UNIVERSITY OF KWA-ZULU NATAL

The Contribution of planned Maintenance on Plant performance at Richards Bay Transnet Port Terminal

By

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ABSTRACT

This study aimed to evaluate the effectiveness of maintenance management function at Transnet Richards Bay Plant (TRP), located in Richards Bay, KwaZulu Natal. 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 TRP employees who were directly and indirectly impacted by the maintenance function. A sample of 95 employees, from all hierarchical levels at TRP, participated and responded to the questionnaire. 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 TRP 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 TRP's maintenance function ineffective. The study also revealed TRP 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 TRP. 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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OEE	Overall Equipment Effectiveness
TPM	Total Productive Maintenance
TRP	Transnet Richards Bay Plant

1.1 CHAPTER ONE: INTRODUCTION

Production firms are realising that there is a critical need for effective maintenance of machinery and assets in operational plants (Alsyouf, 2013). High levels of automation, advanced technology and stringent environmental and safety legislation further compound the significance of effective maintenance management function in organisations (Rolfsen and Langeland, 2012). The chapter outlines the introduction to the study, background thereto, research problem against the objective and the significance of the study. The chapter ends by outlining the structure of this dissertation.

1.1 Background to the Study

Maintenance expenditure embodies a huge portion of operating costs, particularly in the asset intensive sectors. According to Simoes, Gomes and Yassin (2011), in production plants, the maintenance related costs are estimated to be 25 percent of overall operating costs. Simoes *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 (Rolfsen and Langeland, 2012).

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, Turkyilmaz, Acar, Al-Turki and Demirel, 2012). Alsyouf (2013) also acknowledges the significant role of a maintenance function for manufacturing plants, particularly those which strive to attain world-class competitiveness.

1.2 The Research Problem

Wireman (2014) 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 Transnet's maintenance department, for the 2017/18 financial year:

Transnet's maintenance budget equates to 15% of the entire plant's operating budget. Notwithstanding that, Transnet's maintenance expenditure for 2017/18 financial year overspent by 9%. Transnet'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, 2014). The non-existence of a formal maintenance strategy was one of the reasons that caused Transnet's maintenance department to outsource 20% of maintenance work to engineering and maintenance subcontractors, who most of them did not have proven expertise in maintaining the machinery and equipment (Stenstrom, Parida, Kumar, and Galar (2013).

It is the researcher's conviction that the above-mentioned performance scorecard by the TRP's maintenance function reflects the level of ineffectiveness of the maintenance function at TRP. One of Transnet's strategic objectives is to maintain world class blending fees (i.e. low cents/work output). Hence, performance by TRP's maintenance function is a serious indictment to that strategic objective and also adversely impact Transnet's profitability objectives (Stenstrom et al., 2013). Ineffective maintenance function also hinders Transnet's strategic objective of efficiency and profitability, which will be achieved by cost savings on variable costs, such as maintenance. Lower variable costs result into higher margins, and that in turn will make Transnet a brand of reference and subsequently a competitive edge in the market (Ahren and Parida, 2009).

1.3 Aim of the Study

The key aim of the study is to investigate the contribution of planned maintenance on plant performance at Richards Bay Transnet Port Terminal.

1.4 Objectives of the Study

The research objectives of the study were:

i) To establish the effectiveness of the current maintenance structure at Richards Bay Transnet Port Terminal.

ii) To highlight the perceived shortcomings of the maintenance function at Richards Bay Transnet Port Terminal.

iii) To assess employees' perceptions regarding the level of effectiveness of the maintenance function at Richards Bay Transnet Port Terminal.

iv) To recommend on the best strategies for facilitation of the effective maintenance planning at Richards Bay Transnet Port Terminal.

1.5 Research Questions

i) How effective is the current maintenance structure at Richards Bay Transnet Port Terminal.?

ii) What are the perceived shortcomings of the maintenance function at Richards Bay Transnet Port Terminal?

iii) What are the employees' perceptions regarding the level of effectiveness of the maintenance function at Richards Bay Transnet Port Terminal?

iv) What recommendations can be made on the best strategies for the effective maintenance planning at Richards Bay Transnet Port Terminal?

