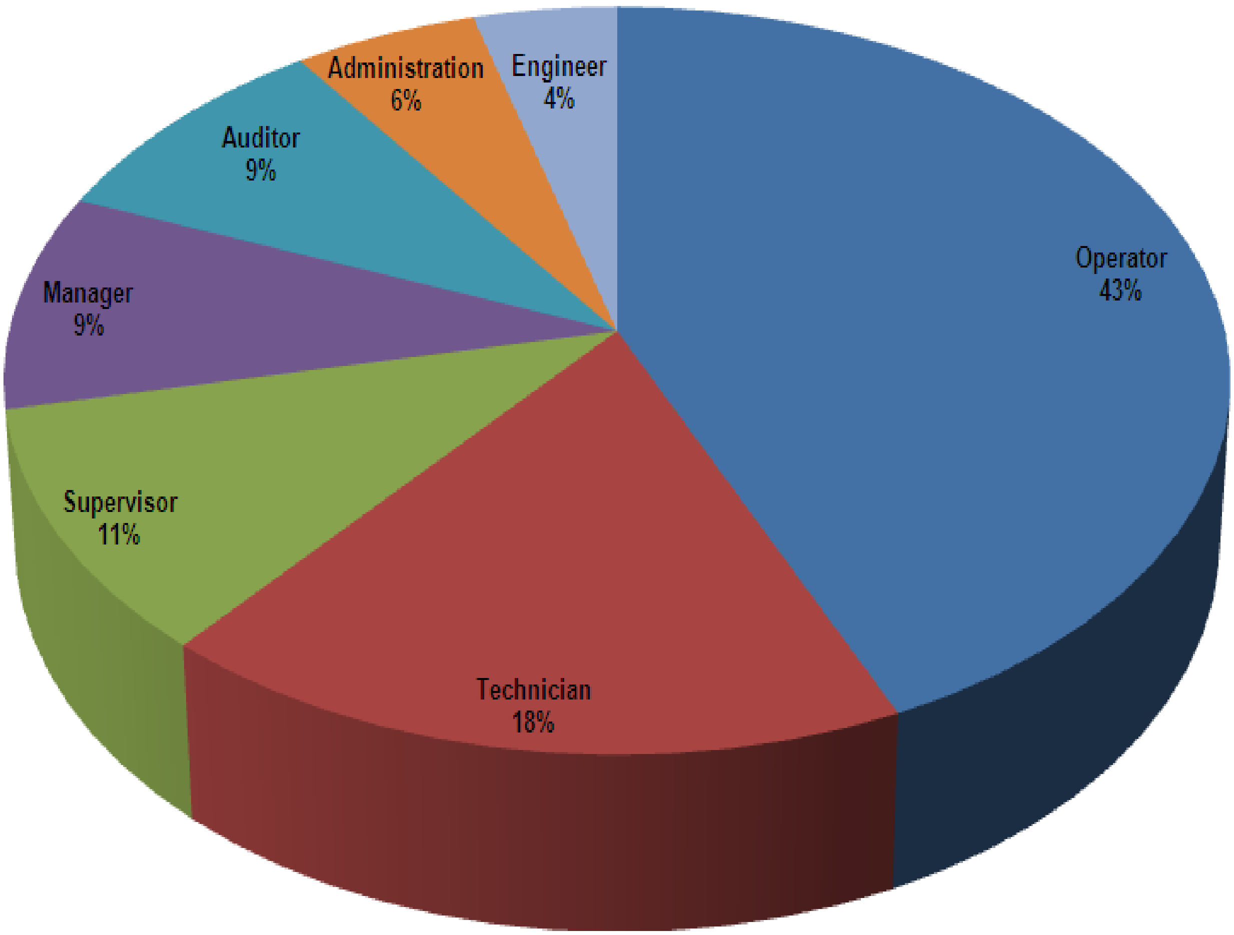
1	**<u>Elimination of Waste</u> - Any activity in production that does not add value to the finished product, such as excess inventory, unnecessary movements of employees, scrap, rework or transportation.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
1.1	Products are manufactured only when required					
1.2	Inventory in stores is kept to a minimum					
1.3	The movement of material within the organisation is kept to a minimum					
1.4	Operators or processes do not wait unnecessarily during production					
1.5	Operators do not move excessively to complete a task					
1.6	There are no unnecessary processing steps in production					
1.7	Defects and scrap are constantly monitored					
1.8	Employees are motivated to be more creative					

		Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
2	**<u>Continuous Improvement</u> – Continuous improvement is an ongoing effort by all employees to improve products, services or processes.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
2.1	All employees are asked to assist in solving problems					
2.2	Training is provided for all employees on continuous improvement					
2.3	Employees are motivated to come up with suggestions					
2.4	Kaizen workshops are held to assist in improving operations					
2.5	The Plan Do Check Act (PDCA) cycle is used to address problems					
2.6	There is order and cleanliness in the organisation					
3	**<u>Zero Defects</u> - Zero defects is a way of thinking and doing production tasks right the first time without manufacturing defects.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
3.1	Operators are responsible to identify defects					
3.2	Operators are encouraged to stop the line should a defect occur					
3.3	Operators are responsible to correct defects					
3.4	Poka-Yoke devices are used to prevent defects					
4	**<u>Just-in-time</u> – It is a concept that controls inventory and material flow throughout the entire organisation. The philosophy involves providing the required part, in the correct quantity at the exact point in time.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
4.1	Components are delivered to each workstation on time					
4.2	Components are delivered to each workstation in the correct quantities					
4.3	Correct components are delivered to each workstation					
5	**<u>Multifunctional teams</u> – A group of employees that are organised in a particular work area and are able to perform many different tasks.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
5.1	Multifunctional teams exist within the organisation					
5.2	Operators within each department know how to perform all operations					
5.3	The organisation does not rely on designated employees to perform specific tasks					
5.4	Tasks are rotated between operators within a department					
5.5	Teamwork promotes trust, support, respect and collaboration					
6	**<u>Decentralised responsibilities</u> - The process of transferring and assigning decision-making authority to lower level employees in an organisation hierarchy.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
6.1	Operators are given more responsibilities in production					
6.2	The hierarchical level in the organisation is kept to a minimum					
6.3	Operators are encouraged to make decisions concerning production and quality					
6.4	Operators have real influence and power when they participate in decision making instead of serving as consultants					

7	**<u>Integrated functions</u> – A philosophy that enables employees to perform many different tasks.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
7.1	Operators are given a broader range of tasks					
7.2	Sufficient training is provided to multi-skill employees					
7.3	Employees are rewarded for learning new skills					
8	**<u>Vertical information systems</u> - The transfer of information to all employees within the organisation.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
8.1	The organisation is transparent in all aspects of the business					
8.2	Strategic information such as the organisations market plans, and financial performance is communicated to all employees					
8.3	Operational information such as productivity, timeliness and quality is communicated to all employees					
8.4	Information is continually displayed in dedicated spaces throughout the organisation					
9	**<u>Pull Instead of Push</u> – A philosophy that emphasises production planning to manufacture to order instead of manufacturing to stock. No one upstream should produce a part until the customer downstream requests for it.**	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
9.1	All employees have profound knowledge on how a pull system works					
9.2	Production is made to actual customer demand rather than to forecasts					
9.3	Each workstation pulls the output from the preceding process					
9.4	A Kanban card system is used to signal when material is required					

Thank you very much for participating and completing this questionnaire.

