

UNIVERSITY OF KWAZULU-NATAL

**AN EVALUATION OF A PLANT MAINTENANCE MANAGEMENT
FUNCTION – THE CASE OF A LUBRICANTS BLENDING PLANT IN
DURBAN**

By

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**A dissertation submitted in partial fulfilment of the requirements for the degree
Of
Master of Business Administration**

**Graduate School of Business and Leadership
College of Law of Management Studies**

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2013

DECLARATION

I, **Cedrick Muziwandile Mkhize** declare that:

(i) The research reported in this dissertation, except where otherwise indicated, is my original research.

(ii) This dissertation has not been submitted for any degree or examination at any other university.

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ACKNOWLEDGEMENTS

I wish to express my sincere appreciation and gratitude to the following individuals, without whose assistance, this study would not have been possible:

- To my Supervisor, Dr Elias Munapo for all the help, support, encouragement and guidance he offered me.
- A special gratitude to my wife, Zama for all the love, care, patience, support, encouragement and most importantly for ensuring that the family is taken care of whilst I focused on the studies. I am profoundly indebted to you, Zama.
- To my lovely daughters, Thando, Owethu and Anele, I apologise for not being there to help you with your homeworks and school projects for the past two and half years. I am sure that one day you will appreciate what dad has to go through to complete his studies.
- To my mother, MaGama, my father Bhekizitha and my sister, Thobe for all the encouragement.
- To my employer, Total SA, for allowing me to use LMP as a unit of analysis for the study.
- A special thank you to all my respondents who took time off their busy schedule to provide me with information to complete my research.
- To my MBA Group members: Bongani Hlophe, Fikie Chiliza, Audrey Zulu, Yash Naicker, Kuben Moodley, Derrick Banda and Thamini Chety – for all the encouragement for the last two and half years.
- To Themba Mbongwa – for all the support, guidance and encouragement during my studies.

ABSTRACT

This study aimed to evaluate the effectiveness of maintenance management function in a Lubricants Manufacturing Plant (LMP), a manufacturing business unit owned Total South Africa (TSA), located in Durban. The highly automated manufacturing machinery, reliable production machines and stringent health and safety legislation have hoisted the significance of the maintenance function within the manufacturing plants into the higher trajectory.

Research data was solicited by conducting a survey of LMP employees who were directly and indirectly impacted by the maintenance function. A sample of 95 employees, from all hierarchical levels at LMP, participated and responded to the questionnaire, in October 2013. Statistical analysis using descriptive and inferential statistics were conducted.

The empirical research done in this study supplemented the theory of maintenance management pertaining to the strategic role of the maintenance function within manufacturing plants. The findings of this study revealed that, the maintenance function at LMP is perceived to be an important business management function which contributes positively towards the company's overall objectives and profitability. The study also revealed that, perceived shortcomings of the maintenance function make LMP's maintenance function ineffective. The study also revealed LMP is a closed system manufacturing firm with a cost centre view towards the maintenance management function. The study also confirmed the positive support towards the implementation of Total Productive Maintenance (TPM) as the panacea for improvement of maintenance effectiveness.

The study recommends that TPM is a maintenance strategy which must be implemented in order to improve maintenance effectiveness and manufacturing operational performance, at LMP. The recommendations with regards to the study findings and the means to ensure expeditious execution to improve the effectiveness of the maintenance function were developed and stated.

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

Manufacturing firms are realising that there is a critical need for effective maintenance of manufacturing machinery and assets in manufacturing plants (Alsyouf, 2009). High levels of automation, advanced technology and stringent environmental and safety legislation further compound the significance of effective maintenance management function in manufacturing organizations (Al Turki, 2011 and Rolfsen and Langeland, 2012).

Maintenance expenditure embodies a huge portion of manufacturing operating costs, particularly in the asset intensive manufacturing sector. According to Simoès *et al.* (2011), in manufacturing plants, the maintenance related costs are estimated to be 25 percent of overall manufacturing operating costs. Simoès *et al.*, 2011 and Salonen and Deleryd, 2011) also assert that maintenance costs in petrochemical manufacturing plants are the highest expenditure in overall operating costs. Notwithstanding that, Salonen and Deleryd (2011) opine that the maintenance function is still regarded as a cost driving necessity rather than a competitive resource, in most manufacturing the manufacturing plants. Khazraei and Deuse, (2011), in agreement with Salonen and Deleryd (2011), also attest to the fact that in most manufacturing plants, the maintenance function is still perceived as a non-value-adding business function that belongs to the operating budget, and also regarded as an inevitable item for cost-saving opportunities.

It is such perceptions that necessitate a need for paradigm shift which will discourage the prevalent propensity by manufacturing plants to view the maintenance function in the narrow operational context which deals with production machinery failure alone (Al Turki, 2011).

The maintenance function has a profound impact on the manufacturing performance areas of Productivity, Cost, Delivery, Quality, Morale and Safety and, as such, it should be viewed as a strategic business function (Zaim *et al.* 2012). Alsyouf (2009) also acknowledges the significant role of a maintenance function for manufacturing plants, particularly those which strive to attain world-class competitiveness.

1.2 Motivation for the Study

For any manufacturing plant, effective maintenance yields cost-effective machine reliability and availability and hence improved productivity throughput with low input production costs. The significance of effective maintenance function in a manufacturing plant is premised on that view. The Lubricants Manufacturing Plant (LMP) is a unit of analysis for this study. LMP is the Total South Africa (TSA)'s lubricants manufacturing plant and distributor of lubricants and greases. LMP is located in Island View, which is South of Durban. LMP has been in existence since 1964. LMP is an asset-intensive manufacturing plant with highly sophisticated production machinery such as: steam boiler, blending vessels, autoclaves, pumps and high speed lubes-filling machines. In asset intensive manufacturing plants, such as LMP, unreliable production equipment is very costly, and adversely impacts on the key manufacturing operational performance areas.

It is the researcher's conviction that LMP's maintenance function responds retrospectively to the functional failure of production machinery. Wireman (2004:197) refers to such a maintenance approach, as a *fire fighting* or *reactive* maintenance approach. The consequences of employing a reactive maintenance approach involve escalating unplanned downtime and expensive unrecoverable manufacturing overhead costs. Such factors adversely erode profit margins on the products which are manufactured at LMP, and thus negatively impact Total SA's competitiveness and profitability. The lubricants manufacturing business is characterised by high input costs, (e.g. raw materials such as base oils, additives, etc.) which adversely affect the cost competitiveness of the business.

There are a plethora of empirically research studies, carried out in countries such as United Kingdom, India, Italy, Jordan and Sweden, which sought to evaluate the effectiveness of maintenance function for the manufacturing plants (Jonsson, 1997, Cholasuke *et al.* 2004, Alsyouf, 2009, Tahboub, 2011, and Srivastava and Mondal 2013). The common thread of those findings of the empirical studies is the low status of maintenance function, where maintenance function is perceived as a cost centre and not a strategic resource. Those empirical studies also revealed the missed opportunities by manufacturing plants to realise the strategic benefits, such as profitability, which are derived by managing the maintenance function effectively. It is worth mentioning that, none of the empirical research studies aimed at evaluating the effectiveness of maintenance function has been conducted on either a South African manufacturing plant lubricants blending plant.

1.3 Problem Statement

Wireman (2004:196) asserts that the manner in which the maintenance function is perceived in manufacturing plants can impact (positively and negatively) on the effectiveness of the maintenance function. On the basis of the foregoing, listed below are the key figures extracted from the performance score card for LMP's maintenance department, for the 2012/13 financial year:

- LMP's maintenance budget equates to 15% of the entire plant's operating budget. Notwithstanding that, LMP's maintenance expenditure for 2012/13 financial year overspent by 9%.
- LMP's Overall Equipment Effectiveness (OEE) for production machinery was 66 % (vs. 85% which is world class standard for OEE). A low OEE is an indication of the ineffective maintenance function (Ahuja and Khamba, 2008).
- Overtime costs for maintenance-related work constituted 8.68% of the entire plant's overtime expenditure (vs. world class standard of <5%). High levels of overtime, suggest a reactive maintenance function, because labour costs due to unplanned maintenance work is one the major *cost drivers of maintenance*. (Wireman, 2004, Ahren and Parida, 2009 and Stenström *et al.* (2013).
- The non-existence of a formal maintenance strategy was one of the reasons that caused LMP to outsource 20% of maintenance work to engineering and maintenance subcontractors, who most of them did not have proven expertise in maintaining the lubricants manufacturing machinery and equipment.

It is the researcher's conviction that the above-mentioned performance scorecard by the LMP's maintenance function reflects the level of ineffectiveness of the maintenance function at LMP. One of Total SA's strategic objectives is to maintain world class blending fees (i.e. low cents/litre of lubricants produced). Hence, performance by LMP's maintenance function is a serious indictment to that strategic objective and also adversely impact Total SA's profitability objectives. Ineffective maintenance function also hinder Total SA's strategic objective of doubling its income by 2015, which will be achieved by cost savings on variable costs, such as maintenance. Lower variable costs result into higher margins for lubricants produced at LMP, and that in turn will make Total SA a brand of reference and subsequently give Total SA a competitive edge in the fierce lubricants market.

1.4 Aim of the study

The overall aim of this study is to evaluate the effectiveness of the maintenance function at Total South Africa (TSA)'s Lubricants Manufacturing Plant (LMP). Therefore, this study seeks to answer the main research question:

“How can the effectiveness of the plant maintenance function at Total South Africa’s Lubricants Manufacturing Plant (LMP) be improved?”

1.5 Research Objectives (RO)

The research objectives for this study are as follows:

RO1: Assess employees’ perception of the maintenance function at LMP.

RO2: Highlight the perceived shortcomings of the maintenance function at LMP.

RO3: Assess the perceived effectiveness level of the maintenance function at LMP.

RO4: Solicit employees’ views about Total Productive Maintenance (TPM)’s contribution towards improving LMP’s maintenance effectiveness and operational performance areas.

RO5: Make recommendations for improving the effectiveness of the maintenance function at LMP.

1.6 Research Questions (RQ)

In order to ensure objective and effective analysis of the above-mentioned main research problem and research objectives, this research study aims to answer the following questions:

RQ1: How do employees at LMP perceive the maintenance function?

RQ2: What are the perceived shortcomings of the maintenance function at LMP?

RQ3: What is the perceived level of effectiveness for the maintenance function at LMP?

RQ4: How can the implementation of Total Productive Maintenance (TPM) improve maintenance effectiveness and manufacturing performance areas at LMP?

RQ5: How can the effectiveness of the maintenance function at LMP be improved?

1.7 Beneficiaries of the study

The beneficiaries of this research study and the benefits which are to be derived from it are as follows:

- LMP's management team will be able to maximise and leverage the maintenance function at LMP in line with LMP's and Total SA's objectives.
- LMP's employees across all hierarchical levels will gain an enhanced level of understanding and awareness towards the significance of the plant maintenance function.
- Total SA's management committee will also gain an advanced level of awareness of the significance of maintenance.
- Management committees (Operations and Maintenance) of other Total blending plants globally will derive insight into maintenance management.
- Maintenance practitioners in the manufacturing sector will derive greater insight into the maintenance challenges within the context of a lubricants manufacturing plant

1.8 Chapter Outline

The approach adopted in this study is a sequential approach which starts with contextualising the research problem, reviewing the theory pertinent to maintenance management, elucidating the research methodology adopted for the study, presentation of analysis of survey results, discussion of findings of the study and concludes with recommendations. The context of each chapter of this research study is summarised below:

- **Chapter 1:** Besides indicating the motivation for the study, this chapter deliberates on the research problem statement, the research objectives and the research questions. This chapter also outlines the beneficiaries of the study.
- **Chapter 2:** This chapter gives a theoretical perspective on maintenance management within the context of manufacturing plants. Crucial aspects of maintenance management covered in this chapter are :
 - Definition of maintenance and maintenance management;
 - Evolution of maintenance management;

- Benefits of maintenance management within the manufacturing industry;
 - Status of the maintenance management function within the manufacturing industry;
 - Maintenance Effectiveness; and
 - Total Productive Maintenance (TPM).
- **Chapter 3:** This chapter outlines the research methodology adopted for this research study.
 - **Chapter 4:** This chapter presents the data collected and discusses the study findings.
 - **Chapter 5:** This chapter serves to discuss the benefits provided by this study. It makes recommendations to address the business problem which was identified for this study. Recommendations for future studies are also discussed in this chapter.

1.9 Concepts and definitions

Due to their prominence in this dissertation, the following terms are elucidated in order to ensure comprehension. Terms are defined within the context in which they were utilised in this dissertation.

- **Maintenance effectiveness:** *“Maintenance effectiveness signifies how well a maintenance department or function accomplishes its objectives or company needs, within the ambits of quality of the service rendered, viewed from the customer’s perspective”* Marquez and Gupta (2009:168). Within the context of this study, this is the extent to which the maintenance function meets the criteria of an effective maintenance system as defined in Chapter 2.
- **Plant maintenance management functioning,** is the responsibility of a department that is responsible for management of maintenance resources. It ensures the execution of all the maintenance-related activities, by planning, organizing and controlling, with the aim of ensuring effective and efficient manufacturing (Ablay, 2013).

- **Manufacturing performance areas:** are Productivity (P), Cost (C), Delivery (D), Quality (Q), Morale (M) and Safety (S)

- **Maintenance system:** This is a set of related and connected processes which seek to achieve a common goal or objective (Bamber *et al.* 2004:28).

- **Manufacturing plant:** this means an entity which converts raw materials into desired finished goods using processes which involve machines.

- **Lubricants Manufacturing Plant (LMP):** this is the production facility where lubricants are produced and filled for selling to different markets. The Lubricant manufacturing process involves: Blending (Base Oils and Additives) > Filling > Packaging into different Stock keeping units (500 millilitres pints, 5 litres bottles, 20 litres pails, 210 litres drums and bulk) .

1.10 Chapter Summary

The effective management of the maintenance function is a very crucial aspect of manufacturing plants, as that provides opportunities to derive sought after cost savings, which in turn results into the improvement of margins.

This chapter served as a preamble to this study and gave a background to the study which was conducted, explaining the motivation of the study, problem statement, aim of the study, research objectives and research questions.

The next chapter is the presentation of the literature review for this research study is. The next chapter also looks at the theoretical frameworks and models and the best practices in the maintenance management field. This captures pertinent maintenance management theoretical foundations as well as presenting a report on empirical studies conducted by a wide variety of scholars, authors and practitioners in the academic field of maintenance management.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This study seeks to evaluate the effectiveness of the maintenance function at LMP. This chapter discusses the concepts and perspectives in the field of maintenance management, within the context of manufacturing plants. Specifically, the maintenance management aspects involved in this chapter are the theory of machine failure, definition of maintenance and maintenance management, benefits of maintenance, characteristics of maintenance, maintenance and its challenges, evolution of maintenance, maintenance types, the maintenance management framework, maintenance effectiveness, the cost of poor maintenance and TPM as a maintenance strategy. The chapter concludes with a summary.

2.1.1 Maintenance definition

Due to its wider scope, maintenance has more than one definition (Kumar *et al.* 2013:233). The layman's definition of the term, maintenance, is the work done to preclude functional failure of the device so as to ensure that it remains in a proper operating condition (Khazrei and Deuse (2011). Sharma *et al.* (2011:5) see maintenance as all the repair work conducted at pre-set time intervals so as to enhance a machine's life-span. The Maintenance Engineering Society of Australia (MESA), defines maintenance as "engineering activities and interventions needed to ensure optimal performance level for the machine or equipment" Kumar *et al.* (2013:234)

However, authors: Salonen (2011), Razak *et al.* (2012:24), Narayan (2012), Kumar *et al.* (2013:234), Srivastava and Mondal (2013) and Dilanthi (2013) opt for a rather broad and pragmatic functional definition of maintenance, which goes like "...integration of the technical, administrative and management activities, aimed at ensuring retention and restoration of a device (or capital equipment) in a state in which it can optimally execute its intended (designated) function"

The crux of the afore-cited maintenance definitions dispels the notion and perception that maintenance is more than just fixing broken machinery or equipment.

2.1.2 Machine failure – the need for maintenance

It is common knowledge that functional failure in any machine or process (actual or impending) stimulates the need for maintenance. Functional failure in a machine or equipment can be induced by a number of things for example, wear and tear, overstress, handling and design failure, amongst others (Wireman, 2004).

The P-F curve in Figure 2.1.2 explains how the functional failure of the machine or equipment takes place over time of usage of that particular machine or equipment.

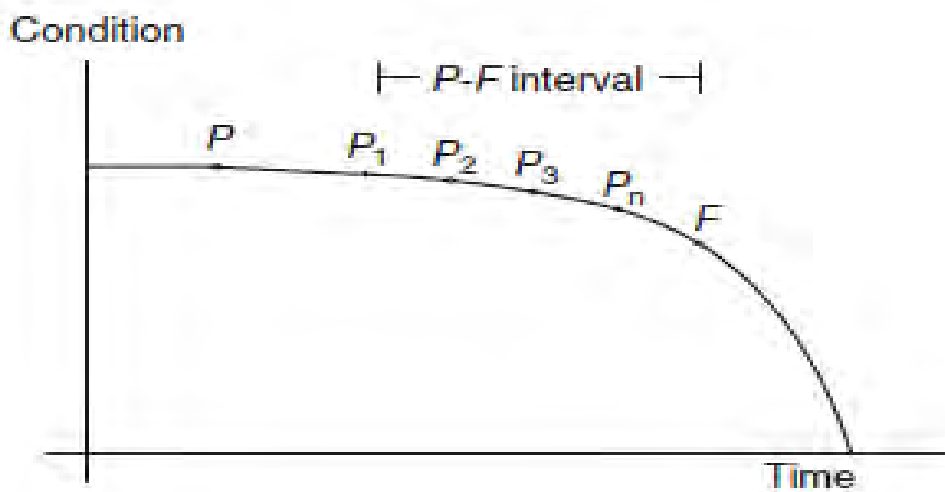


Figure 2.1.2: Machine failure behaviour. Prajapati *et al.* (2012:387)

Machine deterioration starts from point **P** and continues along the P- F interval until the functional failure or breakdown comes into effect at point **F** (Prajapati *et al.* 2012).

The longevity of the P-F interval is influenced by and is dependent on the effectiveness of maintenance to the machine or equipment. The explanation of the machine failure behaviour brings about a crucial question of: what stimulates the need or demand for maintenance?

In a much broader perspective and in the context of manufacturing, the demand for maintenance is also stimulated by the factors listed below:

- Global competitiveness which demands maximum productive capacity (Kumar *et al.* 2013:234).