1.6 Scope of the Study

The scope study is confined to Transnet Richards bay Plant (TRP). In the context of this study, population entails, all the all the technicians at Richards bay Transnet. In total, there are approximately 350 technicians and technicians at Richards bay Transnet.

1.7 Significance of 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 Transnet Richards bay Plant (TRP) is a unit of analysis for this study. TRP 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 TRP, unreliable production equipment is very costly, and adversely impacts on the key manufacturing operational performance areas.

It is the researcher's conviction that TRP's maintenance function responds retrospectively to the functional failure of production machinery. Wireman (2014) 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 TRP, and thus negatively impact Transnet 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 is 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, 2017, Cholasuke, Bhardwa, and Antony 2014, Alsyouf, 2013, 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 in South Africa.

1.8 Organisation of the Study

Chapter one: Briefly outlines the background of the research, problem statement, aim of study, the main objectives of the study and questions to be answered, significance of the study, limitations of the study, a brief outline of the research methodology, Organisation of the study and the conclusion.

Chapter two: 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 three: The chapter serves to discuss the research procedure and the specific methods chosen by the researcher. These include the research design, data collection, the sampling technique, data analysis, and the population of the study.

Chapter four: This chapter presents results and discuss the key findings of the study. Furthermore, this chapter provides the analysis and interpretation of the key findings of the study.

Chapter Five: 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 Conclusion

The chapter outlined the introduction to the study, background thereto, research problem against the objective and the significance of the study. The chapter ends by outlining the structure of this dissertation.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

This study seeks to evaluate the effectiveness of the maintenance function at Transnet. This chapter discusses the concepts and perspectives in the field of maintenance management, within the context of equipment and machinery. 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 Conceptual Review

2.1.1 Maintenance

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 and Yadava (2011) 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, Kamaruddin and Azid, (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.

Most authors like Moubray (2011:7) and Singh and Pycraft (2017) in maintenance management literature agree on defining maintenance as the set of activities required to keep physical assets in the desired operating condition or to restore them to this condition. This imply that maintenance is all the actions taken to prevent a device or component from failing or to repair an equipment that was degraded by an operation and keep it in proper working order (Sullivan, Weck, and Roth, 2014).

While the above maintenance definition may suggest that maintenance is simple, but in reality, maintenance management involve a complex and dynamic process required to implement maintenance practice that improve the operations performance. The key objective of maintenance management is to maximize the availability and reliability of the assets and equipment to produce the desired quantity of products, within the required quality specifications, in a timely manner. Obviously, this objective must be attained in a cost-effective way and in accordance with environmental and safety regulations (Pintelon and Parodi-Herz, 2015).

Good health of any company depends on operations equipments that are kept in proper working order (Campbell, 2015). Nothing lasts forever and all equipments are associated with some predefined life expectancy or operational life. The design life of most equipment requires periodic maintenance, belts need adjustment, alignment needs to be maintained, and proper lubrication on rotating equipment is required. In some cases, certain components need replacement, e.g., a wheel bearing on a motor vehicle, to ensure the main piece of equipment last for its design life. Anytime we fail to perform maintenance activities intended by the equipment's designer, we shorten the operating life of the equipment (Sullivan *et al*., 2014).

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, 2014). The P-F curve in Figure 2.1.3 explains how the functional failure of the machine or equipment takes place over time of usage of that particular machine or equipment.