PROFILE OF PARTICIPANTS **ANNEXURE C**



Department * Position Cross tabulation

			Position							Total
			Operator	Technician	Manager	Supervisor	Engineer	Auditor	Admin	
Department	Production	% within Department	68.4%	9.2%	7.2%	15.1%				100.0%
		% within Position	94.5%	31.1%	45.8%	85.2%				59.8%
		% of Total	40.9%	5.5%	4.3%	9.1%				59.8%
	Quality	% within Department		22.9%	2.9%		8.6%	65.7%		100.0%
		% within Position		17.8%	4.2%		27.3%	100.0%		13.8%
		% of Total		3.1%	0.4%		1.2%	9.1%		13.8%
	Logistics	% within Department	28.6%		23.8%	9.5%			38.1%	100.0%
		% within Position	5.5%		20.8%	7.4%			57.1%	8.3%
		% of Total	2.4%		2.0%	0.8%			3.1%	8.3%
	Maintenance	% within Department		54.5%	27.3%	9.1%	9.1%			100.0%
		% within Position		13.3%	12.5%	3.7%	9.1%			4.3%
		% of Total		2.4%	1.2%	0.4%	0.4%			4.3%
	Purchasing	% within Department			16.7%	16.7%			66.7%	100.0%
		% within Position			4.2%	3.7%			28.6%	2.4%
		% of Total			0.4%	0.4%			1.6%	2.4%
	Customer Centre	% within Department		28.6%	28.6%		14.3%		28.6%	100.0%
		% within Position		4.4%	8.3%		9.1%		14.3%	2.8%
		% of Total		0.8%	0.8%		0.4%		0.8%	2.8%
	Engineering	% within Department		68.2%	4.5%		27.3%			100.0%
		% within Position		33.3%	4.2%		54.5%			8.7%
		% of Total		5.9%	0.4%		2.4%			8.7%
Total		% within Department	43.3%	17.7%	9.4%	10.6%	4.3%	9.1%	5.5%	100.0%
		% within Position	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	43.3%	17.7%	9.4%	10.6%	4.3%	9.1%	5.5%	100.0%

FACTOR ANALYSIS

ANNEXURE D

Rotated Component Matrix

		Component								
		1	2	3	4	5	6	7	8	9
1.1	Products are manufactured only when required	0.140	0.146	0.271	0.193	0.132	0.673	0.095	-0.015	-0.069
1.2	Inventory in stores is kept to a minimum	0.169	0.097	0.224	-0.001	0.168	0.723	-0.054	0.203	-0.032
1.3	The movement of material within the organisation is kept to a minimum	0.415	0.465	0.170	-0.047	0.115	0.333	0.095	0.222	-0.186
1.4	Operators or processes do not wait unnecessarily during production	0.152	0.657	0.138	-0.074	0.084	0.170	0.236	0.084	-0.032
1.5	Operators do not move excessively to complete a task	0.571	0.280	0.110	-0.115	0.169	0.312	0.048	0.207	-0.116
1.6	There are no unnecessary processing steps in production	0.737	0.268	0.074	0.092	0.149	0.079	0.013	0.130	0.085
1.7	Defects and scrap are constantly monitored	0.633	0.228	0.104	0.262	0.168	0.175	0.157	0.088	0.131
1.8	Employees are motivated to be more creative	0.478	0.202	0.190	0.293	0.179	0.159	0.318	0.075	-0.032
2.1	All employees are asked to assist in solving problems	0.225	0.286	0.276	0.188	-0.019	0.444	0.419	-0.026	0.141
2.2	Training is provided for all employees on continuous improvement	0.300	0.174	0.051	0.260	0.166	0.178	0.561	0.160	0.114
2.3	Employees are motivated to come up with suggestions	0.556	0.037	0.166	0.318	0.339	0.311	0.271	-0.022	-0.057
2.4	Kaizen workshops are held to assist in improving operations	0.666	0.141	0.037	0.174	0.212	0.111	0.233	0.066	0.048
2.5	The Plan Do Check Act (PDCA) cycle is used to address problems	0.499	0.231	0.262	0.295	0.194	0.043	0.070	0.213	0.122
2.6	There is order and cleanliness in the organisation	0.464	0.269	0.418	0.428	0.156	-0.027	0.044	0.052	0.051
3.1	Operators are responsible to identify defects	0.520	-0.055	0.122	0.353	0.122	0.380	0.282	0.173	-0.092
3.2	Operators are encouraged to stop the line should a defect occur	0.432	0.159	0.069	0.307	0.055	0.337	0.314	0.277	-0.018
3.3	Operators are responsible to correct defects	0.290	0.161	0.003	0.514	0.127	0.324	0.185	0.202	-0.108
3.4	Poka-Yoke devices are used to prevent defects	0.420	0.145	0.177	0.547	0.272	0.081	0.131	0.139	-0.085
4.1	Components are delivered to each workstation on time	0.175	0.754	0.055	0.129	0.052	0.090	0.213	0.097	0.086
4.2	Components are delivered to each workstation in the correct quantities	0.247	0.777	0.097	0.207	0.136	0.050	0.037	0.074	0.046
4.3	Correct components are delivered to each workstation	0.231	0.652	0.266	0.365	0.128	0.032	-0.049	0.085	-0.012