- A high degree of automation and mechanization of production equipment and machinery (Zuashkiani *et al.* 2011, Rolfsen and Langeland, 2012 and Naughton and Tiernan 2012).
- Impacts from manufacturing firms' quest for quality improvement, cost reductions and capacity expansion (Kutucuoglu *et al.* 2001:173).
- Impacts due to globalization and rising pressure for effective exploitation of resources (Green, Jr. *et al.* 2012:306).
- Fierce competitive trends and business pressures (Ahuja and Khamba 2008).
- High levels of complexity and technological advancement of manufacturing processes (Al-Turki 2011, Razak *et al.* 2011).
- Stringent regulatory environment: safety, health and environmental (Al-Turki 2011).

2.13 Contemporary challenges pertinent to maintenance in the manufacturing industry

Some of the challenges of maintenance within manufacturing industries are, captured below:

- Incorrectly perceived status of maintenance function, within manufacturing plants, due to:
 - the low level of awareness of the basic principles of maintenance management (Wireman 2004:196, Salonen, 2011, Zaim *et al.* 2012:18 and Srivastava and Mondal, 2013).
 - the lack of interest and commitment towards the maintenance function (Jonsson, 1997).
- Soaring maintenance costs in manufacturing plants (Al-Turki ,2011), Simoes *et al.* ,2011, Salonen and Deleryd ,2011, Zaim *et al.* 2012).
- Ambiguity in connecting maintenance activities with the firms' profitability (Salonen 2011).
- The complex *relationship* between the maintenance function and other business functions such as production, Health, Safety, Environmental and Quality (Reis *et al.* 2009 and Portioli-Stauacher and Tantardini (2012:42).
- Inadequacy of maintenance and engineering technical know-how (Razak *et al.* 2012).

2.1.4 Benefits of maintenance within the manufacturing industry

Postulated below are the benefits of maintenance as cited by an array of scholars, authors and practitioners in the maintenance management academia:

- Maintenance is the integral and support function for manufacturing plants (Pintelon *et al.* 2006, Ahuja and Khamba ,2008, Al-Turki ,2011 and Koochaki *et al.* 2011).
- Maintenance contributes meaningfully to the firm's bottom line (i.e. *profitability*) – (Sharma *et al.* 2011, Koochaki *et al.* 2011, Zaim *et al.* 2012, Razak *et al.* 2012, Kumar and Maheshwari 2013, Dilanthi 2013 and Srivastava and Mondal 2013)
- Maintenance is the cornerstone for the manufacturing plant's optimum functionality, efficiency and effectiveness - Koochaki *et al.* 2011, Zaim *et al.* 2012, Maletic *et al.* 2012, Razak *et al.* 2012, Dilanthi ,2013, Kumar and Maheshwari 2013).
- For manufacturing plants, maintenance has a profound impact on *Return on Fixed Assets* (Ahren and Parida 2009:250) and in a similar way on the *Return On Investment* Simoes *et al.* 2011 and Zuakishiani *et al.* 2011).
- Maintenance is a source of competitive advantage – (Uysal and Tosun '2012, Rolfsen and Langeland ,2012 and Srivastava and Mondal 2013).
- Maintenance supports the manufacturing firm's quest for *world class competitiveness* – (Zaim *et al.* 2012, Naughton and Tiernan 2012 and Srivastava and Mondal 2013).
- Maintenance underpins the manufacturing plant's endeavours towards compliance with safety, health and environmental legislation - (Al-Turki 2011, Zuashkiani *et al.* 2011, Zaim *et al.* 2012, Rolfsen *et al.* 2012, Razak *et al.* (2012), Dilanthi (2013)

On the basis of the foregoing, it is concluded that the role played by maintenance management within manufacturing plants is of absolute importance, and will remain so for the unforeseeable future.

2.1.5 Plant Maintenance

It is important to put the plant maintenance into perspective right from the outset.

Plant maintenance is defined as the engineering activities and processes aimed at ensuring production system functionality and in that way rendering requisite support to the manufacturing or production plant (Ben-Daya and Duffua 1995:21, Deac *et al.* 2010 and Salonen 2011:24).

Figure 2.1.5 depicts the relationship between plant maintenance and production in a manufacturing or production plant.

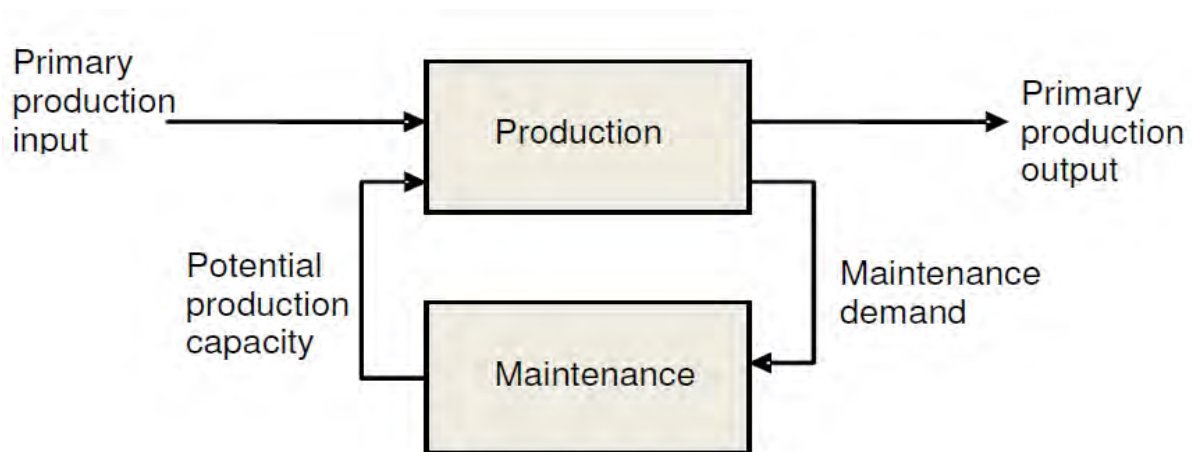


Figure 2.1.5: Plant maintenance in the context of production system. Salonen, (2011:24)

As illustrated in Figure 2.1.5 a production department depends on the plant maintenance function to achieve production throughput (Salonen, 2011). Ahuja and Khamba (2008) concur with that view and further assert that within manufacturing enterprises, plant maintenance is an indispensable business function. The UK Department of Trade and Industry recognises a plant maintenance function as a necessary business function in manufacturing (Bamber *et al.* 2004). Koochaki *et al.* (2011) reiterate the fact that in manufacturing plants, especially in processing, the plant maintenance function ensures optimum plant availability, production efficiency and most importantly compliance with legislation for safety, health and environment.

2.2 MAINTENANCE FUNCTION, SYSTEM AND ORGANIZATION

The terms ‘maintenance system’, ‘maintenance function’ and ‘maintenance organization’ are used interchangeably in most journals and publications. Due to the prominent feature of these terms and the significance of these terms in this study, each of them will be explained for the sake of clarity.

2.2.1 Maintenance System

Maletič *et al.* (2012), Salonen and Bengtsson (2011) and Parida and Kumar (2006) acknowledge the significance of an efficient and effective maintenance system in the manufacturing firm’s success and sustainability. According to Al-Turki (2011) a maintenance system is a transformation process. As illustrated in Figure 2.2.1 a maintenance system is positioned as a business function central or at the core of the manufacturing plant.

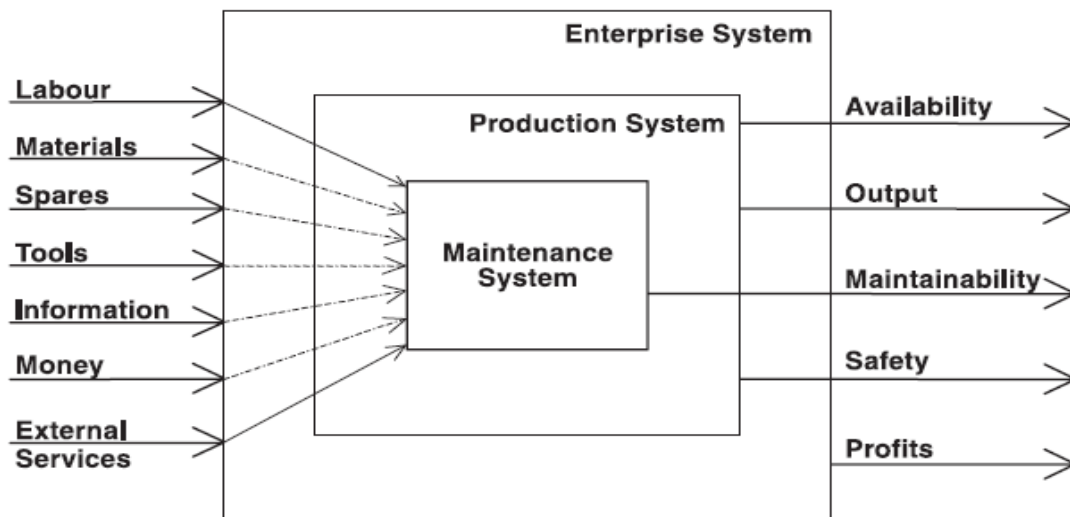


Figure: 2.2.1 Maintenance Input-Output Model. Al-Turki, (2011:153)

As depicted in Figure 2.2.1 inputs of a maintenance system are: labour, materials, spares, tools, etc. Inputs are deployed as demanded by the production system. The execution of maintenance activities ensures availability, reliability, profits, safety and quality. Such deliverables, in turn, result in profitability and in the acquisition of a competitive advantage for the manufacturing firm (Al-Turki , 2011). In view of the foregoing, maintenance system is obviously the centrepiece of the manufacturing plant. The next section elaborates on the maintenance function and organization within the context of a manufacturing plant.

2.2.2 Maintenance Function

The significance of the effective maintenance function within manufacturing plants is widely acknowledged and extensively covered in the literature (Garg and Deshmuk ,2006, Ahuja and Khamba ,2008, Marquez et al. 2009, Khazrei and Deuse ,2011, Simoes *et al.* 2011 Savsar 2011 and Kumar *et al.* 2013:233).

Kumar *et al.* (2013) define the maintenance function as, “...the *engineering decisions* and corresponding activities which are required *for the optimization* of pre-determined *capability* of the production system or machine, such that it yield envisaged performance”. Within the context of a manufacturing plant, a maintenance function can be likened to a department or unit entrusted with the responsibility for ensuring optimal reliability and availability of the production system (Visser, 2009).

According to Stenström *et al.* (2013:224), the core of the maintenance function in the manufacturing plants is embodied by maintenance value drivers, namely: asset (equipment) utilisation, resource allocation, cost control and Health, Safety and Environment (HSE).

Figure 2.2.2 is an illustration of the maintenance function of a manufacturing plant.

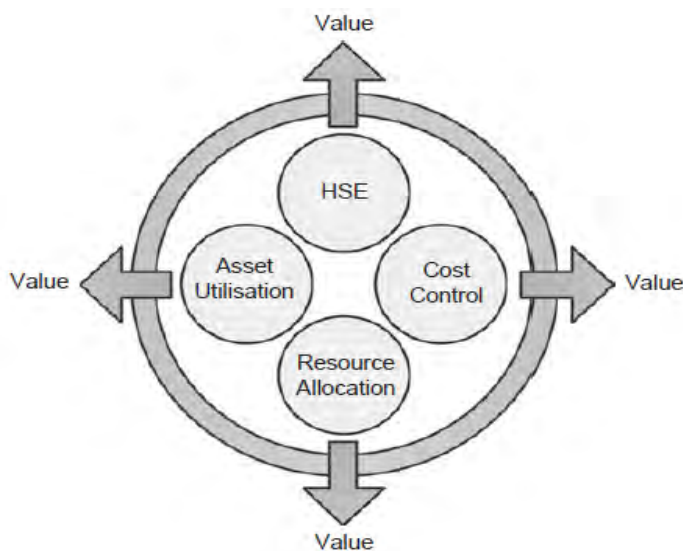


Figure 2.2.2: Maintenance function in a manufacturing plant. (Stenström *et al.* 2013:226)

As postulated in Figure 2.2.2, the maintenance function effectiveness, is accomplished only when a good balance is struck between the various maintenance value drivers (Stenström *et al.* 2013).

Pun *et al.* (2002:352), assert that maintenance function effectiveness is reflected by expeditious and cost effective restoration of production equipment to normal working condition (i.e. long Mean Time between Failure (MTBF) and short Mean Time to Repair (MTTR)).

2.2.3 Maintenance Organization

Maintenance organization matches maintenance resources with maintenance workload with the aim of ensuring optimum production equipment reliability (Visser 2009). It comprises a maintenance resource structure, a work planning system, an administrative system and a control system. The main objective of the maintenance organization is the effective application of maintenance resources to the execution of maintenance work, as pre-determined by the maintenance plan (Nel, 2006). Figure 2.2.3 below is the depiction of a maintenance organization.

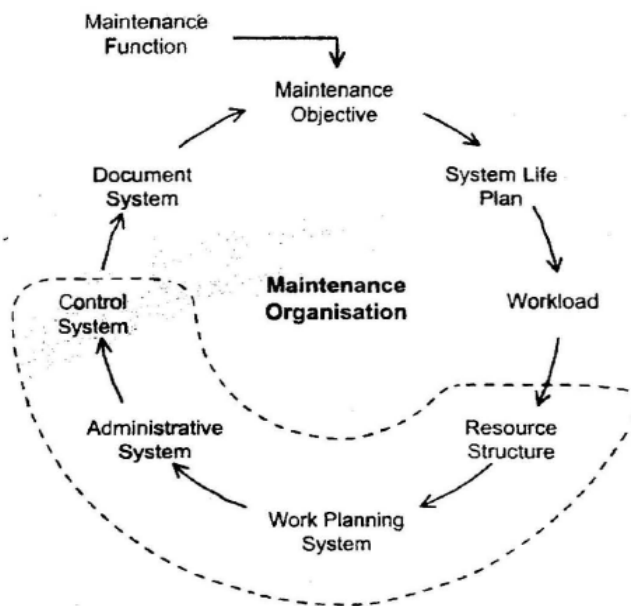


Figure 2.2.3: Maintenance organisation. (Visser 2009:28)

Figure 2.2.3, above clarifies the position of the maintenance function in the context of maintenance organization within a manufacturing plant.

2.2.4 Maintenance Classifications and Approaches

Notwithstanding its clear-cut meaning and intention, plant maintenance is often classified further into different maintenance classifications in accordance with different international maintenance standards, namely:

- *US Department of Energy (US DOE)* - reactive, predictive, preventive and RCM;
- *German Standard DIN 31051* - preventive, inspection and repair; and
- *European Standard EN 13306* - corrective and preventive.

Khazrei and Deuse (2011: 96-98)

Khazrei and Deuse claim that, amidst all the different maintenance classifications, the *European Standard EN 13306* is purported to be the standard reference classification for a plethora of countries.

Maintenance is categorized into three different types or approaches, namely *preventive*, *corrective* and *predictive* (Gebauer *et al.* 2008, Moayed and Shell, 2009, Utne, 2010, Sharma *et al.* 2011, Lind and Muyingo 2012, Prajapati *et al.* 2012:392 and Srivastava and Mondal 2013). Razak *et al.* (2012) echo the view that the fulfilment of the maintenance function is through the application of maintenance approaches for a machine or equipment.

Each maintenance type or approach is explained in details below:

Corrective maintenance (also called breakdown or failure based or ‘run to failure’ or unplanned maintenance) – This is a reactive, failure-driven and unscheduled maintenance approach where repairs to the machine / equipment are carried out after failure or malfunction has occurred (Sharma *et al.* 2011 and Srivastava and Mondal 2013). Ahren and Parida (2009:250), purport that the maintenance function is reactive if the ratio of unplanned maintenance to the entire plant maintenance exceeds 20%.

Predictive maintenance (also called condition based maintenance (CBM)) – Srivastava and Mondal (2013), assert that with predictive maintenance the operating parameters of the machine are monitored and compared to set operating standards. Zaim, *et al.* (2012), assert that CBM is highly utilised in petroleum and petrochemical manufacturing firms.

Preventive maintenance (or planned) – This is a proactive maintenance approach. In this maintenance approach, the equipment is repaired at set intervals (planned and periodic) which are scheduled, so as to keep the equipment in good running condition and to preclude failure or fault of equipment (Sharma *et al.* 2011. and Srivastava and Mondal 2013).

Salonen and Bengtsson (2011), argue that the maintenance costs due to preventive maintenance are usually less than similar costs for corrective maintenance. Farrero *et al.* (2002), purport that the proper integration of the maintenance approaches mitigates the risk of sub-optimality and a premature equipment failure.

As postulated in Table 2.2.4, below, each maintenance approach has its advantages and disadvantages.

Corrective Maintenance	Preventive Maintenance	Predictive Maintenance
<p>Advantages:</p> <ul style="list-style-type: none"> • Simplicity • Cheap <p>Disadvantages:</p> <ul style="list-style-type: none"> • Unplanned breakdowns • High possibility of equipment downtime 	<p>Advantages:</p> <ul style="list-style-type: none"> • Increased life span for machinery • Reduction of machinery failure <p>Disadvantages:</p> <ul style="list-style-type: none"> • Done on more frequent basis • Relies on manpower 	<p>Advantages:</p> <ul style="list-style-type: none"> • Enhance plant availability and reliability • Reduction of maintenance costs • <p>Disadvantages:</p> <ul style="list-style-type: none"> • Expensive • Sophisticated

Table 2.2.4 Advantages and disadvantages of maintenance types (Srivastava and Mondal 2013:34)

Pun *et al.* (2002) assert that, maintenance approaches are the predictors of the effectiveness of the maintenance function within the manufacturing industry.

Bamber *et al.* (2004), assert that a significant number of manufacturing firms have employed various maintenance approaches in a quest to improve maintenance effectiveness. According to Wireman (2004), failure patterns for machinery differ, and some of the machine failure patterns are: wear out, bathtub, slow aging, random and early infant failures.

The bathtub curve, Figure 2.2.4, below, depicts different machine failure patterns on a machine, in the form of a bath tub.