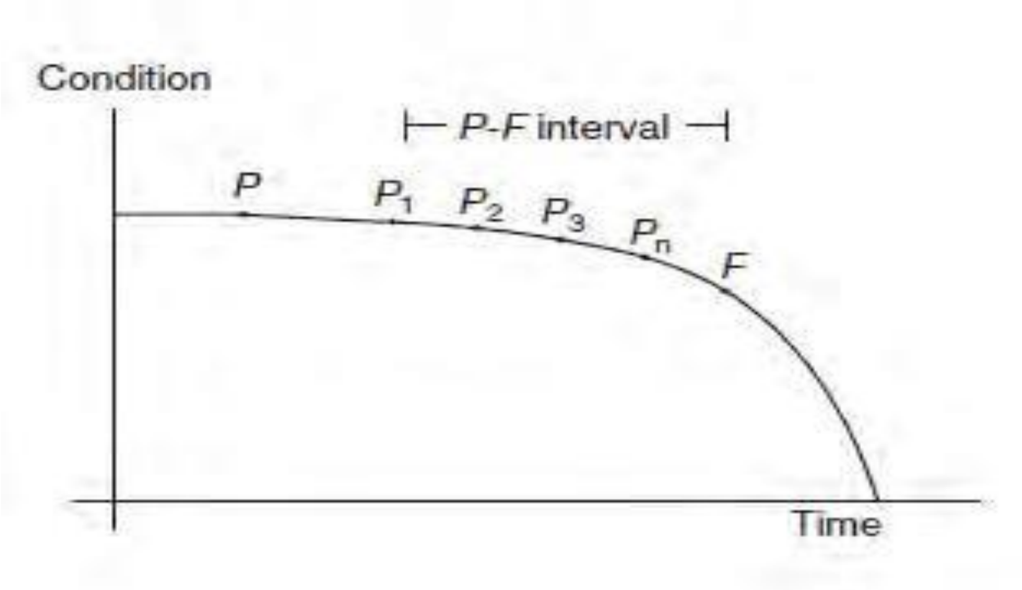

Figure 2.1: Machine failure behaviour. Prajapati *et al.* (2012:387)

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 plant operation, the demand for maintenance is also stimulated by the factors listed below:

Global competitiveness which demands maximum productive capacity (Kumar *et al.* 2013:234). In any operations failures can have undesired consequences, it may affect operations, production quality, safety or environment. But the right maintenance intervention will bring the following benefits, namely: Increased reliability: This leads to less disruption to normal activities of the operation (Singh and Pycraft, 2017:711); Lower operating costs: Most equipment run more efficiently when regularly serviced (Singh and Pycraft, 2017); Enhanced safety: Well maintained machine are less likely to behave unpredictable or fail outright or caused something that can pose hazard to staff (Singh and Pycraft, 2017); Longer life span: Regular care, cleaning or lubrication can prolong the effective life of machinery by reducing the small problems in operation whose cumulative effect causes wear or deterioration (Singh and Pycraft, 2017);

Higher quality: Badly maintained equipment is more likely to perform below standard and cause quality errors (Singh and Pycraft, 2017); Higher end value: Well maintained machined can be easily disposed of into the second-hand market (Singh and Pycraft, 2017).

2.1.3 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 (Duffua and Ben-Daya, 2015, Deac *et al.* 2010 and Salonen 2011:24).

Figure 2.1.4 depicts the relationship between plant maintenance and production in a manufacturing or production plant.