5.1	Multifunctional teams exist within the organisation	0.217	0.038	-0.042	0.407	0.228	0.494	0.151	0.046	0.247
5.2	Operators within each department know how to perform all operations	0.127	0.308	0.081	0.500	0.242	-0.020	0.192	0.234	-0.156
5.3	The organisation does not rely on designated employees to perform specific tasks	0.337	0.219	0.372	0.080	0.055	0.065	0.142	0.348	-0.063
5.4	Tasks are rotated between operators within a department	0.495	0.209	0.273	0.131	-0.045	0.074	0.294	0.302	0.001
5.5	Teamwork promotes trust, support, respect and collaboration	0.078	0.034	-0.012	-0.068	-0.028	-0.028	0.016	-0.036	0.883

6.1	Operators are given more responsibilities in production	0.151	0.078	0.292	0.649	0.005	0.203	0.087	0.253	0.036
6.2	The hierarchical level in the organisation is kept to a minimum	0.428	0.108	0.210	0.138	0.193	0.135	0.159	0.425	0.107
6.3	Operators are encouraged to make decisions concerning production and quality	0.325	0.057	0.205	0.242	0.057	0.042	0.147	0.655	-0.003
6.4	Operators have real influence and power when they participate in decision making instead of serving as consultants	0.086	0.222	0.111	0.275	0.258	0.187	0.014	0.613	-0.098

7.1	Operators are given a broader range of tasks	0.059	0.084	0.609	0.184	0.147	0.314	-0.035	0.232	0.014
7.2	Sufficient training is provided to multi-skill employees	0.283	0.116	0.351	0.236	0.359	0.065	0.383	0.148	0.037
7.3	Employees are rewarded for learning new skills	0.208	0.195	0.006	0.039	0.333	0.031	0.528	0.306	0.049

8.1	The organisation is transparent in all aspects of the business	0.112	0.158	0.291	0.062	0.621	0.195	0.184	0.236	0.153
8.2	Strategic information such as the organisations market plans, and financial performance is communicated to all employees	0.250	0.087	0.163	0.060	0.760	0.071	0.117	0.098	-0.120
8.3	Operational information such as productivity, timeliness and quality is communicated to all employees	0.346	0.075	0.215	0.279	0.581	0.291	0.081	0.025	0.001
8.4	Information is continually displayed in dedicated spaces throughout the organisation	0.290	0.250	0.242	0.331	0.532	0.233	0.049	0.046	-0.057

9.1	All employees have profound knowledge on how a pull system works	-0.076	0.349	0.515	0.099	0.357	0.029	0.256	0.174	-0.009
9.2	Production is made to actual customer demand rather than to forecasts	0.198	0.025	0.681	0.109	0.316	0.227	0.055	0.136	0.083
9.3	Each workstation pulls the output from the preceding process	0.221	0.222	0.674	0.072	0.138	0.212	0.180	0.029	-0.118
9.4	A Kanban card system is used to signal when material is required	0.250	0.264	0.403	0.105	0.111	-0.062	0.568	-0.073	-0.218

LETTER OF CONSENT **ANNEXURE E**

Heat up. Cool down.

BEHR

15 June 2009

Durban University of Technology
Faculty of Management Sciences
Department of Operations and Quality Management
M L Sultan Campus
1st Floor, MB1-17

To whom it may concern:

Dear Sir / Madam,

Please note that Mr. Raveen Rathilall, DUT Graduate Student, has the permission of Behr South Africa to conduct research at our Durban facility for his study, "Improving Quality and Productivity at an Automotive Manufacturing Organisation in Durban".

On behalf of Behr South Africa, I am writing to formally indicate our awareness of the research and that Mr. Rathilall will be administering a survey to the employees. Mr. Rathilall's on-site research activities will be concluded by 19 March 2010.

If you have any questions and concerns, please feel free to contact my office at (031) 719 7600.

Sincerely,

[redacted]

Rodney Peter
Quality Manager, Behr South Africa

Member of the Behr Group
Behr South Africa (Pty) Ltd
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