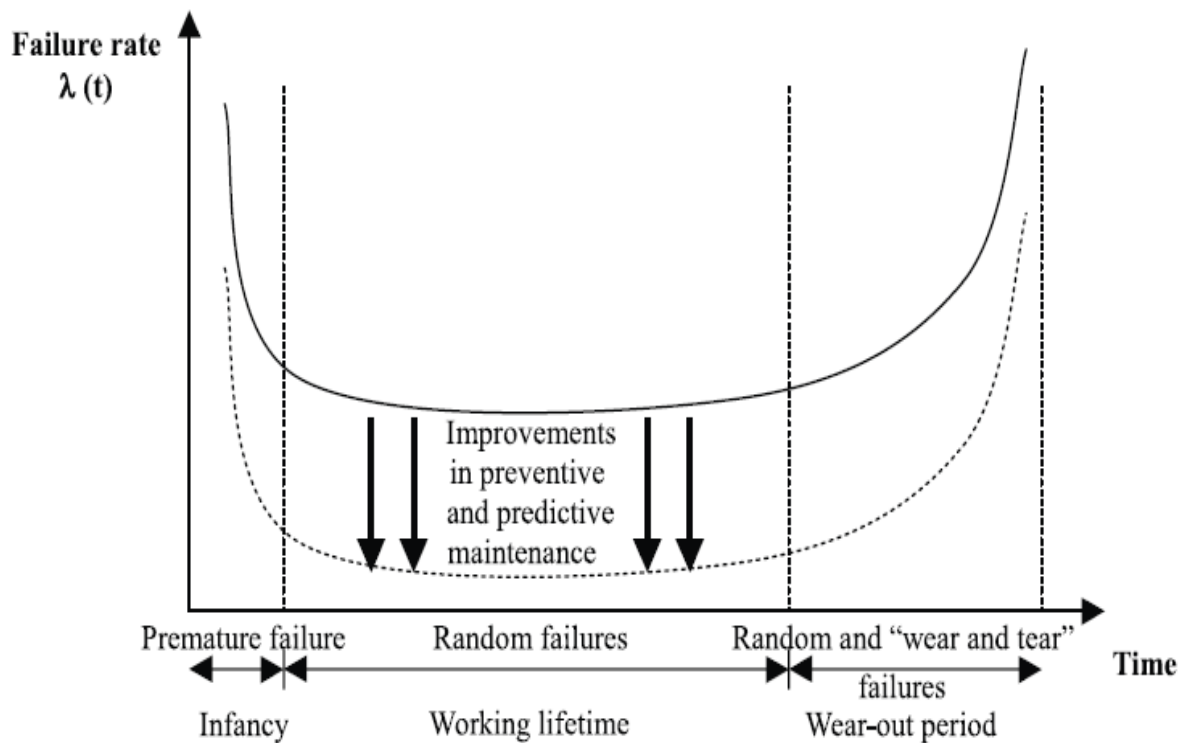


Figure 2.2.4 Bathtub (machine life cycle) curve. (Farrero *et al.* 2002:189).

Figure 2.2.4 illustrates the failure behaviour of the machine with time, which is divided into three periods, namely: infancy, working lifetime and wear-out (Farrero *et al.* 2002). Farrero *et al.* (2002), assert that the correct combination and application of maintenance approaches or types (i.e. preventive and predictive) and the maintenance strategy minimises and curbs the effects of functional failure and sub-optimality, and subsequently extends the working lifetime of the machine or equipment, as depicted in Figure 2.2.4 .

The role played by maintenance is to minimize or hinder premature functional failure, deterioration and degradation of the machine, thus ensuring efficient running of the machine for a longer time period.

2.2.5 Maintenance strategies and concepts

Salonen and Bengtsson, (2011), assert that different authors use maintenance related terminology interchangeably and differently. It is very common in the maintenance management literature, to find terms such as ‘maintenance concepts’ and ‘maintenance strategies’ in an attempt to explain maintenance management concepts. Case in point, Gebauer *et al.* (2008), refer to Total Productive Maintenance (TPM) and Reliability Centred Maintenance (RCM) as maintenance strategies, whilst Salonen and Bengtsson, 2011 and Ahuja and Khamba (2008) view TPM and RCM as maintenance concepts. Notwithstanding the manner in which authors use different terminology, for the purpose of this research study, the context in which the terms ‘*maintenance strategy*’ and ‘*maintenance concept*’ will be defined. For the purpose of this research study:

- **Maintenance strategies** - are TPM and Outsourcing. This assertion is endorsed by authors: Pintelon *et al.* (2006), Ahuja and Khamba (2008) and Gebauer *et al.* (2008).
- **Maintenance concept** - is RCM. Salonen and Bengtsson, (2011) concur with this claim.

Maintenance strategy – Lind and Muyingo (2012:18) define maintenance strategy as a plan (long term) which entails maintenance management fundamentals and a course of action for accomplishing optimum or effective maintenance. Formulation of maintenance strategy is of absolute significance in ensuring optimal machinery life and effective maintenance (Pintelon *et al.* 2006). The distinguishing factor of an optimal maintenance strategy is the utilisation of more than one maintenance type or approach for a single piece of equipment or machinery, taking into consideration the criticality and financial value involved through failure of such machinery (Kahn , 2005).

Maintenance concepts – this is a combination of maintenance approaches (i.e. corrective, preventive and predictive) and the holistic structure which combines approaches (Lind and Muyingo 2012:18). Salonen (2011:26) asserts that maintenance concepts are developed to enhance the effectiveness of maintenance systems as well as to align maintenance activities in a manufacturing plant. According to Naughton and Tiernan (2012), maintenance concepts differ from one machine to another. RCM is a typical example of a maintenance concept (Ahuja and Khamba ,2008, and Salonen and Bengtsson, 2011).

2.2.6 Cost of maintenance

There is general consensus on the part of various scholars that in the asset-intensive manufacturing plants, maintenance is usually the highest expense in the operating budget (Al-Turki, 2011, Simoes *et al.* 2011, Salonen and Bengtsson, 2011 and Zaim *et al.* 2012). Different scholars purport that in manufacturing plants maintenance spending is a percentage of manufacturing operating costs and that these differ from plant to plant, for instance:

- 15 % - 40 % Razak *et al.* (2012:25),
- 15 % – 70 % Zaim *et al.* (2012:17)
- 20% - 50% Visser and Kotze (2010) - **South African** manufacturing industries

The aforementioned draws attention to the significance of maintenance function effectiveness in a manufacturing plant. Wireman (2004) purports that in the US, the maintenance expenditure is often in the excess of trillions of dollars per annum.

2.2.7 Cost of poor maintenance model (CoPM)

Salonnen and Deleryd (2011) hold the view that maintenance management activities should be viewed in a similar light to quality management activities and that cost of poor maintenance should be treated like cost of poor quality. It is on that basis that the cost of poor maintenance (CoPM) model was devised (Salonnen and Deleryd, 2011:67). The basic premise of the CoPM is that all the planned maintenance costs and activities that contribute to maintenance, should be viewed as costs of conformance, whilst the costs for all the maintenance activities that do not add value should be treated and viewed as costs of non-conformance (Salonnen and Deleryd, 2011). In essence, the CoPM model succinctly elucidates how the maintenance management function contributes to the firm's profitability and viability (Salonen, 2011).

On the basis of the foregoing, it is clear that high maintenance costs in the manufacturing plants reaffirm the strategic importance of the maintenance function. It is evident that maintenance is not just a 'passing fad' but it is instead a cornerstone and a strategic imperative for manufacturing firms.

2.3 EVOLUTION OF MAINTENANCE

This section discusses how maintenance has evolved with time. Authors: Cooke (2003), Parida and Kumar (2006), Ahuja and Khamba (2008), Lind and Muyingo (2012) and Razak *et al.* (2012), acknowledge the evolution of maintenance over the past decades, citing automation and high levels of mechanisation as the causal factors.

The evolution of maintenance over time is classified into different generations and perspectives (Cooke 2003:240, Sharma *et al.* 2006:258, Ahuja and Khamba 2008:712-15, Lind and Muyingo 2012:18 and Kumar and Kapil 2013:3).

Each generation and perspective is outlined below:

- *First Generation* (<1950): Reactive maintenance and maintenance was perceived as a cost;
- *Second Generation* (1950 – 1979) : Planned maintenance approach and cost centre view; and
- *Third Generation* (1980s -): Proactive maintenance philosophies e.g. TPM, RCM, etc.

The evolution of maintenance has changed the perceived importance of maintenance in the manufacturing sector, and has given rise to three perspectives, namely the *cost centre view*, the *production capacity assurance view* and the *strategic view* (Zuashkiani *et al.* 2011:75).

The *Cost centre view* is tantamount to the first and second generation maintenance perspectives, where maintenance is viewed as an inevitable expenditure for a manufacturing plant (Zuashkiani *et al.* 2011). The *Production capacity assurance view* is congruent with the third generation maintenance view. Consistent with this view, is the profound repercussion of the maintenance function on the manufacturing process. *Maintenance* expenditure is viewed as being an investment which brings substantial returns for a manufacturing firm (Zuashkiani *et al.* 2011). Gebauer *et al.* (2008) assert that the focus of both *cost centre* and *production capacity assurance views* is more on machinery and not on the business in its totality.

The *Strategic view* - Murthy *et al.* (2002), Tsang (2002) and Zuashkiani *et al.* (2011) tout this view as the *Fourth Generation* perspective of maintenance. According to the *strategic view*, maintenance management must be viewed in the long strategic context, as opposed to a narrow tactical or operational context (Murthy *et al.* 2002, and Gebauer *et al.* 2008). To date, the maintenance function is gaining recognition and acceptance as being a strategic imperative and an integral element of a manufacturing business (Lazmin and Ramayah ,2010, Al-Turki ,2011, Simoes *et al.* 2011, Rolfsen *et al.* 2012, Maletič *et al.* 2012, and Dilanthi 2013). Maintenance management academics are in the forefront of advocating for the adoption of the strategic maintenance approach, particularly, within manufacturing plants (Tsang ,2002, Murthy *et al.* 2002, Al-Turki 2011 and Maletic *et al.* 2012). The reasons cited include recognition of the significance of the physical asset management drive for competitive advantage and automation.

Tsang (2002), Murthy *et al.* (2002), Al-Turki (2011) and Sharma *et al.* (2011), assert that outsourcing of maintenance activities by manufacturing plants is a classic example of the strategic maintenance approach. According to the European Federation of National Maintenance Societies in 2011, 24% of manufacturing plants outsourced their maintenance activities Marttonen *et al.* (2013:430). Furthermore, Marttonen *et al.* (2013) assert that in Finland, 30% of industrial maintenance is outsourced.

The Strategic Maintenance Management Approach Model is another embodiment of the strategic maintenance approach, which also perpetuates the significance of managing maintenance strategically from a holistic business perspective, as well as through the adoption of a multidisciplinary approach in handling it (Gebauer *et al.* 2008, and Al-Turki 2011:152).

Tsang (2002) claims that there are four strategic dimensions of maintenance, namely: service delivery strategy, organisation and work structure, maintenance methodology and the support system.

Pursuant to the strategic maintenance approach, Al-Turki (2011:157), introduced the framework for strategic maintenance strategic planning which seeks to integrate the maintenance function to other manufacturing business functions at all levels, i.e. tactical, operational and strategic levels.

Consistent with the strategic maintenance approach, Simoes *et al.* (2011:128/9) categorise manufacturing plants into two classes, namely: open and closed system manufacturing organizations.

In a closed system manufacturing organization, a maintenance function is perceived as a necessary manufacturing expense, whilst in the open system, the manufacturing organization maintenance function is deemed as a strategic competitive resource (Simoes *et al.* 2011).

Closed system manufacturing organizations have a propensity to perceive the maintenance function as a standalone operational function (Simoes *et al.* 2011:128). Simoes *et al.* (2011) assert that open system manufacturing organizations are characterised by the propensity of utilising the IT systems for integration of the maintenance function with other business functional areas within manufacturing plants.

Sharma *et al.* (2011:18), assert that there are two views of maintenance, namely the traditional and the contemporary views. Table 2.3 (a) below explains each view.

Traditional view	Contemporary view
Maintenance is a support function	Maintenance is strategic and business-driven
Maintenance is operationally driven	Maintenance focuses on up-time and quality
Maintenance is a target for cost saving in operations	Maintenance is an opportunity to add value to operations
Less regard for stakeholders	Strives for added value for stakeholder
Cost-effectiveness is not a priority or driver	Cost-effectiveness is the main driver.

Table 2.3 (a) Traditional vs. Contemporary views of maintenance. (Sharma *et al.* 2011:18)

Maintenance evolution culminates to, *changing world of maintenance*, which is characterised by two paradigms, namely, old and new paradigm Moubray (2001).

Table 2.3 (b), below, serves to contrast the old and new paradigms of maintenance.

Old paradigm	New paradigm
Solution to maintenance ineffectiveness is a ‘silver bullet’ approach.	Solution to maintenance ineffectiveness is a systematic approach.
Maintenance preserves equipment	Maintenance preserves optimal functionality of the production equipment throughout its life cycle.
Maintenance is to cost effectively <i>optimise</i> equipment availability	Maintenance impacts business operational performance areas, either positively or negatively

Table 2.3 (b) Comparison between Old and New paradigms in maintenance. (Moubray 2001)

In a nutshell, the consequences of maintenance management evolution are summarised below:

- The propensity to miss-perceive the maintenance function (Zuashkiani *et al.* 2011:75)
- Instead of viewing the maintenance function from an operational perspective, maintenance management is now recognised as a significant strategic function (Murthy *et al.* 2002, Simoes *et al.* 2011, and Lind and Muyingo 2012).
- A paradigm shift. Instead of viewing maintenance as a ‘cost centre’ or a ‘necessary evil’, maintenance is now accepted and recognized as a significant and profitable business function (Veldman *et al.* 2011, and Lind and Muyingo 2012).
- A paradigm shift from focussing on technical aspects of physical assets to a business-driven *Asset Management (AM)* approach El-Akruti and Dwight (2013:400).

In view of the foregoing, it is quite evident that maintenance evolution is the impetus of the realisation and acceptance that the maintenance function is indeed not a passing fad, rather it is a strategic imperative which must be embraced.

The contemporary trends of maintenance are discussed in the next section.

2.3.1 Contemporary trends of Maintenance

After discussion on how maintenance has evolved over time, and the ramifications of such evolution, it is useful to discuss the trends of maintenance as they prevail. Each trend is discussed in turn below:

Asset Management (AM) – the asset management definition by the Asset Management Council (2009) is that it is *life cycle management* of assets such as machinery. Concurring with that view, Schuman and Brent (2005:556) assert that AM is a *strategic*, combination of defined processes, inclusive of *engineering, maintenance, financial* and *operations* to ensure optimal effectiveness and return on from equipment. El-Akruti and Dwight (2013) acknowledge and accentuate the significance of AM, as a holistic approach, towards maintenance of physical assets such as machines

Terotechnology – this is integration of management functions, namely: finance, engineering and procurement, in a bid to prolong the life span of the equipment Mitchel *et al.* (2002:234). According to El-Akruti and Dwight (2013), *terotechnology* is one of the building blocks or aspects of AM.

Life cycle management – this is a concept of managing physical assets from *cradle to grave*, i.e. from acquisition to disposal of an item, taking into cognisance all the costs, from design, maintenance and disposal El-Akruti and Dwight (2013). This has a profound impact on life cycle costs.

International Maintenance norms and standards – increase in global competitiveness and robust market demands have brought another dimension and paradigm in the field of maintenance. That is the relevance and significance of *International Maintenance norms and standards*, such as PAS 55. According to Farinha *et al.* (2013), PAS 55 is a standard by the British Standards Institution that specifies and governs the requirements for an asset management system for the management of physical assets and asset systems over their life cycles.

On the basis of the foregoing, maintenance effectiveness is improved by synthesising the AM tools with traditional maintenance management tools, such as TPM, RCM, etc.

2.4 MAINTENANCE MANAGEMENT

It is important that maintenance management is defined so as to ensure full comprehension and prevent ambiguity.

Marquez and Gupta (2009) write that maintenance management is the:

“management activities which set objectives, priorities, strategies, responsibilities and also ensure the execution of such activities by utilising management functions, namely: planning, organizing, leading and controlling”.

2.4.1 Characteristics of maintenance management

The fundamental characteristics of maintenance management, as cited by different scholars, are listed below. Maintenance management is:

- a business function, that inclusive of *strategic, tactical* and *operational* aspects - Arsovski (2011:351)
- is *complex* El-Akruti and Dwight (2013:400).
- multi-disciplinary – Karim *et al.* (2013)

Further to the afore-mentioned maintenance management characteristic's, Murthy *et al.* (2002:292), claim that maintenance management entails three crucial activities and deliverables, namely:

- comprehension of plant or machinery that requires maintenance;
- optimal maintenance planning ; and
- execution of maintenance activities.

2.4.2 Maintenance management model

Maintenance management model is a descriptive model that explains management functions of maintenance within a manufacturing context. The maintenance management model depicted in Figure 2.4.2, below captures the context of the maintenance cycle as explained by Coetze (1997) and Nel (2000).

This model contextualises the application of general management functions (planning, organising, leading and controlling) within the context of the maintenance management in a manufacturing plant.

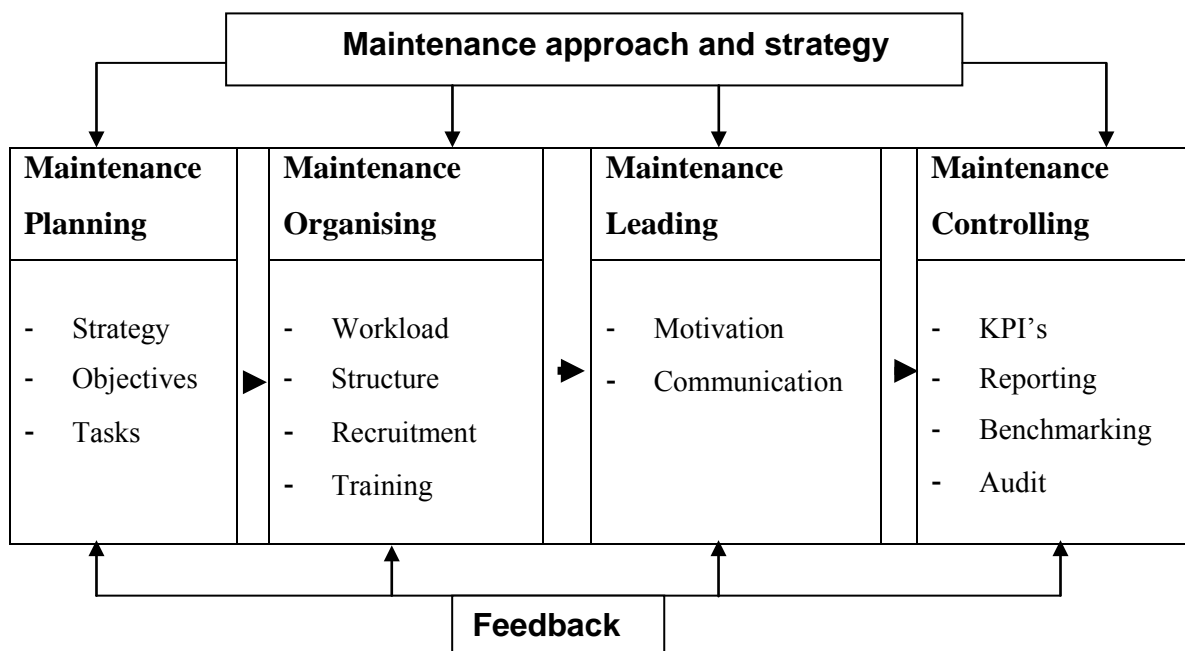


Figure 2.4.2 Maintenance Management Framework. (Nel, 2000:204)

The management function of any system which must be managed comprises the sub-functions of: planning, organising, staffing and controlling (Nel 2000). Figure 2.4.2 also shows the sub-aspects sought for execution of each maintenance function within a manufacturing plant. The maintenance management model in Figure 2.4.2 further embodies processes and practices, which must be put in place to implement the maintenance strategy within a manufacturing plant.