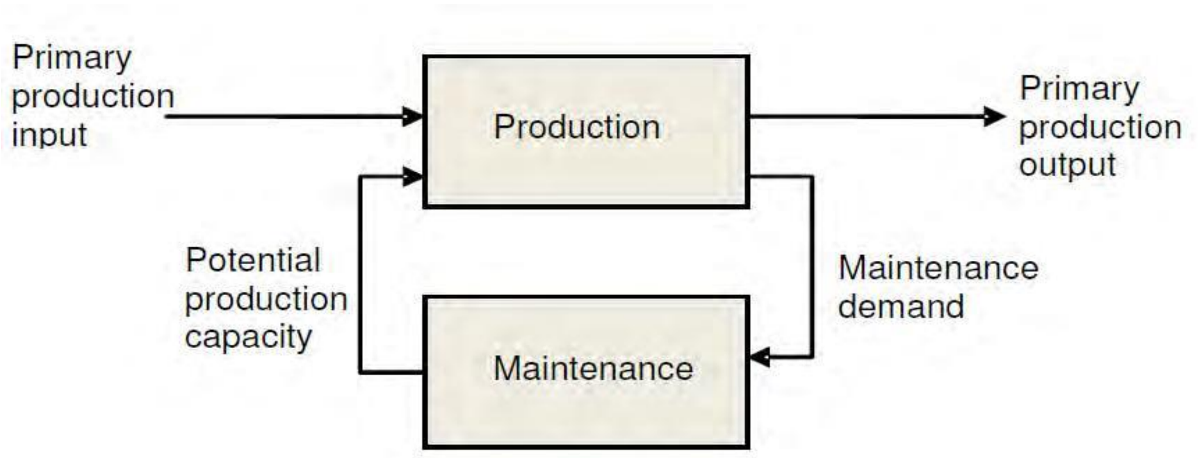

Figure 2.2: Plant maintenance in the context of production system. (Salonen, 2011)

As illustrated in Figure 2.1.4 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 Empirical review

2.2.1 Maintenance Function, System and Organisation

The terms ‘maintenance system’, ‘maintenance function’ and ‘maintenance organisation’ 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.

2.2.2 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.

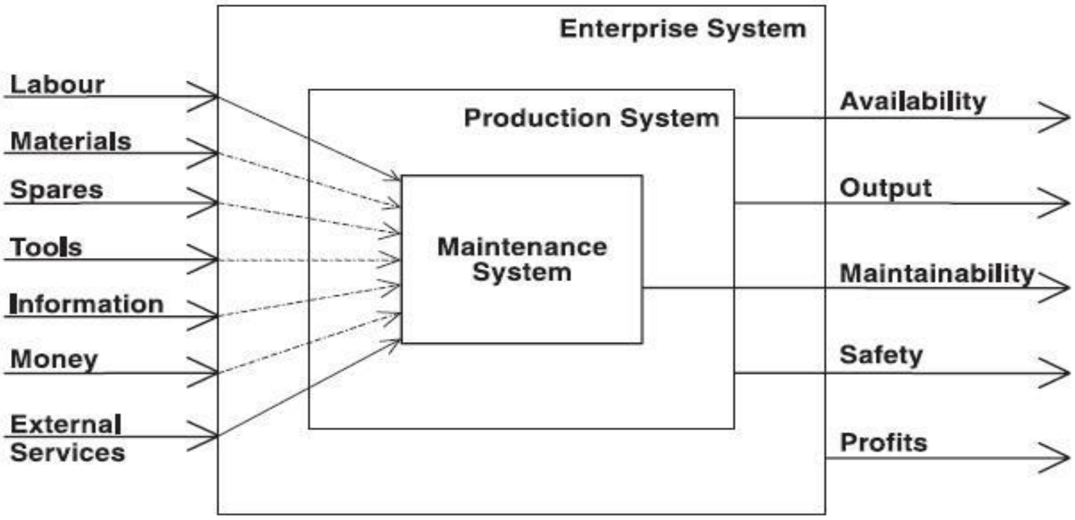

Figure: 2.3: Maintenance Input-Output Model. (Al-Turki, 2011)

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 organisation within the context of a manufacturing plant.

2.2.3 Maintenance Function

The significance of the effective maintenance function within manufacturing plants is widely acknowledged and extensively covered in the literature (Garg and Deshmuk ,2016, 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.