In the next section the status of maintenance management, is discussed.

2.4.3 Status of maintenance the management function within the manufacturing industry

The significance of the maintenance function within the manufacturing industry is widely acknowledged and has been mentioned above, it is extensively covered in the literature.

Notwithstanding that, the prevailing perception within manufacturing industries suggests that the status of the maintenance function is low (Ollila and Malmipuro 1999). In most manufacturing firms, the decisions pertinent to the maintenance function and the manner in which maintenance management practices are disregarded attest to that view and line of thinking. This is a perception which Tsang (1998: 87) describes as myopic.

There are a plethora of research studies pertinent to the field of maintenance management (Reis *et al.* 2009:260).

To this end, researchers, namely: Jonson (1997), Mitchel *et al.* (2002), Cholasuke *et al.* (2004), Pintelon and Pinjala (2004), Alsyouf (2009), Chinese and Gherard (2010), Tahboub (2011), Ablay (2013) and Srivastava and Mondal (2013) have all conducted research studies to evaluate the effectiveness of maintenance functioning using their research studies on manufacturing plants focusing on aspects such as the perceived status of maintenance management within manufacturing and on the application of maintenance practices.

Jonsson's (1997) study on the perceived status of maintenance management within Swedish manufacturing firms concluded that:

- The status of the maintenance function is low compared to other business functions;
- The Maintenance function is perceived as a cost centre and not as a strategic resource. Alsyouf (2009) and Ablay's(2013) empirical study also confirmed this finding;
- Senior management lacks the interest and commitment towards the maintenance function; and
- There was a low level of awareness of maintenance management fundamentals and principles.

Pintelon *et al.* (2006) conducted a study on assessing the role and contribution of maintenance strategies to the manufacturing firms' competitiveness, using the Hayes and Wheelbright four stage model.

Cholasuke *et al.*'s (2004) study within the UK manufacturing firms concluded that:

- The maintenance function supports manufacturing activities and manufacturing firms cannot survive without such support; and
- The significance of the maintenance management function is acknowledged, as are the benefits derived due to the maintenance management function.

Chinese and Ghirardo (2010) conducted an empirical study on *The status of maintenance management within Italian manufacturing plants*. The study concluded the following:

- There was a low status regarding the maintenance function in Italian manufacturing plants;
- There was an excessive adoption of reactive maintenance approaches;
- There was inadequate usage of computerised maintenance management systems (CMMS); and
- There was the adoption of TPM as a maintenance strategy, by most manufacturing plants in Italy.

In view of the foregoing empirical studies, the following crucial inferences pertinent to the status of maintenance management within the context of manufacturing industry are derived:

- The status of the maintenance function is low and not adequately recognised in manufacturing plants;
- There are low levels of awareness and understanding of maintenance management principles;

- The strategic importance of the maintenance management function, particularly in pursuance and sustainance of world class competitiveness by manufacturing firms is not understood.
- Maintenance is perceived as necessary expense and not a strategic resource;
- Reluctance to accept the profound impact on manufacturing companies' bottom line (profitability) and other strategic benefits of a maintenance function, is counter-productive; and.
- There is still a prevalence for and dominance of first generation maintenance perspectives and approaches.

2.5 MAINTENANCE MANAGEMENT FRAMEWORK

Marquez *et al.* (2009) defines a maintenance management framework as the structural support and the rudimentary system sought for the maintenance management function in a manufacturing plant. Chinese and Ghirardo (2010) write that there are three maintenance management frameworks, which can be utilised to evaluate the status and effectiveness of the maintenance function within manufacturing plants. Pintelon *et al.* (2006), Cholasuke *et al.* (2004) and Jonsson (1997) also concur with that view.

Each framework is explained below, in Table 2.5. Notably, from Table 2.5, below, the most recent maintenance management framework is that devised by Pintelon *et al.* (2006). It is for that reason that it is adopted here for the purposes of this research study.

Pintelon <i>et al.</i> (2006:10)	Cholasuke <i>et al.</i> (2004:7)	Jonsson (1997:236)
<p><u>Structural elements:</u></p> <ol style="list-style-type: none"> 1. Maintenance capacity 2. Maintenance facility 3. Maintenance technology 4. Vertical integration – i.e. outsourcing <p><u>Infrastructural elements:</u></p> <ol style="list-style-type: none"> 5. Maintenance organization 6. Maintenance approach 7. Planning and control 8. Human resources 9. Performance measurement 	<ol style="list-style-type: none"> 1. Maintenance organization 2. Maintenance approach 3. Maintenance planning 4. Information management 5. Human resources 6. Spare parts management 7. Financial aspects 8. Continuous improvement 	<ol style="list-style-type: none"> 1. Goals and strategy 2. Human aspects 3. Support mechanisms 4. Maintenance tools 5. Maintenance organization

Table 2.5 Maintenance management frameworks. (Chinese and Ghirardo 2010:158)

In Table 2.5 above, structural elements pertain to maintenance resources, whilst infrastructural elements pertain to maintenance management (Pintelon *et al.* 2006).

Pintelon *et al.* (2006) further assert that the maintenance management function's ability to support manufacturing firm's overall objectives and strategies is dependent on the manner in which structural and infrastructural elements are managed. Effective management of structural and infrastructural elements is realised by adopting and ensuring replication of maintenance practices (Pintelon *et al.* 2006, Tedele 2007, and Alsyouf 2004).

Wireman (2003:38) defines maintenance practices as “... *practices that enable the manufacturing firm to attain the competitive advantage over its competitors in the maintenance management process*”.

Prudent operationalisation of maintenance practices pertinent to structural and infrastructural elements augments the effectiveness of the maintenance function within the manufacturing firms (Fore and Mudavanhi 2011:205, Narayan 2012 and Kumar and Kapil 2013).

An empirical study to investigate the impact of adoption of maintenance practices on the overall performance of manufacturing, in Italy, concluded that good operational performance is achieved by adopting maintenance best practices (Reis *et al.* 2009).

In line with the objectives and scope of this research, the maintenance practices pertinent to structural and infrastructural elements which will be examined are: maintenance planning, maintenance leadership, maintenance organization, maintenance approach, performance measurement, spare parts management and continuous improvement. The reason why these maintenance practices warrant more attention is the profound impact which they have on maintenance effectiveness. Each maintenance practice is discussed below.

Maintenance approaches - According to Khazrei and Deuse (2011), corrective maintenance adversely affects the efficiency of the manufacturing plant. Narayan (2012) asserts that high reliability and availability are realised through proactive maintenance. Prajapati *et al.* (2012) and Tan and Raghavan (2007), assert that predictive maintenance is the most cost-effective maintenance approach. Predictive maintenance optimises plant reliability and availability (Veldsman 2011:197).

Maintenance Scheduling - Paz and Leigh (1994) assert that maintenance scheduling is a vital component of maintenance management, as it underpins maintenance planning. Notwithstanding that, Wireman (2004:105) asserts that maintenance planning and scheduling are often neglected, despite their significance in ensuring maintenance effectiveness. Maintenance scheduling matches the availability of maintenance resources with the demand for such resources (Wireman, 2004). Hence the deliverables of maintenance scheduling within the manufacturing plant are: maintenance work priority, artisan utilisation, and schedules for planned and unplanned maintenance work (Wireman 2004).

The work order system controls and monitors maintenance planning and scheduling activities (Yam *et al.* 2000). Wireman (2004) and Adale (2009) concur that a maintenance work-order system is the cornerstone of effective maintenance because it ensures optimization of maintenance resources and enables measurement and control of maintenance activities

Continuous Improvement - Continuous improvement is a vital maintenance practice, and an effective way of ensuring maintenance performance improvement (Cholasoke *et al.* 2004, Gebauer *et al.* 2008 and Maletic *et al.* 2012). Maletic, *et al.* (2012), commissioned an empirical survey within Slovenian manufacturing plants which confirmed the significance and positive contribution of continuous improvement towards maintenance efficiency and effectiveness. Cholasoke *et al.* (2004), assert that continuous improvement in maintenance management can be realised by using maintenance performance indicators. Benchmarking on maintenance best practice is a vital tool and a necessity for ensuring continuous improvement of the maintenance function (Tsang, 2000, Wireman, 2003, Simoes *et al.* 2011 and Lewis 2012) and for improvement of efficiency and effectiveness of the maintenance process (Ahren and Parida 2009:248).

Computerised Maintenance Management System (CMMS) - The effectiveness of the maintenance function relies heavily on the effective communication management (Uysal and Tosun ,2012 and Kumar and Kapil 2013). Moreover, Labib (2004) and Uysal and Tosun (2012: 213) write that CMMS ensures effective and efficient management of maintenance information, by converting maintenance records and data into usable information that enables decision-making in maintenance. Mahmood *et al.* (2009) acknowledges the reliance of manufacturing firms on CMMS, as a necessity to achieve world-class maintenance.

Marquez and Gupta (2006:319) and Uysal and Tosun (2012) , mention that the role of CMMS within the maintenance function is : management of maintenance work orders, analysis of historical maintenance data, tracking of the maintenance KPI's and provision of support for maintenance planning and scheduling activities.

Maintenance organization and staffing - Maintenance organizational structure is the backbone of the effective maintenance function in a manufacturing firm as it addresses all the issues pertaining to maintenance organization, communication, problem-solving and decision-making (Simoes *et al.* 2011). Fore and Mudavanhu (2011) and Cholasuke *et al.* (2004) stress the fact that the efficiency of the maintenance function is dependent on the maintenance organisational structure. Fore and Mudavanhu (2011) also stress the significance of allocating adequate human resources with requisite skills and know-how as a necessity for the effective maintenance function. That assertion is further endorsed by Razak *et al.* (2012) and Parida and Kumar (2006) who claim that inadequacy of maintenance technical know-how and skills renders the maintenance function ineffective.

Wireman (2004) claims that in at least one-third of the manufacturing plants in the US, there are no maintenance planners and hence he strongly advocates for their inclusion. According to Wireman (2004:106) the exclusion of the maintenance planner in the maintenance organisational structure is the major impediment to effective maintenance planning and scheduling. Simoes *et al.* (2011) assert that attitude, conduct and personality of maintenance personnel are significant to the effectiveness of the maintenance function. Jonsson (1997) asserts that competence and motivation are crucial necessities of effective maintenance.

Spare parts Management - The second-highest cost element of maintenance is spare parts (Cholasuke *et al.* 2004). Adale (2009) asserts that on time availability of maintenance spare parts, materials and engineering services is vital for an effective maintenance function. According to Wireman (2003:138) the fundamental requirements for the effective maintenance inventory system are: tracking balances for spare parts, maintenance requisitions and purchase orders and record keeping for spare parts lists especially the strategic maintenance spares.

Maintenance Leadership - The success of the maintenance function depends on the manner in which leadership is exercised (Cholasuke *et al.* 2004). Maintenance leadership drives the maintenance strategy with a clear vision which must be externalised within the maintenance itself. Effective maintenance leadership is a fundamental element of effective maintenance organizations (Campbell and Reyes-Picknel 2006).

Maintenance Planning - Maintenance planning underpins the coordination of the efforts for maintenance management activities, inclusive of engineering technical know-how and maintenance resources (i.e. labour, materials, tools and spare parts) (Chelsom 2005 and Adale 2009). Wireman (2004: *viii*), claims that within the manufacturing industry, the cost ratio of planned maintenance work to the unplanned maintenance work is 1:5. Shrinking profitability margins in manufacturing plants justifies the necessity of good maintenance planning and control (Uzun and Ozdogan 2012).

Salonen and Deleyerd (2011), say that poor maintenance planning results in unwarranted expenditure to the extent of at least one third of the maintenance costs within a manufacturing industry. Cholasuke *et al.* (2004) assert that inadequacy in maintenance planning impedes the maintenance function from accomplishing its goals. According to Al-Turki (2011:151), maintenance planning is an essential part of planning for the manufacturing firm. According to Wireman (2004:175), maintenance planning is the cornerstone of any firm's drive to optimize the effectiveness and efficiency of the maintenance function.

Maintenance Control - Maintenance control pertains to the measurement and alignment of the maintenance performance so as to ensure that maintenance objectives and plans formulated to attain them are achieved (Nel, 2000). Sharma *et al.* (2011), acknowledge the significant role played by maintenance control in optimizing the maintenance function. Maintenance control ensures adequate maintenance control mechanisms, such as setting quantitative objectives and standards, planning and scheduling maintenance tasks and most importantly selecting effective maintenance actions to enhance reliability and availability.

Maintenance Performance measurement - Maletic *et al.* (2012) and Århén and Parida (2009) opine that performance measurement is of vital importance in ensuring effectiveness of the maintenance function. Parida and Kumar (2006) cited in Al-Turki (2011) assert that maintenance performance measurement is the cornerstone of strategic maintenance management. Furthermore, maintenance performance measurement focuses on the efficiency and effectiveness of the maintenance function (Arts *et al.* 1998). Inadequacy of maintenance performance measurement compromises the capability to optimise the scarce maintenance resources, and the enhancement and improvement of the effectiveness and efficiency of the maintenance function (Simoes *et al.* (2011). Most importantly, without the maintenance performance measurement, value created by the maintenance function cannot be measured hence compromising justification of maintenance investment and resource allocation (Simoes *et al.* (2011).

2.6 MAINTENANCE EFFECTIVENESS

Kaur *et al.* (2013:70) and Ahuja and Khamba (2008), opine that effective maintenance contributes immensely toward increasing machine reliability and availability, productivity efficiency and subsequently, profit margins for manufacturing firms. Maletič *et al.* (2012) further assert that effective maintenance increases the firm's profit margins as well as the competitiveness. Aoudia *et al.* (2008), accentuate the significance of improving the maintenance function effectiveness by recognising the strategic role of maintenance.

2.6.1 Characteristics of an effective maintenance system

In the context of maintenance management, maintenance effectiveness is an embodiment of the overall satisfaction by the firm with its throughput and operating condition of the production equipment, as well as overall cost reduction accrued due to the consistent availability of the production capacity (Marquez *et al.* 2009). Onawoga and Akinyemi (2010) remind us that factors such as high productivity, highly competitive markets and short product lifecycles accentuate the significance of the effective maintenance systems within a manufacturing industry.

There is a consensus view from a wide variety of authors about what constitutes the elements of an effective maintenance system (Jonsson, 1997, Dhilon, 2002, Pun *et al.* 2002, Cholasuke *et al.* 2004, Kodali *et al.* 2009 and Rachidi *et al.* 2013)

According to Pun *et al.* (2002:352) : effective maintenance is realised by usage of appropriate maintenance approaches, effective utilization of maintenance resources as well as proper coordination of elements within the maintenance organization.

Jonsson (1997) claims that the following elements contribute to maintenance effectiveness: senior management responsibility and commitment, healthy communication between production and maintenance departments and technical know-how and motivation of the maintenance staff.

Dhilon, (2002) defines the elements of an effective maintenance management function as: maintenance policy, material control, work order system, preventive and corrective maintenance, job planning and scheduling, and performance management.

Cholasuke, *et al.* (2004:7) propose that the key ingredients for effective maintenance are : a sound maintenance policy, a defined maintenance approach, effective human resource management, continuous improvement, a Computerised Maintenance Management System (CMMS), spare parts management, task planning and scheduling, maintenance outsourcing and strong financial aspects.

Rachidi *et al.* (2013:504): assert that the elements of effective maintenance are: general organization, work method, technical follow up of the equipment, stock management of the spare parts, technical documentation, maintenance organization and information management.

According to the maintenance strategy decision elements, cited in Pintelon *et al.* (2006), it is evident that most of the aforementioned elements are inclined towards the infrastructure decision elements of maintenance strategy. This then suggests that the elements of effective maintenance management cited by Cholasuke *et al.* (2004) and Rachidi *et al.* (2013) can be the main pillars of an effective maintenance strategy.

According to Cholasuke *et al.* (2004) factors cited in Table 2.6.1 below are elements of an effective maintenance system with actions or deliverables associated with an effective maintenance system.

Element	Actions associated with effective maintenance
Policy deployment and organisation	- Formal written maintenance policy - Visible maintenance leadership
Maintenance Approach	- Adoption of predictive and proactive maintenance approaches - Adoption of proactive maintenance strategy, i.e. TPM
Maintenance planning	- Higher percentage of maintenance work planned (>90%) - Lower percentage of maintenance overtime (< 5%)
CMMS	- Availability and effective usage of CMMS
Spare parts	- Effective spare parts management.
Human Resources	- Motivated and adequately trained maintenance personnel
Financial Aspects	- Tracking and recording of all maintenance related expenditure
Continuous Improvement	- Adoption of maintenance KPI's – as per World Class

Table 2.6.1 Factors associated with effective maintenance system. (Cholasuke, *et al.* 2004:11)

In summary, the characteristics of an effective maintenance management system are cited below from different academics in the maintenance management field.

- Maintenance strategy and policy deployment: Jonsson (1997), Dhilon, (2002), Cholasuke *et al.* (2004) and Rachidi *et al.* (2013).
- Maintenance Planning and scheduling: Cholasuke *et al.* (2004), Macchi and Fumagalli (2013) and Rachidi *et al.* (2013).
- Effective maintenance resource organization: Jonsson (1997), Pun *et al.* (2002), Cholasuke *et al.* (2004) and Rachidi *et al.* (2013).
- Effective spare parts management: Cholasuke *et al.* (2004) and Rachidi *et al.* (2013).
- Continuous improvement: Cholasuke *et al.* (2004).
- Maintenance costs control: Cholasuke *et al.* (2004).

2.6.2 Maintenance Ineffectiveness

Aoudia *et al.* (2008) asserts that maintenance ineffectiveness has adverse effect on manufacturing plant availability, maintenance costs and manufacturing efficiencies.

The losses (financial and goodwill) incurred by manufacturing firms due to maintenance ineffectiveness or omission is extensively written about by scholars such as Ahlmann (1998), Al-Najjar (1997), Alsyouf (2006), Aoudia *et al.* (2008), Onawoga and Akinyemi (2010) and Tahboub (2011:315).

Some of the adverse outcomes of maintenance ineffectiveness include: escalation of downtime, and overtime costs, poor quality, excessive change over time, unreliability on production machinery (Onawoga and Akinyemi 2010).

Cited below are some of the repercussions of maintenance ineffectiveness:

Within the South African context, Eskom's power crisis (load shedding) in 2007/8, is cited as being one of the prime examples of maintenance ineffectiveness.

According to the research conducted by Econometrix®, maintenance ineffectiveness in Eskom's power-generating plants nationally was singled out as the main causal factor of the catastrophic power cuts (Jammie 2009). Those power cuts due to ineffective maintenance adversely affected the South African economy, as millions of Rands were lost subsequently (Jammie 2009).

Maintenance ineffectiveness was the causal factor of the most catastrophic power cut in history in the USA and Canada in 2003, which did not only cost USA and Canadian economies billions of dollars, but adversely affected the lives of over 35 million people (Zuashkiani *et al.* 2011:76).

As cited in the literature, the adverse incidents mentioned below also occurred due to maintenance ineffectiveness:

- The explosion of BP's Deep-water Horizon rig, in April 2010, which resulted in eleven fatalities, and a major oil spillage (Zuashkiani *et al.* 2011:76).
- 61 railway related accidents in Sweden between 1988 and 2000 were attributed to maintenance ineffectiveness (Holmgren 2005:15).
- The Bhopal disaster where 2 500 people were fatally wounded (Raouf 2004).

In view of the foregoing, it is concluded that the maintenance function within manufacturing plant is of strategic significance.

The next section elaborates on how Total Productive Maintenance (TPM), as a maintenance strategy, can be an impetus for improvement of both maintenance effectiveness and the manufacturing operational performance areas as previously defined.

2.7 TOTAL PRODUCTIVE MAINTENANCE (TPM)

TPM was introduced in 1971 by Nakajima, in response to the maintenance and productivity challenges that were encountered within manufacturing plants in Japan (Tsarouhas, 2007).

A wide variety of authors describe TPM, from different perspectives. For instance:

- TPM is a maintenance *philosophy* : Ionescu, (2013);
- TPM is a maintenance *strategy* : Pintelon *et al.* (2006) and Kaur, *et al.* (2013);
- TPM is a maintenance *best practice* : Kumar and Maheshwari (2013:21) and Campbell and Reyes-Picknel (2006);
- TPM is a maintenance *concept* : Salonen (2011) and Ahuja and Khamba (2008);
- TPM is a maintenance *system* : Moayed and Shell (2009:288); and
- TPM is a maintenance *model*: da Silve *et al.* (2008).

For the purpose of this study, the description adopted for TPM is that of a maintenance strategy. That view is underpinned by the context in which Lind and Muyingo (2012:18) define maintenance strategy as “a long-term plan, which entails all maintenance management aspects essential for navigating the direction for maintenance management, and embodies concrete plans of action for accomplishing a desired future state for the maintenance function”.

It is worth mentioning that the view adopted in this study in the description of TPM, neither contrasts nor disputes the context of other TPM descriptions as provided by academics in the field of maintenance management.

The next section elaborates on the TPM definition.

2.7.1 Definition of TPM

Lazim and Ramayah (2010:389) define TPM as: “*a resource based maintenance strategy that pertains to the execution of activities aimed at maximising plant effectiveness...*”.

Ahuja and Khamba (2008:718) define TPM as an “...holistic company-wide machine-centric enhance process which strives to improve productivity efficiency and effectiveness by eradicating machine and plant efficiency losses throughout the production system life cycle by a holistic team based participation of all employees across all levels of the operational hierarchy”.

Campbell and Reyes-Picknell (2006:341) define TPM as “an organization-wide machine management program “with a great emphasis on the involvement of machine operator in first equipment maintenance and continuous improvement in plant effectiveness.

In essence, what resonates from the above TPM definitions are the following distinct fundamentals:

- TPM adopts a holistic approach towards optimization of the maintenance effectiveness, and
- TPM adopts an integrated life-cycle approach to plant maintenance;

According to Sharma (2006:262), the term ‘Total’ in the TPM acronym, encapsulates three important meanings:

- Total effectiveness – This indicates that TPM supports manufacturing plant’s objectives of profitability, productivity, quality, delivery, safety, health and morale;
- Total maintenance - This refers to the proactive maintenance approach; and
- Total participation – This pertains to the holistic involvement and participation of all employees in a manufacturing plant.

2.7.2 The Essential components (Pillars) of TPM

Ahuja and Kumar (2008:722) purport that TPM is premised on the eight pillar model, which comprises: *planned maintenance, quality maintenance, autonomous maintenance, Safety, Health and Environment (SHE), office TPM, management development, education and training and focused improvement.*

According to Kodali, *et al.* (2009), if all the TPM pillars are prudently adopted, manufacturing plant’s performance improves significantly.

Ahuja and Khamba (2008:722), postulate that there are eight rudimentary TPM practices namely:

“leadership and administration; people management and focused improvement; policy and strategy and early management, autonomous maintenance, process and planned maintenance, people satisfaction and training and education, customer satisfaction and quality maintenance, and impact on society and safety and environment management”.

TPM practices associated with each pillar of the eight pillar model are presented in Table 2.7.2 below.

TPM Pillar	TPM Best Practice
Autonomous maintenance	- Performing of first line maintenance by operators.
Planned Maintenance (PM)	- Execution of PM's and predictive maintenance for production machinery.
Quality Maintenance	- Tracking of machine problems and their root causes. - Reduction in quality and stoppage related waste.
Development management	- Plant maintenance improvement initiatives. - Promotion of learning and growth for all employees in the plant
Safety, Health and Environment	- Elimination of accidents and incidents
Education and Training	- Multi-skilling of employees by structured training programmes.

Table 2.7.2 Practices to be executed in each TPM pillar. (Ahuja and Khamba 2008:722)

2.7.3 Benefits of implementing TPM in manufacturing firm

The benefits derived by manufacturing plants from TPM, particularly in improvement of manufacturing operational performance areas and business excellence is extensively written about. Kaur, *et al.* (2013:71) cite Ahuja and Singh (2012), who purport that accomplishing good operational performance and manufacturing excellence is a necessity for survival for any manufacturing plant.

TPM optimises the effectiveness of a manufacturing plant by eradicating all the unplanned downtime due to machine breakdowns, by ensuring maximisation of the condition and effectiveness of production machinery by the holistic involvement of all employees in the manufacturing plants, i.e. both white and blue collar workers (Kaur, *et al.* 2013 and Ahuja and Khamba 2008).

TPM enhances production capacity, whilst ensuring reduction in maintenance and overall operational costs, hence profoundly impacting on the manufacturing firm's profitability (Aspinwall and Elgharib 2013:690).

Rohanian, *et al.* (2012), assert that TPM increases reliability and availability of production machinery, and in turn manufacturing plant's throughput without incurring major capital costs in maintenance.

Garg and Deshmukh (2006) validate the contribution of TPM in maximization of Overall Equipment Effectiveness (OEE) in manufacturing plants. According to Garg and Deshmukh (2006), OEE is maximised by implementing TPM practices which results in reduction of six manufacturing losses, which impedes operational performance of a manufacturing plant.

Zuakishiani *et al.* (2011) note that empirical studies reveal that marginal or incremental change in the *OEE* figure culminates in significant and positive enhancement of the return on investment (ROI), e.g. a ten unit increase in a plant's OEE is certain to double the firm's ROI. This typifies another TPM contribution to business excellence and to manufacturing operational performance areas.

Rohanian, *et al.* (2012) expands on benefits derived from TPM, and explains their link to manufacturing performance areas: Productivity, Cost, Delivery, Quality, Morale and Safety.

In that context, Table 2.7.3 below illustrates TPM's contribution towards each operational area.

Manufacturing goals	TPM contribution
Productivity (P)	<ul style="list-style-type: none"> - Reduction of unplanned machine breakdowns - Improved machine availability and plant throughput
Quality (Q)	<ul style="list-style-type: none"> - Reduction of quality problems due to unreliable machines - Decrease in product failures due to improved quality.
Cost (C)	<ul style="list-style-type: none"> - Effective and efficient maintenance
Delivery (D)	<ul style="list-style-type: none"> - Enhanced <i>delivery efficiency, speed and machine reliability.</i> - Enhanced production capacity, availability and throughput.
Safety, Health and Environment (SHE)	<ul style="list-style-type: none"> - Improved workplace environment - Minimal absenteeism and occupational injuries and diseases - Zero occupational accidents and incidents
Morale (M)	<ul style="list-style-type: none"> - Increased problem solving capability and autonomy - Employee involvement and empowerment - Increased employee skills and technical know-how

Table 2.7.3 Manufacturing operational performance areas realized through TPM. (Ahuja and Khamba 2008:719)

2.7.4 Success of TPM in the manufacturing sector

Kaur *et al.* (2013: 68) assert that a significant number of manufacturing firms worldwide are realizing positive feedback and results since deployment of TPM as a maintenance strategy. An empirical study within Italian manufacturing plants proved that TPM as a maintenance strategy is a pinnacle for maintenance effectiveness (Chinese and Ghirardo 2010). Ionescu, (2013) expands on that view by asserting that in developing countries where employees are under-qualified, adoption of TPM as a maintenance strategy contributes plausibly towards maintenance effectiveness. Cited below are the manufacturing plants where TPM implementation culminated in improved manufacturing performance areas (Ahuja and Khamba 2008):

- The adoption of TPM, as a maintenance strategy by American leading manufacturing firms, like *Procter and Gamble*, *DuPont* and *Ford* demonstrates that TPM can be adopted for improvement in operational performance areas for large and important manufacturing plants.
- For, *Hindustan Lever Limited (HLL)*, the Indian fast moving consumable goods (FMCG) manufacturing plant, the internal efficiencies improved significantly, and that culminated in the realization of long-term competitiveness and sustainability.
- *Nissan Motor Company* realized a significant reduction of assembly-line machine breakdowns and a decrease in overtime hours, thus demonstrating effective maintenance.

Within the South African context, there are also reports on the successes realized by manufacturing organizations which adopt TPM as a maintenance strategy. Ionescu (2013) purports that the introduction of TPM in one of the South African manufacturing plants, in Johannesburg, helped in forging a new relationship between management and employees across all the hierarchical levels, i.e. improved morale. The notion of ‘them and us’ was dispelled and instead converted into just an ‘us’ mentality in that particular manufacturing plant.

A South African pulp and paper manufacturing entity accomplished significant productivity increase after implementation of the TPM at one of its mills, Enstra Mill, (van der Wal and Lyn, 2002). Literature does not mention TPM implementation cases within the petrochemical manufacturing plants.

2.7.5 Critical Success Factors (CSFs) of TPM implementation

Panneerselvam (2012) categorizes the CSFs for TPM implementation into two major classifications, namely: Human-oriented factors and Process-oriented factors, as depicted in Table 2.7.9 below.

Human-oriented factors	Process-oriented factors
Top Management Commitment	Conventional and Proactive maintenance strategies
Total Employee Involvement	Training and Development
Cultural Transformation	Failure prevention and focused machine improvements

Table 2.7.5 Critical Success factors for implementing TPM Adapted from Panneerselvam (2012:6)

According to Panneerselvam (2012), human-oriented factors become necessary and imperative before the TPM implementation, whilst the process-oriented factors are essential for phases post the implementation, to ensure prudent and sustainable TPM implementation.

2.7.6 Barriers to TPM implementation in manufacturing companies

There is a consensus view from various authors about the barriers and impediments of TPM implementation within the manufacturing industry (Cooke 2000 and Ahuja and Khamba 2008).

According to Ahuja and Khamba (2008), TPM implementation encounters a lot of resistance in a unionized environment. That can, to a large extent, be attributed to the notion and perception that TPM is only concerned with the pursuance of improved production efficiency, labour force reduction, and increased labour productivity.

Within the South African context, issues of trade unionism and adversarial employer-employee relationship pose a serious threat to manufacturing firms that are contemplating the implementation of TPM as a maintenance strategy.

South African labour force is known for its collectivist orientation, which cannot only impede TPM implementation, but can also deprive manufacturing firms of the accrual of strategic benefits which are derived by adopting and implementing TPM as a strategy.

The ‘brain drain’ for tradespeople and technicians, in South African manufacturing firms further exacerbates the challenges of TPM implementation in most South African manufacturing companies. According to Too (2012), inadequacy of skilled and experienced engineering and maintenance personnel remains a critical challenge in maintenance management.

Panneerselvam (2012), broadly groups the impediments to successful TPM implementation by manufacturing firms, into: behavioural, organizational, cultural, technological, departmental, financial and operational. Table 2.7.10, below summarises each impediment.

Behavioural Impediments	Organizational Impediments
<ul style="list-style-type: none"> - Resistance to change and stern mindset - Issues with working on cross-functional teams 	<ul style="list-style-type: none"> - Absence of top management commitment and communication - Unions and Industrial relation
Cultural Impediments	Departmental Impediments
<ul style="list-style-type: none"> - Lack of motivation: top-down - Resistance from shop floor employees to adopt autonomous maintenance activities 	<ul style="list-style-type: none"> - Lack of coordination between departments - ‘Us and Them’ mentality between production and maintenance departments
Financial Impediments	Operational and Technological Impediments
<ul style="list-style-type: none"> - Minimal investment in TPM initiatives - Scarcity of resources (financial, human, time and technological) to support TPM 	<ul style="list-style-type: none"> - Inadequate training on maintenance improvement methods. - Inadequate usage of Computerized Maintenance Management System (CMMS)

Table 2.7.6 Impediments to successful TPM implementation Adapted from Panneerselvam (2012:5)

2.8 Summary of the chapter

This chapter has served to highlight the theoretical foundations and perspectives of maintenance and maintenance management in the context of a manufacturing plant.

Consistent with the objectives of this study, maintenance theoretical aspects deliberated on were: maintenance objectives, benefits, challenges, types or approaches, strategies, and concepts. Furthermore, this study also investigated maintenance evolution, and its ramification. All these theoretical aspects serve as the fundamental premise for maintenance effectiveness, which this study sought to evaluate.

Maintenance management theoretical foundations were also discussed. Topics included, amongst others: a maintenance management model and framework, empirical studies on the status of maintenance management functions within manufacturing plants and maintenance effectiveness and ineffectiveness. TPM was also discussed, as an approach for improvement of maintenance effectiveness. TPM contributes immensely to the improvement of the manufacturing operational performance areas, as defined. In view of the foregoing literature review, the following is concluded:

- Macro-environment impacts, such as: globalization, automation, regulatory framework and market demands necessitate the need for maintenance in the manufacturing industry.
- Maintenance is neither a ‘passing fad’ nor a ‘necessary evil’, as it is oft-perceived in the manufacturing fraternity. Maintenance is, nonetheless, a strategic imperative, with a profound impact on bottom line earnings, manufacturing excellence and competitive advantage.
- Despite the significance of the maintenance function within manufacturing plants, it is still perceived as a secondary function for manufacturing and not as a strategic imperative.
- There are strategic benefits which can be accrued from the maintenance function.
- Maintenance effectiveness can be improved by adoption and replication of maintenance best practices as well as TPM implementation

The next chapter elaborates on the comprehensive research methodology adopted for this study.

CHAPTER THREE – RESEARCH METHODOLOGY

3.1 Introduction

This chapter serves as an explanation of the research methodology applied during the execution of this research study, titled: *An evaluation of a plant maintenance management function - the case of a lubricants blending plant in Durban.*

This chapter outlines the aims and objectives of the study and discusses the research design as well as the selection of the sample. The questionnaire design, its subsequent administration as well as recruitment and ethical treatment of study participants is also discussed. The chapter also describes the process of questionnaire pretesting, validation and reliability and data analysis.

3.1.1 Aim and Objectives of the Study

The main aim of this research study is to evaluate the effectiveness of the plant maintenance function at a lubricants manufacturing plant, and to provide recommendations on how to optimise and improve the plant maintenance function. The main research question that this study seeks to answer is: *“How can the effectiveness of the plant maintenance function at Total South Africa’s Lubricants Manufacturing Plant (LMP) be improved?”*.

The objectives of this study were broken down as follows:

- Assess employees’ perception of the maintenance function at LMP.
- Highlight the perceived shortcomings of the maintenance function at LMP.
- Assess the perceived effectiveness level of the maintenance function at LMP.
- Solicit employees’ views about Total Productive Maintenance (TPM)’s contribution towards improving LMP’s maintenance effectiveness and operational performance areas.
- Make recommendations for improving the effectiveness of the maintenance function at LMP.

3.1.2 Participants and Location of the Study

The target population of this research study comprises of all the people who are currently employed at Total South Africa (TSA)'s Lubricants Manufacturing Plant (LMP), which is located in Durban. That group equates to a total of 95 LMP employees. Such people are from all hierarchical levels whose day-to-day jobs are directly or indirectly impacted by the maintenance function. The target population, included section managers, supervisors, administrators, lab technicians, maintenance artisans, line/shift leaders, plant operators, filling operators, temps, learnership trainees, intern and lab assistants.

3.2 RESEARCH STRATEGY

Sekaran and Bougie (2010) asserts that the research strategy is the procedure pursued in addressing the research questions and in ensuring accomplishment of the research objectives. Amaratunga et al. (2002) assert that the choice of the research strategy is informed by the research situation. According to Biggam (2008), the common research strategies are: survey and case studies. However, for the purposes of this study, only surveys will be discussed.

3.2.1 Survey

A survey is a descriptive, quantitative research tool which entails soliciting information, such as opinions, perceptions or attitudes about individuals or groups (Leedy and Ormrod 2005). According to Amaratunga et al. (2002), the application of descriptive research is appropriate when a particular phenomenon is studied to ascertain or confirm the validity of the existing theories. Furthermore, Blumberg et al. (2005) also commends surveys for versatility in business research. Sekaran and Bougie (2010), state that descriptive research studies accomplish that by measuring relationships of the phenomenon being studied.

For the purposes of this research study, the research strategy applied was a survey. The focal point of this research study was on a specific management function (i.e. Maintenance).

Further to that, this research study embodies perspectives and views solicited from the respondents of the study (LMP employees) as well as views from the scholarly community (i.e. relevant maintenance management literature).

3.3 RESEARCH APPROACH

Spens and Kovacs (2006:375) defines a research approach as a “... *path of conscious scientific reasoning*”. The main purpose of research is to collect empirical data in a systematic way and to examine that data so that there is better understanding and explanation of social life (Neuman, 2011). According to Leedy and Ormrod (2005) the research approach has a profound impact on the manner in which the research study is executed. Hyde (2000) asserts that the two oft-cited research approaches are: inductive and deductive. However, for the purposes of this study, only deductive reasoning is elucidated below.

- *Deductive reasoning*: this is a process of testing theory, which builds up from an already established theory or generalisations and aims to ascertain and validate the applicability of the theory to the *phenomena* that are being studied or investigated Leedy and Ormrod (2005).

The main purpose of this research study is to evaluate the effectiveness of the plant maintenance function of a lubricants blending plant. In view of the foregoing, the research approach adopted for the purposes of this study is deductive reasoning. That choice of research approach is informed by the research problem and the purpose of the research study. Furthermore, what made the deductive reasoning approach the most suitable research approach for this study is the fact that it involves distinct variables between which the nature of relationships is sought.

3.4 RESEARCH METHODS

Leedy and Ormrod (2005), describe quantitative research (also known as the positivist approach) “*as a research which seeks to answer questions pertaining to relationships amongst variables with the objective of elucidating, foretelling and controlling phenomena*”, whilst the qualitative research (also known as the post-positivist approach) yields narrative elucidations of the complex phenomena that are being studied, based on how the respondent views the phenomena. The most suitable research method which has been adopted for the purposes of this study is quantitative (positivist). The rationale behind that option was the following:

- The quantitative research uses mathematical measures and statistical techniques to determine relationships and differences among samples of target populations (Shao, 2002).
- In this research study, the deductive reasoning approach was adopted, hence quantitative research is known for being suitable for concepts that are in the form of distinctive variables (Neuman, 2011)

3.4.1 Data Collection Methods

There are two types of data sources which are equally important for any research study, and they are: primary and secondary data. According to Spens and Kovacs (2006), primary data is solicited from study participants, whilst secondary data is solicited sources which are already in existence, such as from journals and publications. Leedy and Ormrod (2005), assert that it is of vital importance for the research to have good data for analysis and interpretation, as that ensures that valid conclusions are formulated from the research study.

Leedy and Ormond (2005), assert that primary data can be collected using three different methods, namely: questionnaires, interviews and observations. According to Sekaran and Bougie (2010), a questionnaire is a group of pre-written questions where respondents must write their answers. Heukelman (2008) asserts that for most quantitative research studies, a questionnaire is the most preferred and utilised measuring instrument, due to its efficiency and effectiveness. Sekaran and Bougie (2010), further assert that a questionnaire is an effective data collecting tool when the researcher has determined the unit of analysis, and the variables which must be measured. Other advantages of using a questionnaire are: cost effectiveness, and simplicity in administration (Bryman and Bell 2007).

Disadvantages associated with questionnaires are: possibly a low response rate and difficulty in comprehension due to language barriers, etc. (Leedy and Ormrod 2005)

For the purposes of this research study:

- The instrument used for primary data collection was the questionnaire.
- The sources of the secondary data were from academic journals from Emerald insight, textbooks and publications on maintenance management

3.4.2 Questionnaire Design

Blanche and Durrheim (1999), define a questionnaire as a collection of questions utilised to collect data from the study respondents.

Sekaran and Bougie (2010) assert that there are two fundamental principles of good questionnaire design. These are:

- Wording of questions; and
- Questionnaire appearance and structuring of the questionnaire, pertaining to aspects such as variables categorisation, scaling and coding.

According to Madu (1998) the characteristics of a good questionnaire are: short, concise, specific and easily comprehensible questions. Forza (2002), is of the view that the good questionnaire is characterised by attributes such as:

- Precision; unambiguity of questions;
- objectivity of questions; and
- questions which are neither leading nor suggestive.

For this research study, the premise for the questionnaire design is the thorough and extensive literature review on maintenance management (Chapter 2) which was conducted by the researcher. Table: 3.4.2(a), below serves to illustrate how the questions were structured and categorised in the questionnaire.

Section	Category	Questions
Section A	Demographics	A1 to A7
Section B : RQ 1	Perceived status of maintenance function at LMP	B1 to B11
Section C : RQ 2	Perceived shortcomings of maintenance system at LMP	C1 to C11
Section D : RQ 3	Maintenance effectiveness at LMP	D1 to D9
Section E : RQ 4	Total Productive Maintenance (TPM)	E1 to E9

Table: 3.4.2(a) Structuring of questions in the questionnaire (Formulated by the researcher).

Table: 3.4.2(b) below outlines the types of questions and response strategies applied in the questionnaire.

Section	Types of questions and response strategies
Section A	<ul style="list-style-type: none"> ▪ A1 to A7 : Multiple Choice
Section B	<ul style="list-style-type: none"> ▪ B1 to B8 & B11 : Closed type questions using Likert-type scales ▪ B9 : Free response – open-ended questions ▪ B10 : Ranking
Section C	<ul style="list-style-type: none"> ▪ C1 to C10 : Closed type of questions using Likert-type scales ▪ C11 : Free response – open-ended questions
Section D	<ul style="list-style-type: none"> ▪ D1 to D9 : Closed type questions using Likert-type scales
Section E	<ul style="list-style-type: none"> ▪ E1 : Multiple Choice ▪ E2 and E9 : Dichotomous ▪ E3 to E8.4 : Closed type questions using Likert-type scales ▪ E10 : Free response – open-ended questions

Table: 3.4.2(b) Types of questions and response strategies used in the questionnaire (Formulated by the researcher).

3.4.3 Administration of the Questionnaire

For the purpose of this study, the questionnaire was personally administered, i.e. a total of 93 hard copies of questionnaires were distributed to all the employees currently working at LMP. This research study is confined within LMP, which made it easy to convene the large group of respondents, and simultaneously administer the questionnaire. According to Sekaran (1992) personal administering a questionnaire is ideal when the survey is confined to a local area and the organization is willing and able to assemble groups of employees to respond to the questionnaires at the workplace. This study was confined at Total South (TSA)'s Lubricants Manufacturing Plant (LMP), which is located in Durban. According to Sekaran (1992), personal administration of questionnaires makes it easy, cost effective and less time consuming to administer questionnaires to a large number of individuals simultaneously. Personal administration of the questionnaires also made it easy for the researcher to collect all the completed responses within a short period of time. Furthermore, any doubts regarding any question could be clarified on the spot. Personal administration of the questionnaires also allowed the researcher an opportunity to introduce the research topic and motivate the respondents to give their honest answers (Sekaran, 1992).

3.4.4 Questionnaire Pretesting, Validation and Reliability

The practices of questionnaire pretesting, validity and reliability are rudimentary premises of the scientific research method.

3.4.4.1 Questionnaire Pretesting

Madu (1998) asserts that questionnaires must be tested before they are administered to the target population to ascertain the following: elimination of any potential ambiguity, to check content validity and terminology and to ensure that the questionnaire is comprehensible. Madu (1998) also stresses the importance of using or involving subject matter experts in the pretesting of the questionnaire. For the purposes of this study, the pretesting of the questionnaire was accomplished by: administering the completed questionnaire to five respondents, two of whom are Professional Engineers practicing in Maintenance Management. This was done in order to ascertain if there are any challenges in answering questions and to eliminate any potential bias or ambiguity in the questionnaire. Amendments on the questionnaire were effected based on the feedback received.

3.4.4.2 Questionnaire Validation

According to (Biggam 2008) validity is the extent to which the research instrument yields a measure of what it claims or intends to measure and measures that correctly. Sekaran and Bougie (2010) maintain that validity testing is divided into three categories, namely content validity, face validity and construct validity.

- **Construct validity** confirms the ability of the instrument to yield results pertinent to theories which the instrument is intended to measure. For the purposes of this study, the questionnaire was assessed by two Professional Engineers who are practicing in the field of maintenance management, to ensure that the questions are aligned to the study objectives.
- **Content validity** ascertains that the measurement instrument is capable of measuring all items of the content area which are to be measured. Literature on maintenance management underpinned the questions asked on the questionnaire. That ensured content validity.

3.4.4.3 Reliability

Reliability is the extent to which collection and analysis of research data yielded results which are consistent all the times (Amaratunga et al. 2002:29) and Saunders et al, 2009). In essence, reliability seeks to ensure that research measurements are consistent. According to Leedy and Ormrod (2001), four forms of reliability which are widely utilised in research studies, are: *interpreter reliability, internal consistency reliability, equivalent forms reliability and test-retest reliability*. Further to the four forms of reliability, Saunders et al. (2009) maintain that reliability can be ensured by precluding errors and biases.

Those errors and biases are mentioned in Table 3.4.4.3 below, and how each was addressed in this research study:

Error / Bias	How error or bias was addressed in this research study
Subject or Participant error	95 Respondents (in 3 groups) were convened into one room and answered the questionnaire
Subject or Participant bias	This was precluded by accentuating to each respondent that anonymity and confidentiality is guaranteed.
Observer error	The questionnaire design and structure addressed this
Observer bias	This was precluded by interpreting all the answers in a similar way.

Table 3.4.4.3 Explanations of how errors and biases were addressed in this study. (Formulated by the researcher).

Further to the interventions listed in **Table 3.4.4.3 above**, the reliability of this research study was accomplished by ensuring the following:

- By pre-testing the questionnaire; and
- By making sure that there was no partiality in the manner in which the research study was conducted.

3.5 DATA ANALYSIS

The data analysis process is the final stage of the research process. The objective of data analysis is to ensure categorical data summation into mathematical number which the researcher can utilise to draw conclusive and objective findings about the research problem (Biggam, 2008). The primary data for this research study, collected using questionnaires, is quantitative. The data for this research study was analysed using Statistics Programme for Social Sciences (SPSS) and Microsoft Xcel. Furthermore, descriptive statistics were used for analysis. The results were summarized using descriptive summary measures such as mean and Standard deviation (SD) for continuous variables and percentages for categorical variables. Student t-test was utilised to draw comparison of the means between two groups. Analysis of Variance (ANOVA) was used for comparing means among three or more groups and to elucidate causal relationships between variables and theories. Levene's Test was used to test homogeneity of variances. Whilst, Post-Hoc Tukey test (t-test) was carried out for multiple comparisons. Descriptive statistics involve the number of observations which are gleaned through frequencies, presented in different formats such as: figures, tables and narrative text (Biggam, 2008).

3.6 ETHICAL TREATMENT OF RESEARCH PARTICIPANTS

Ethics is of absolute importance in the research study, particularly when data must be collected from the research participants. Cooper and Schindler (2003), advocates for ethical consideration in research design, as that ensures that the rights of the study respondents are protected and safeguarded at all times. Leedy and Ormrod (2005) emphasise the fact that ethical considerations, such as, assurance of anonymity, confidentiality, voluntarism and disclosure protection must be taken into consideration in the design and administration of the measuring instrument. That is achieved by appending the informed consent form as part of the questionnaire (Cooper and Schindler 2003). The informed consent basically serves to explain to the respondents that their participation is voluntary and it also reassures them about confidentiality.

The approval to conduct this study was ethically approved by the University of KwaZulu-Natal's ethics committee under the Protocol Reference Number: **HSS/0171/013M**.

The sample of the ethical clearance is appended in APPENDIX I.

Total South Africa's Lubricants Manufacturing Plant (LMP) is the unit of analysis for this study, hence, permission to conduct research and to administer the questionnaire to LMP employees was granted by Total South Africa Management Committee Senior Members: Chris Walkinshaw, General Manager: Specialities and Dr Jerry Gule General, Manager: HR & Transformation, respectively.

The sample of the signed Gatekeepers letter is appended in APPENDIX II.

3.7 CHAPTER SUMMARY

The discussion on the research methodology for this study focused on how data will be collected and analysed. The method of sampling and the scope of the survey were also discussed. The research instrument used to collect data was also elaborated on. Data collection method utilised in this treatise was also elaborated on. This chapter also elaborated on the significance of ethical treatment of research, reliability, and research limitations.

Table 3.7 below encapsulates a high level overview of the research methodology for this research study:

Research approach	Research strategy	Research method	Data collection method	Data analysis
Deductive reasoning	Survey	Quantitative	Secondary Data - Questionnaire	SPSS and descriptive statistics

Table 3.7 Overview of the research methodology pursued for the study (Formulated by the researcher).

The presentation and discussion of empirical results for this study are discussed in the next chapter.

CHAPTER FOUR – PRESENTATION AND DISCUSSION OF RESULTS

4.1 Introduction

This chapter serves as the detailed presentation and discussion of the empirical results of this study. Data was collected by questionnaire which was distributed to the target population. The hard copy questionnaires were self-administered to the target population. Out of 95 LMP employees, 93 participated in the survey, yielding a response rate of 97%. The presentation of results is in tabular format. This chapter draws a comparison of the empirical results to the literature review in Chapter two, and by so doing makes inferences which are informed by previous research. Most importantly, in this chapter, the research objectives and questions as outlined in Chapter one are tested using the data analysis.

4.2 PRESENTATION AND DISCUSSION OF RESULTS

The study questionnaire was designed to capture the following demographic profile of the respondents: gender, age group, educational level, position, department, length of service and type of employment.

4.2.1 Demographic profile of a sample

Table 4.2.1, below, is the tabular presentation of the respondents' demographic information.

From Table 4.2.1, it can be gleaned that males constituted the majority of respondents (77%) compared to females (23%). As shown in Table 4.2.1, the largest age group of respondents (30%) was 35 to 44 years. In terms of length of service, 48% of the respondents had been working at LMP for a period of less than 5 years. Table 4.2.1, also revealed that 72% of the respondents were permanently employed. The dispersion of positions held by respondents reveals that, more than a quarter of respondents (31%) were working as plant operators followed by filling operators at 11%. Plant operator is the entry position as LMP. Table 4.2.1, revealed that 36% of respondents were working in the lubricants filling department. That can be attributed to the fact that 71% of LMP's production is filled into stock keeping units, such as 500ml and 5liters plastic bottles, hence most of the respondents work as in that department as filling operators. In terms of the highest qualification completed, the study revealed that one in five respondents (20%) did not have any formal education and 47% of the respondents have a matric as the highest qualification.

Table 4.2.1 Demographic distribution of the study respondents

Demographics Description		Percentage
GENDER	Male	77
	Female	23
AGE GROUP	18 – 24	21
	25 – 34	28
	35 – 44	30
	45 – 54	15
	Over 50 years	6
EDUCATIONAL LEVEL	No formal education	20
	Matric	47
	Post Matric	12
	Diploma	13
	Degree	6
	Post-Grad Degree	2
POSITION	Plant Operator	31
	Filling Operator	11
	Section Manager	7
	Supervisor	4
	Lab Technician	3
	Administrator	6
	Maintenance Artisan	5
	Line / Shift Leader	7
	Other	26
DEPARTMENT	Lubricants Filling	36
	Grease Plant	11
	Blending	6
	Planning	18
	Maintenance	9
	Distribution	2
	HSEQ / Laboratory	9
	Admin / Finance	5
	Other	4
LENGTH OF SERVICE (YEARS)	0 – 5	48
	6 – 10	38
	11 – 20	13
	Over 20 years	1
TYPE OF EMPLOYMENT	Permanent	72
	Temporary	13
	Other	15

4.3 DESCRIPTIVE STATISTICS – VIEWS FROM RESPONDENTS

A series of statements were put to respondents to which they had to indicate levels of agreement or disagreement. Below is the presentation and discussion of results in accordance with the objectives of this research study.

4.3.1 Objective one: To assess LMP employees' perception towards the maintenance function at LMP.

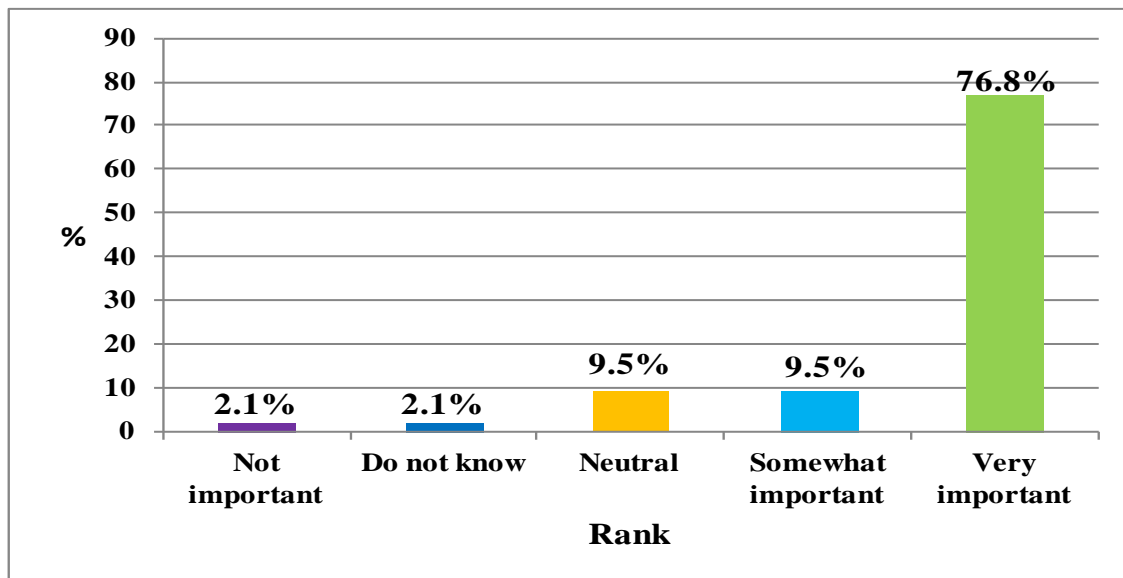


Figure 4.3.1 Frequency distribution for ranking the importance of maintenance function at LMP

As depicted in Figure 4.3.1(a), the results of the survey revealed that the majority (76.8%) of the respondents felt that maintenance function is very important at LMP. This finding is consistent with the empirical study conducted in UK manufacturing plants, which concluded that the maintenance function is very important, and manufacturing firms cannot attain the acceptable and envisaged productivity throughputs without the support of the maintenance function (Cholasuke *et al.* 2004). The empirical result in Table 4.3.1(a) is however, in contrast with the findings of the empirical studies conducted in Swedish and Italian manufacturing plants, which concluded that the status of the maintenance department was low, compared to other functional areas, (Jonsson 1997, and Chinese and Ghirardo 2010). Furthermore, the empirical result in Table 4.3.1(a), also suggests a characteristic of an open system organization (Simoes *et al.* 2011:129).

Table 4.3.1 is a summary of each of the eight statements for objective one.

A mean which is **less than three** (< 3) suggests that majority of respondents either strongly disagree, or simply disagree.

Table 4.3.1 Respondents perceived status of maintenance function at LMP

Statements	N	Likert Scale Rating (%)					Mean	Std. Deviation
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree		
I know about different maintenance types used at LMP	95	8.4	22.1	18.9	43.2	7.4	3.19	1.123
Maintenance is a secondary function	94	17	23.4	23.4	33	3.2	2.82	1.164
Maintenance is only about fixing broken machines	94	28.7	27.7	9.6	26.6	7.4	2.56	1.349
Maintenance is very costly, yet an important function at LMP	95	8.4	6.3	10.5	44.2	30.5	3.82	1.185
Maintenance helps my department to achieve its objectives	94	3.2	6.4	13.8	46.8	29.8	3.94	0.993
Maintenance contributes to TOTAL SA's profitability	94	4.3	9.6	10.6	45.7	29.8	3.87	1.08
Maintenance is a strategic function	95	5.3	2.1	16.8	45.3	30.5	3.94	1.019
Maintenance is a cost centre	94	9.6	14.9	14.9	40.4	20.2	3.47	1.242

The respondents' views from Table 4.3.1, above, are summarized below:

It is evident from Table 4.3.1, that majority of respondents agree that they are aware of different maintenance types at LMP (Mean = 3.19). Empirical studies conducted in Jordanian and Indian manufacturing plants, revealed that nearly employees at all hierarchical levels were not aware of fundamental principles of maintenance such as different maintenance types (Tahboub, 2011:315) and Kaur *et al.* (2013:76). An empirical study carried out within Italian manufacturing plants, gave conclusive evidence that maintenance effectiveness is adversely affected by the low level of awareness towards maintenance principles by stakeholders of the maintenance function, such as senior management and operators (Chinese and Ghirardo, 2010).

Table 4.3.1 revealed that majority of respondents (Mean = 3.94 and SD = 1.019) agreed that maintenance management is a strategic function. That is in contrast with the conclusion of an empirical study conducted within Swedish manufacturing plants where majority of respondents felt that maintenance management function is not a strategic function (Jonsson 1997). In contrast with this finding, Lazim and Ramayah (2010:387), Al-Turki (2011), Simoes *et al.* (2011), Rolfsen *et al.* (2012) and Maletič *et al.* (2012) are in agreement that maintenance function is a strategic imperative and an integral part of manufacturing.

Table 4.3.1 revealed that majority of respondents agreed (Mean = 3.94 and SD = 0.993) that the maintenance department supports their departments' objectives. Empirical studies conducted within UK and Malaysian manufacturing plants confirmed the significance of the maintenance management function in supporting the manufacturing activities within manufacturing plants (Reis *et al.* 2009:260). Lazim and Ramayah (2010:388) and Naughton *et al.* (2013:289) acknowledge that the maintenance function supports operations.

It is evident from Table 4.3.1, that majority of respondents (Mean = 3.87 and SD = 1.08) agreed that the maintenance management function contributes positively to the company's (Total SA) profitability. Sharma *et al.* (2011), Zaim *et al.* (2012), Razak *et al.* (2012) and Dilanthi (2013) assert that the maintenance management function contributes to the firm's bottom line (i.e. profitability) as well as to the Return On Fixed Assets (ROFA) (Ahren and Parida 2009:250).

It is evident from Table 4.3.1, that majority of respondents (Mean = 3.47 and SD = 1.24) agreed that maintenance is a cost center. That is, in line with the conclusion of an empirical study conducted within Swedish manufacturing plants where 70% of the respondents perceive the maintenance function as a cost centre and not a competitive resource (Salonen and Bengtsson 2011:338).

Table 4.3.1, revealed that majority of respondents (Mean = 3.82 and SD = 1.18) agreed that maintenance is an important function. There is consensus amongst academics that for manufacturing plants, the maintenance function is the cornerstone for efficiency and effectiveness (Koochaki *et al.* 2011, Zaim *et al.* 2012, Maletic *et al.* 2012, Razak *et al.* 2012, Dilanthi, 2013, Kumar and Kapil 2013).

Based on the empirical results for **objective one**, conclude and confirm the following:

- The maintenance management function at LMP is perceived as being a very important functional management area.

- There is a paradigm shift in LMP's maintenance function from a traditional view of perceiving maintenance function from a tactical perspective to a rather strategic context. That phenomenon is also re-iterated by different scholars, who attest to the following:
 - A paradigm shift from viewing maintenance as a "*cost or expense centre*" and instead viewing it as a "*profit generating*" business function (Veldman *et al.* 2011).

 - A paradigm shift from viewing maintenance from the "*operational context*" and instead viewing it as a "*strategic context*" (Murthy *et al.* 2002).

Objective Two: To highlight the perceived shortcomings of the maintenance function at LMP.

Summary of each of the statements are shown in Table 4.3.2.

Table 4.3.2 Perceived shortcomings of the maintenance function at LMP

Statements	N	Likert Scale Rating (%)					Mean	Std. Deviation
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree		
Machines are repaired only when they are broken at LMP	95	10.5	24.2	10.5	28.4	26.3	3.36	1.375
Maintenance planning is effective at LMP	95	14.7	20	20	31.6	13.7	3.09	1.289
Maintenance scheduling is effective at LMP	95	12.6	24.2	38.9	21.1	3.2	2.78	1.023
Predictive maintenance is practiced at LMP	95	20	32.6	27.4	13.7	6.3	2.54	1.147
Planned maintenance is practiced at LMP	94	9.6	22.3	29.8	29.8	8.5	3.05	1.12
Root cause analysis for machine failures is conducted	94	9.6	26.6	30.9	28.7	4.3	2.91	1.054
SAP-PM module is used for planning and scheduling	94	28.7	19.1	31.9	18.1	2.1	2.46	1.152
Maintenance staff is trained on maintenance principles	94	6.4	18.1	36.2	28.7	10.6	3.19	1.06
Plant maintenance KPI's at LMP are well understood	95	15.8	22.1	34.7	17.9	9.5	2.83	1.182
There is a maintenance planner at LMP	95	28.4	28.4	21.1	16.8	5.3	2.42	1.217
Valid N (list wise)	92							

The respondents' views from Table 4.3.2, above, are summarized below:

It is evident from Table 4.3.2, that majority of respondents (Mean = 3.36 and SD = 1.37) agreed that at LMP, machines are only repaired when they are broken, an indication of a reactive maintenance approach. Empirical studies conducted within Chinese and Italian manufacturing plants confirmed the excessive adoption and prevalence of reactive maintenance approach (Gebauer *et al.* 2008, and Chinese and Ghirardo 2010).

According to Khazrei and Deuse (2011), reactive maintenance adversely affects the efficiency of the manufacturing plant. The cost of unplanned or breakdown maintenance is three times higher than the cost of planned or preventive maintenance (Wireman 2004. and Gebauer *et al.*2008).

It is evident from Table 4.3.2, that majority of respondents (Mean = 2.54 and SD = 1.14) disagreed that predictive maintenance is practiced at LMP. This result suggests an inclination towards a first generation maintenance perspective. Empirical studies in Italian and Jordanian manufacturing plants confirmed the limited usage of preventive and predictive maintenance approaches (Chinese and Ghirardo 2010, and Tahboub 2011). Srivastava and Mondal (2013) maintain that predictive maintenance is the most effective maintenance approach.

Table 4.3.2, revealed that majority of respondents (Mean = 2.42 and SD = 1.217) disagreed that there is a maintenance planner at LMP. Wireman (2004) reports that an empirical study conducted within US manufacturing plants, concluded that only one-third of manufacturing plants employ a maintenance planner. According to Wireman (2004:106) the exclusion of the maintenance planner in the maintenance organisational structure is a major impediment to effective maintenance planning and scheduling.

From Table 4.3.2, majority of respondents (Mean = 3.09 and SD = 1.28) agreed that maintenance planning at LMP is effective, whilst (Mean = 3.05 and SD = 1.12) of respondents were of the view that maintenance scheduling is not effective. In a survey which involved maintenance managers for US manufacturing plants, over 40% of respondents indicated that maintenance planning and scheduling is their biggest challenge (Wireman 2004). Salonen and Deleyerd (2011), purport that poor maintenance planning results into unwarranted expenditure of at least one third of maintenance costs within manufacturing industry.

Cholasuke *et al.* (2004) and Alsyouf (2009) are in agreement that ineffectiveness maintenance planning and scheduling impedes the maintenance function from accomplishing its goals. According to Wireman (2004:175), maintenance planning is the cornerstone of any firm's drive to optimize the effectiveness and efficiency of the maintenance function.

It is evident from Table 4.3.2, that majority of respondents (Mean = 2.46 and SD = 1.15) of respondents are of the view that SAP-PM™ module is not effectively utilised for maintenance planning and scheduling. An empirical study conducted within Italian manufacturing plants concluded that computerised maintenance management systems (CMMS) are not effectively utilised in manufacturing plants in Italy Chinese and Ghirardo (2010). The effectiveness of the maintenance function relies heavily on the effective utilisation of the CMMS Uysal and Tosun (2012) and Kumar and Kapil (2013). Marquez and Gupta (2006:319) and Uysal and Tosun (2012), mention that one of the crucial roles of the CMMS within the maintenance function is: provision of support to maintenance planning and scheduling activities.

Overall, the statistical analysis of the quantitative data collected from questions for objective two, indicated that the following are the perceived shortcomings of the maintenance function:

- A strong reactive maintenance approach (Mean = 3.36 and SD = 1.37).
- Non practice of predictive maintenance (Mean = 2.54 and SD = 1.14).
- Maintenance scheduling is ineffective (Mean = 3.05 and SD = 1.12).
- Ineffective utilisation of CMMS (Mean = 2.46 and SD = 1.15).
- Non-availability of the maintenance planner (Mean = 2.42 and SD = 1.217).

Objective Three: To assess LMP employees' perceptions regarding the level of effectiveness of the maintenance function at LMP.

Summary of the statements are shown in Table 4.3.3 below.

Table 4.3.3 Perceived level of maintenance effectiveness at LMP

Statements	N	Likert Scale Rating (%)					Mean	Std. Deviation
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree		
I am aware of LMP's maintenance strategy and policy	94	20.2	38.3	22.3	14.9	4.3	2.45	1.103
LMP's maintenance strategy is linked with objectives	93	9.7	20.4	24.7	34.4	10.8	3.16	1.164
Maintenance staff at LMP is well trained	95	4.2	20	29.5	37.9	8.4	3.26	1.013
Percentage of planned maintenance work is > 90%	94	12.8	30.9	34	17	5.3	2.71	1.064
Maintenance overtime at LMP is low	95	18.9	23.2	35.8	18.9	3.2	2.64	1.091
Spare parts are well managed and controlled	95	27.4	29.5	24.2	12.6	6.3	2.41	1.198
Maintenance costs are tracked and monitored	94	19.1	25.5	37.2	16	2.1	2.56	1.043
Maintenance performance is managed by KPI's	95	10.5	20	45.3	22.1	2.1	2.85	0.956
Maintenance audits are conducted	95	15.8	22.1	34.7	17.9	9.5	2.59	1.125
Valid N (list wise)	91							

The respondents' views from Table 4.3.3, above, are summarized below:

It is evident from Table 4.3.3 that majority of respondents (Mean = 2.45 and SD = 1.103) disagree that they are aware of LMP's maintenance strategy and policy. An empirical study conducted within Swedish manufacturing plants concluded that only 48% of respondents had a maintenance strategy and policy (Salonen and Bengtsson 2011:338). Maintenance strategy is a fundamental premise for effective plant maintenance management functioning (Lazim and Ramayah 2010:392).

It is evident from Table 4.3.3(a) that majority of respondents (29.5%, Mean = 2.41 and SD = 1.198) are in agreement that maintenance spare parts are poorly managed and controlled. The survey conducted within US manufacturing plants, concluded that maintenance spare parts inventory is the second highest cost of plant maintenance (Cholasuke *et al.* 2004:8, and Wireman 2004: *xiv*). Adale (2009) asserts that on time availability of maintenance spare parts and materials is vital for an effective maintenance function.

It is evident from Table 4.3.3 majority of respondents disagreed on: maintenance overtime (Mean = 2.64), tracking and monitoring of maintenance costs (Mean = 2.56), maintenance KPI's (Mean = 2.85) and maintenance audits (Mean = 2.59).

On the basis of the foregoing, the level of effectiveness of the maintenance function at LMP is thus low.

Overall, the statistical analysis of the quantitative data collected from questions for **objective three**, indicated that the effectiveness level of the plant maintenance management function at LMP is perceived to be very low and therefore ineffective.

Alsyouf (2009), argues that the fundamental premise of an effective maintenance function in a manufacturing plant is determined by the prudent adoption and replication of all the practices pertinent to each characteristic of the effective maintenance system. The response from the survey clearly depicts scepticism from the respondents about replication of the maintenance practices pertinent to the characteristics of an effective maintenance system.

Furthermore, Aoudia *et al.* (2008), maintain that maintenance ineffectiveness negatively impacts on the manufacturing plants' operational performance. - Productivity (P), Cost (C), Delivery (D), Quality (Q), Morale (M) and Safety (S).

Objective Four: To solicit LMP employees' views about Total Productive Maintenance (TPM)'s contribution towards improving LMP's operational performance areas.

Figure 4.3.4(a) revealed that majority (42.1%) of respondents describes TPM as a combination of strategy, philosophy, approach, concept, and best practice.

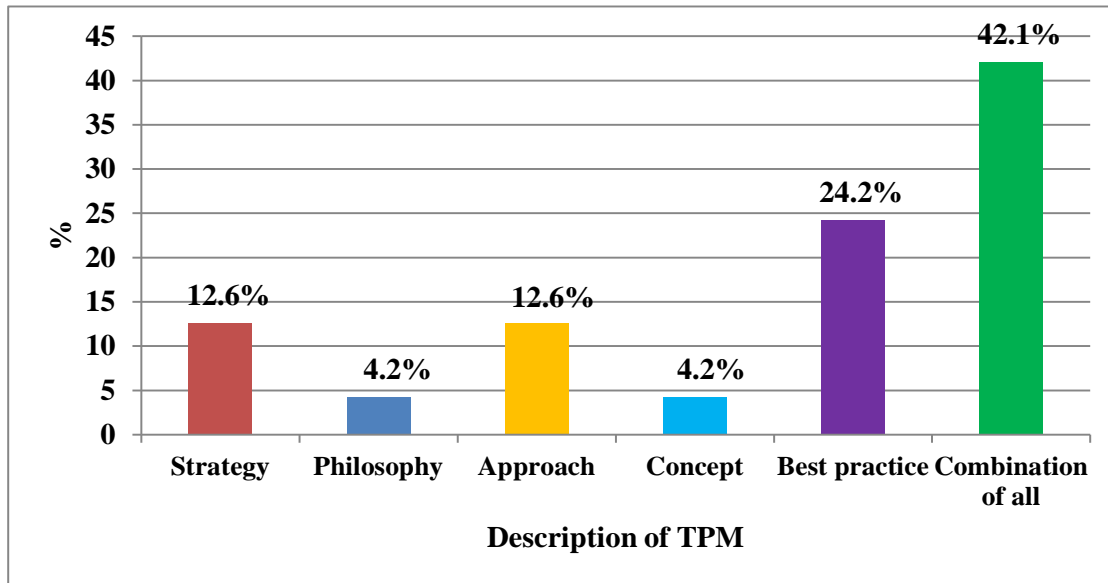


Figure 4.3.4(a) Description of TPM by LMP employees

Empirical results in Figure 4.3.4(b) reveal that majority (97%) of respondents', (91/95) answered positively that LMP's maintenance function effectiveness can be improved by implementing TPM at LMP.

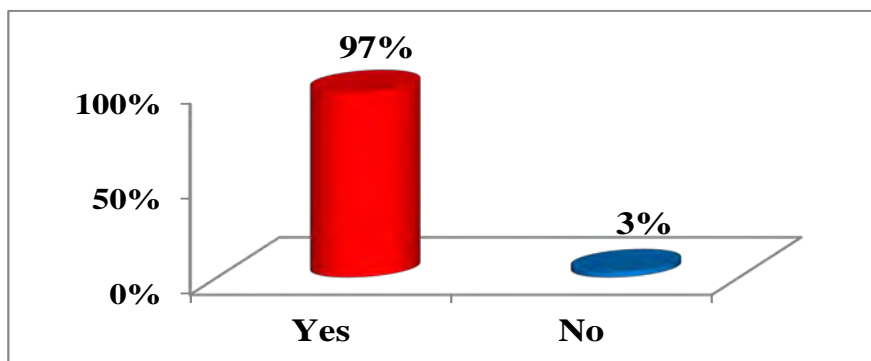


Figure 4.3.4(b) TPM can improve maintenance effectiveness

The finding in Figure 4.3.4(b) is in line with the views of Ahuja and Kumar (2009), Lazim and Ramayah (2010:393), Aspinwall and Elgharib (2013) and Kaur *et al.* (2013), who assert that TPM contributes positively to the improvement of the plant maintenance effectiveness in manufacturing plants. Empirical evidence also attests to the effectiveness of aggressive maintenance strategies such as TPM in improving manufacturing performance areas (Sari and Shaharoun, 2013).

A summary of each of the statements is shown in Table 4.3.4

Table 4.3.4: Total productive maintenance at LMP

Statements	N	Likert Scale Rating (%)					Mean	Std. Deviation
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree		
I think TPM can improve OEE	95	4.2	4.2	12.6	46.3	32.6	3.99	1.005
I think that TPM can reduce unplanned machine breakdown	95	4.2	6.3	8.4	50.5	30.5	3.97	1.015
I think that TPM can reduce quality defects	94	1.1	4.3	23.4	39.4	31.9	3.97	0.909
I think that TPM can improve plant efficiency and effectiveness	93	1.1	5.4	10.8	49.5	33.3	4.09	0.868
I think that TPM can improve workplace environment and morale	90	2.2	3.3	14.4	50	30	4.02	0.887
Impediments of TPM implementation								
Resistance to change	92	6.5	8.7	18.5	44.6	21.7	3.66	1.112
Poor communication by senior management	94	8.5	8.5	11.7	40.4	30.9	3.77	1.222
Limited resources	93	5.4	5.4	12.9	46.2	30.1	3.9	1.064
Lack of motivation	93	2.2	4.3	17.2	47.3	29	3.97	0.914
Valid N (list wise)	93							

The respondents' views from Table 4.3.4 above are summarized below:

Analysis of responses in Table 4.3.4 reveals that majority of respondents (Mean = 3.99 and SD = 1.005) agree that TPM can improve OEE. Zuashkiani *et al.* (2011), remind us that in oil and petrochemical manufacturing plants, enhancing OEE by any margin creates a meaningful competitive advantage and return on investment for the firm because OEE minimizes manufacturing cost per product output, hence yielding a higher profit margin.

Analysis of responses in Table 4.3.4 reveals that majority of respondents (Mean = 3.97 and SD = 1.015) agree that TPM can reduce unplanned machine breakdowns, thus improving machine availability. This result is in line with the results of a survey in USA manufacturing plants which highlighted the positive correlation between TPM and improvement in plant availability, product quality and manufacturing costs (Macchi and Fumagalli 2013:297). Another empirical study conducted within Chinese manufacturing plants revealed that a one per cent improvement on machine availability yields a two to four per cent increase in a manufacturing firm's profit (Gebauer *et al.* 2008).

The empirical results in Table 4.3.4 suggest that majority of respondents (Mean = 3.97 and SD = 0.909) agree that TPM can improve plant efficiency and effectiveness. An empirical study carried out in Malaysian manufacturing firms concluded that adoption and implementation of TPM practices improves manufacturing performance and excellence (Lazim and Ramayah 2010:393). Sharma *et al.* (2006), assert that TPM could increase manufacturing efficiency and effectiveness in manufacturing plants

Analysis of responses in Table 4.3.4 reveals that majority of respondents (Mean = 4.09 and SD = 0.868) agree that TPM can improve workplace environment and morale. Team autonomy is one of the characteristics of TPM (Ahuja and Khamba 2008). Empirical studies carried out in UK and Canadian manufacturing plants concluded that high workforce morale and a change in management thinking were some of the intangible benefits accrued after TPM implementation (Bamber *et al.* 1999:255, and Rolfsen and Langeland 2012).

TPM implementation in manufacturing plants is usually fraught with challenges, and that delays the accrual of TPM's strategic benefits (Ahuja and Khamba 2008:169). Academics cite a plethora of causal factors which can impede TPM implementation in manufacturing plants.

According to Panneerselvam (2012), the impediments to TPM implementation in most manufacturing firms, are: behavioral, organizational, cultural, technological, departmental, financial and operational.

Analysis of responses in Table 4.3.4 reveals that majority of respondents agree that TPM implementation can be impeded by:

- Resistance to change (Mean = 3.66 and SD = 1.112)
- Poor communication by management (Mean = 3.77 and SD = 1.222)
- Limited resources (Mean = 3.9 and SD = 1.064)
- Lack of motivation (Mean = 3.97 and SD = 0.914)

4.3.4.1 Analysis of variance (ANOVA): gender, age group and level of education

Tables 4.3.4.1 (a) and Table 4.3.4.1 (b) depicts comparison of average TPM score by gender, age group, position and educational level. It is evident from Table 4.3.4.1 (a) that females had the higher average score however this was not statistically significant: $p = 0.352$.

Table 4.3.4.1(a): Mean comparison test for TPM score by gender

	Levene's Test			t-test	
	F	p-value	t	df	p-value
Equal variances assumed	0.65	0.422	0.936	93	0.352
Equal variances not assumed			1.003	38.809	0.322

It is evident from Table 4.3.4.1 (b) that for an average score among the different age groups, the study found similar average scores among the groups: $p = 0.936$. Table 4.3.4.1 (b) also reaffirms that education level had a significant effect on the TPM score. There was significant mean score for different groups for the level of education: $p = 0.048$ (at $p < 0.05$).

Table 4.3.4.1(b): ANOVA - mean comparison of TPM: by age groups and education

	ANOVA output for mean comparison for age group					ANOVA output for mean comparison for level of education				
	Sum of squares	df	Mean square	F	<i>p</i> -value	Sum of squares	df	Mean square	F	<i>p</i> -value
Between groups	35.325	4	8.831	0.2	0.936	347.533	5	69.507	2.356	0.048
Within groups	3873.79	89	43.52			2360.34	80	29.504		
Total	3909.11	93				2707.87	85			

Table 4.3.4.1 (c) is a Turkey HSD test which showed that participants with a diploma or a degree had significantly higher scores for TPM compared to participants having no formal education ($p < 0.05$). In Table 4.3.4.1 (c), a post-hoc comparisons using the Turkey HSD test indicated that the mean score for people having no formal education was significantly different from the group of people holding a Diploma ($p= 0.044$), suggesting that the people with diplomas have a better perception of TPM than those having no formal education (Mean difference = 6.34524).

Table 4.3.4.1(c): Output of multiple comparison test (Turkey HSD test)

Dependent Variable: TPM						
(I) Level of education	(J) Level of education	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
No formal education	Matric	-2.64808	1.68139	0.617	-7.5576	2.2615
	Post matric	-3.61039	2.18853	0.569	-10.0007	2.7800
	Diploma	-6.34524*	2.13685	0.044	-12.5847	-.1058
	Degree	-6.26190	2.65044	0.182	-14.0010	1.4772
	Post-grad	-5.92857	4.10604	0.700	-17.9179	6.0608
Diploma	No formal education	6.34524*	2.13685	0.044	0.1058	12.5847
	Matric	3.69715	1.78278	0.311	-1.5084	8.9028
	Post matric	2.73485	2.26735	0.833	-3.8857	9.3554
	Degree	.08333	2.71589	1.000	-7.8469	8.0136
	Post-grad	.41667	4.14859	1.000	-11.6969	12.5303
*. The mean difference is significant at the 0.05 level.						

4.3.5 Reliability Tests

The reliability test presents the scale's internal consistency. This refers to the degree to which the items that make up the scale hang together. The Cronbach's coefficient was used as an indicator of consistency. Ideally, the Cronbach's coefficient Alpha should be above 0.7 (DeVellis, 2003). The tables below present the Cronbach's coefficient for the scales. Except from the scale *perceived status of maintenance* the other scales presented a good Cronbach' alpha (> 0.7) indicated in the column Cronbach's Alpha based on standardized items.

Table 4.3.5, below, elucidates reliability tests for this study.

Table 4.3.5: Reliability Tests

Perceived status of maintenance function at LMP		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
0.824	0.828	9
Maintenance effectiveness level at LMP		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
0.752	0.753	9
Perceived shortcomings of the maintenance system at LMP		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
0.76	0.767	10
Total Productive Maintenance (TPM)		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
0.824	0.828	9

4.4 Chapter summary

The research question for this study was: *How can the effectiveness of the plant maintenance function at LMP be improved?*

The research question was further broken down into six research sub-questions, which were meticulously answered by analysis of the empirical results and literature review in Chapter 2. The data analysis indicates that the majority of respondents were male. The majority of respondents were in the age group of 35 – 44 years. The majority of respondents occupied the position of Plant Operator. The years of service for majority of respondents was 0 -5 years and 72% of respondents were permanently employed. The inferences drawn from the analysis of the empirical results for this study are:

- Maintenance function at LMP is perceived to be an important business management function that contributes positively towards the company's overall objectives and profitability.
- Characteristics of the maintenance function at LMP are: secondary function and first generational perspective maintenance approach.
- LMP is a closed system manufacturing organization with a cost centre view towards the maintenance function.
- The perceived shortcomings of the maintenance function at LMP are namely: a reactive maintenance approach, absence of the predictive maintenance, ineffective maintenance scheduling, poor utilization of CMMS and non-availability of the Maintenance Planner in the maintenance departmental structure.
- The perceived shortcomings of the maintenance function negatively affect the maintenance function's effectiveness level.
- Majority of respondents support the implementation of TPM, as an apparent panacea for maintenance ineffectiveness without any capital expenditure. Moreover, TPM contributes positively towards the manufacturing performance areas. The study results reveal that Educational level has a positive impact towards the TPM implementation.
- Resistance to change, lack of motivation, poor communication and lack of resources were identified by respondents as being the potential impediments to TPM implementation.

The next chapter is the discussion on recommendations pertinent to the findings of this research study.

CHAPTER FIVE – RECOMMENDATIONS AND CONCLUSIONS

5.1 Introduction

This chapter synthesises the study results presented and discussed in Chapter 4. This chapter determines whether or not the research questions of this study were answered, while ascertaining the extent to which the research objectives were accomplished. The implications of this research study are also deliberated upon. Recommendations on how maintenance function effectiveness can be improved at LMP are discussed in this chapter. Furthermore, recommendations for the future research are also provided. Also discussed in this chapter, are research limitations and recommendations for future research.

5.2 Achievement of research objectives

The researcher is satisfied that all the objectives of this study were achieved. This was accomplished by conducting a meticulous analysis and interpretation of data received from the questionnaire responses. Discussion on how each objective was achieved is outlined below:

The first objective was to assess LMP employees' perception towards the maintenance management function. The results revealed that, the maintenance function at LMP is perceived to be very important. There was a strong agreement by respondents that the maintenance function is an important function which contributes positively to Total SA's profitability. Sharma et al. (2011), Zaim *et al.* (2012), Razak *et al.* (2012) and Dilanthi (2013) are all in consensus that the maintenance management function contributes to the firm's bottom line (i.e. profitability) as well as to the Return On Fixed Assets (ROFA) (Ahren and Parida 2009:250). That was in line with the findings of the empirical studies conducted in UK and Malaysian manufacturing plants which confirmed the significance of the maintenance management function in supporting the manufacturing activities within manufacturing plants (Reis *et al.* 2009:260).

The second objective was to highlight the perceived shortcomings of the maintenance function at LMP. The results revealed that the perceived shortcomings of the maintenance function at LMP are: the reactive maintenance approach, an absence of the predictive maintenance, ineffective maintenance scheduling, and ineffective utilisation of CMMS and unemployment of the maintenance planner in the maintenance departmental structure. These shortcomings render the maintenance function ineffective.

Wireman (2004) reports that an empirical study conducted within US manufacturing plants, concluded that only one-third of manufacturing plants employ a maintenance planner.

Wireman (2004:106) further asserts that the exclusion of the maintenance planner in the maintenance organisational structure is a major impediment to effective maintenance planning and scheduling.

The third objective was to assess the perceived level of effectiveness of the maintenance function at LMP. The empirical evidence indicated that the effectiveness level of the maintenance function at LMP is perceived to be very low suggesting that maintenance function is ineffective. Non-replication of the best practices pertinent to the effective maintenance system, such as: absence of maintenance strategy and policy, non-tracking of the maintenance costs and failure to conduct maintenance audits renders LMP's maintenance function ineffective.

The fifth objective of the study was to solicit LMP employees' views about Total Productive Maintenance (TPM)'s contribution towards improving LMP's operational performance areas and effectiveness of the maintenance function. The study results confirmed that the majority of LMP employees are of the opinion that LMP's operational performance areas can be improved by TPM implementation. Empirical studies in the maintenance management literature attest to that. Furthermore, there was also a consensus from LMP employees on the potential impediments of the TPM implementation, namely: resistance to change, poor communication by senior management, lack of motivation and limited resources. One of

Total SA's strategic objectives is to double in income by 2015. That strategic objective is underpinned by optimization of all Total SA's business units, including LMP, without incurring capital expenditure. Ahuja and Khamba (2008) and Lazim and Ramayah (2010) attest to the fact that successful TPM implementation has been realized by a lot of manufacturing plants without incurring costs.

Overall, the empirical evidence from this study confirms that LMP's maintenance perspective is a closed system manufacturing organization. The fact that LMP is the only manufacturing business unit under Total SA, further compounds this finding. According to Simoes *et al.* (2011:128), in a closed system manufacturing organization, the maintenance function is viewed as a standalone operational function and perceived as a necessary manufacturing expense.

Moreover, the results of the study also confirmed that LMP's maintenance function is inclined towards both cost centre view and first generation maintenance perspective, tantamount to a reactive maintenance approach. Such aspects negatively affect the effectiveness of LMP's maintenance function, and in turn contribute to the negative perception towards maintenance. TPM is viewed by most employees as a kind of panacea for maintenance ineffectiveness as well as a positive contributor to the operational performance areas.

In view of the foregoing, the maintenance function at LMP is not effective. TPM implementation is the solution for improvement of maintenance effectiveness and manufacturing operational performance.

5.3 Recommendations based on the research findings

The main objective of this research study was to evaluate the effectiveness of the maintenance function at LMP. The results revealed a gap between LMP's maintenance system and when compared with the characteristics of an effective maintenance system. On the basis of the foregoing, LMP's maintenance function is ineffective. It is against that background that the researcher outlines recommendations of how to improve LMP's maintenance effectiveness.

5.3.1 The perception towards the maintenance function in manufacturing plants has a profound impact on the effectiveness of the maintenance function (Wireman 2004:196). Issues pertaining to Health, Safety and Quality are held at high regard at Total South Africa. Maintenance management function should also be afforded similar status. On the basis of the foregoing, an urgent paradigm shift in the manner in which maintenance function is perceived by all the stakeholders at LMP, becomes an imperative. Such paradigm shift towards perceiving the maintenance function as a strategic imperative with value to add towards sustainability of the company can be expedited by considering the following course of action:

- Senior executives of Total South Africa must play an active role in LMP's maintenance strategy and policy formulation and implementation process.

That can be accomplished by driving advocacy towards linking the maintenance strategy to the overall manufacturing and corporate strategy. Furthermore, Total SA's senior executives must double their efforts in advocating the significant role played by the

maintenance function and its impact towards accomplishment of the company's strategic goals.

- LMP management team must also advocate and drive for pursuance of an organization wide approach towards improvement of maintenance ineffectiveness. That can be realised to fruition by playing an active role towards supporting the implementation and replication of maintenance best practices
- LMP management must enhance the level of maintenance management awareness to all employees at LMP about more in particular about its role and significance to the Total SA's viability and sustainability. That can be realised by soliciting the services of the reputable maintenance training institutions that can customise maintenance-related training courses to suit LMP employees' maintenance training needs.
- LMP management must ensure transparency and full comprehension of maintenance KPI's and how those link to LMP's and Total SA's overall objectives. Cholasoke *et al.* (2004), assert that continuous improvement in maintenance management can be realised by using maintenance performance indicators. It is vital that the maintenance KPI's are linked to LMP's overall objectives. Inadequacy and ambiguity of maintenance KPI's compromises the capability to optimise the scarce maintenance resources, as well as to improve the maintenance function efficiency and effectiveness (Simoes *et al.* 2011).

5.3.2 The fundamental premise for maintenance effectiveness within manufacturing plants depends on the prudent adoption and replication of maintenance best practices (Alyouf, 2004). Such initiative can be realised and accomplished by considering the following short term interventions:

- Immediate recruitment of a maintenance planner. According to Wireman (2004:106) the exclusion of the maintenance planner in the maintenance organisational structure is the major impediment to effective maintenance planning and scheduling.
- Formulate and implement maintenance strategy for the plant, which is informed by the stage on the life cycle for the assets at LMP.

Kahn (2005), purports that an effective maintenance strategy for production machinery aims for an optimum blend of maintenance types: Corrective - 10%, Preventive – 30%, Predictive – 50% and Proactive – 10%.

- An optimum spare parts inventory must be built up as part of the maintenance strategy. According to Wireman (2003:138) the fundamental requirements for the effective maintenance inventory systems are: tracking balances for spare parts, maintenance requisitions and purchase orders and record keeping for spare parts lists especially the strategic maintenance spares.
- To expedite and support effective maintenance planning and scheduling, CMMS utilisation by: maintenance artisans, supervisors shift/team leaders and section managers must be enforced. Labib (2004), Uysal and Tosun (2012: 213) write that CMMS ensures effective and efficient management of maintenance information, by converting maintenance records and data into usable information that can enable decision-making in maintenance.
- Time-based maintenance audits and benchmarking must be mandated and driven as part of the company's (Total SA) procedures. Benchmarking of maintenance best practices is a vital tool and a necessity for ensuring continuous improvement of maintenance function (Tsang, 2000, Wireman, 2003, Ahren and Parida, 2009, Simoes *et al.* 2011, and Lewis 2012).

5.4 Implications of the research study

This study adds to the existing knowledge in the area of maintenance management, particularly within the context of the manufacturing industry. From the outset, this study contributes to the previous studies on the status of maintenance management within the manufacturing industry in a developing country (South Africa). The results of this research study, reveal that maintenance effectiveness of a manufacturing plant is profoundly affected by perception of the maintenance function and by non-adoption of maintenance practices, such as maintenance planning and scheduling, usage of reactive maintenance approaches, non-usage of CMMS and inadequate or lack of resources (e.g. maintenance planner).

This study also revealed that TPM supports plant maintenance effectiveness, and also positively contributes to the improvement of manufacturing performance areas. This study highlights the significance of maintenance effectiveness improvement in the lubricants manufacturing industry. Moreover, the study reaffirms the potential of TPM as a possible solution to improvement of manufacturing operational performance.

5.5 Limitations

The study respondents consisted of LMP employees who are much occupied with their day-to-day work, and hence had varying interest in participating in the survey, particularly blue collar and bargaining (unionised) employees, who are the majority at LMP.

5.6 Recommendations for future studies

The focus of the study was on the maintenance management function in a lubricants manufacturing plant. The study could be extended to other manufacturing sectors, where maintenance function is crucial for productivity, such as petrochemical, mining, automotive and FMCG. Some recommendations for the future studies are as follows:

- Effects of maintenance practices adoption on maintenance effectiveness in manufacturing plants.
- The implementation of proactive maintenance approaches in manufacturing plants and their strategic benefits.

5.7 Chapter Summary

This research study sought to evaluate the effectiveness of the maintenance function at LMP. The empirical research done in this study supplemented the theory of maintenance management pertaining to the strategic role of the maintenance function within manufacturing plants. Empirical evidence provided by the study findings revealed that maintenance function is perceived to be a very important management function at LMP, notwithstanding the low effectiveness level of that function, which adversely impact both LMP's and Total SA's operational performance.

The findings of this study further revealed that, the maintenance function at LMP is perceived to be an important business management function which contributes positively towards the company's overall objectives and profitability. The study also revealed that, perceived shortcomings of the maintenance function make LMP's maintenance function ineffective. The study also revealed LMP is a closed system manufacturing firm with a cost centre view towards the maintenance management function.

The perceived shortcomings of LMP's maintenance function are: a reactive maintenance approach, non-usage of the predictive maintenance, ineffective maintenance scheduling, poor utilisation of CMMS and non-availability of a maintenance planner in the maintenance departmental structure. Furthermore, conspicuous absence of the best practices associated with effective maintenance system, such as: absence of maintenance strategy and policy, non-tracking of the maintenance costs and failure to conduct maintenance audits adversely contributes to LMP's maintenance function ineffectiveness.

The study also confirmed the positive support towards the implementation of Total Productive Maintenance (TPM) as the panacea for improvement of maintenance effectiveness. The study recommends that TPM is maintenance strategy which must be implemented in order to improve maintenance effectiveness and manufacturing operational performance, at LMP. TPM implementation at LMP can be expedited by counter-acting the potential impediments of TPM implementation which were outlined in this study. It is therefore recommended that TPM be implemented at LMP to improve both maintenance effectiveness and the manufacturing operational performance areas.

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TOTAL SOUTH AFRICA (PTY) LTD

18 March 2013

University of KwaZulu Natal
Graduate School of Business & Leadership
Private Bag X54001
Durban
4000

Dear Sir / Madam

APPROVAL TO CONDUCT AN MBA RESEARCH STUDY AT TOTAL SA – LMP

This letter serves to confirm that TOTAL SA grants permission to **Cedrick M. Mkhize** (Student No: 211520662) to conduct an MBA research study on the topic: *“An evaluation of a plant Maintenance Management function – the case of a Lubricants Blending Plant in Durban”* within the Lubricants Manufacturing Plant (LMP).

Yours faithfully,

Jerry GULE
General Manager
Human Resources and Transformation

Chris WALKINSHAW
General Manager
Specialities

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05 April 2013

Mr Cedrick M Mkhize (211520662)
Graduate School of Business & Leadership
Westville Campus

Protocol Reference Number: HSS/0171/013M

Project Title: An evaluation of a plant maintenance management function – the case of a lubricants blending plant in Durban

Dear Mr Mkhize

Expedited Approval

I wish to inform you that your application has been granted Full Approval through an expedited review process:

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

.....
Professor Steven Collings (Chair)
/ms

cc Supervisor: Dr Elias Munapo
cc Academic Leader: Dr E Munapo
cc School Admin: Ms Wendy Clarke

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