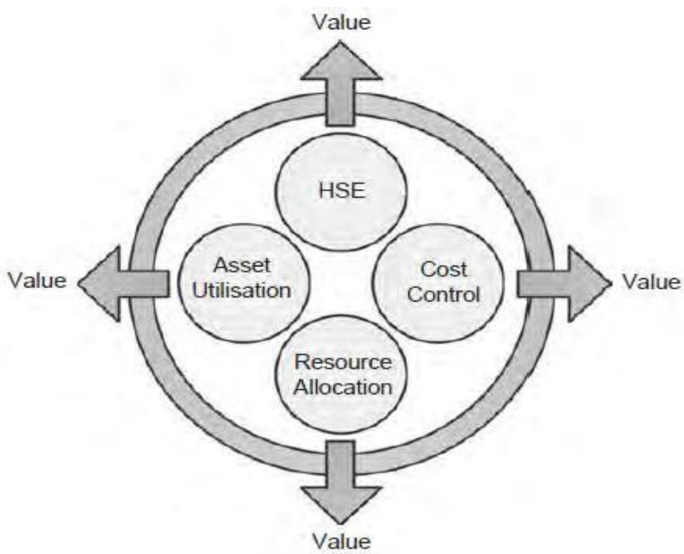

Figure 2.4: Maintenance function in a manufacturing plant. (Stenström *et al.* 2013:226)

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.* (2012:352), 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).

2.2.4 Maintenance Organisation

Maintenance organisation 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 organisation is the effective application of maintenance resources to the execution of maintenance work, as pre-determined by the maintenance plan (Nel, 2014).

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.

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.* 2015). 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:

i) *15 % - 40 %* Razak *et al.* (2012:25),

ii) *15 % – 70 %* Zaim *et al.* (2012:17)

iii) *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 (2014) 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 Theoratical review

Over the last 30 years, different approaches to how maintenance can be performed to ensure equipment reaches or exceeds its design life have been developed. In addition to waiting for a piece of equipment to fail (reactive maintenance), preventative maintenance, predictive maintenance, or reliability centered maintenance can be used as one of maintenance philosophies (Sullivan *et al*., 2014). In practice the maintenance activities will consist of some combination of the following approaches:

2.3.1 Reactive Maintenance or Run to Breakdown

This approach allows the machinery to run to failure without any intervention. Maintenance work is performed after failure has taken place. The advantages to reactive maintenance can be viewed as a double-edged sword. When dealing with new equipment, one can expect minimal incidents of failure. If the maintenance program is purely reactive, there will be no money spent on labour and maintenance costs until something breaks. This approach can be viewed as saving money especially during the quiet period. However, the reality is that you are really spending more money than you would have under a different maintenance approach. The reason is that breakdowns happened when unexpected, therefore it requires more manpower, more materials and
more time. It is estimated that the cost of a breakdown is normally three to four time the planned maintenance costs. Reactive maintenance is associated with large material inventory of repair parts. This is a cost that can be minimized under a different maintenance strategy (Sullivan *et al*., 2014).

2.3.2 Preventative Maintenance

Preventative maintenance approach attempts to eliminate or reduce the chances of failure by services the machinery at pre-planned intervals. This type of maintenance is practiced where consequences of failure while in service can have serious consequences (Singh and Pycraft 2017). By simply spending the necessary resources to conduct maintenance activities, equipment life is extended and its reliability is increased. In addition to an increase in reliability, preventative maintenance will save more money than using reactive maintenance. Studies indicate that this savings can amount to as much as 12% to 18% on the average. This approach will not prevent equipment catastrophic failures, but it will decrease the number of failures. Minimizing failures translate into maintenance and capital cost savings (Sullivan *et al*., 2014).

2.3.3 Condition Based or Predictive Maintenance

Condition based maintenance attempts to perform maintenance only when the asset requires it. Condition based maintenance require continuous monitoring of equipment and use the information to decide whether to stop the machinery and do maintenance or not (Singh and Pycraft, 2017). Basically, predictive maintenance differs from preventive maintenance by basing maintenance need on the actual condition of the machine rather than on some pre-set schedule.

Some of the advantages of predictive maintenance are that it eliminates catastrophic equipment failures and minimize costs and inventory. Predictive maintenance can optimize the operation of the equipment, saving energy cost and increasing plant reliability. Past studies have estimated that a properly functioning predictive maintenance program can provide a savings of 8% to 12% over a program utilizing preventive maintenance alone. Depending on a facility’s reliance on reactive maintenance and material condition, it could easily recognize savings opportunities exceeding 30% to 40% (Sullivan *et al*., 2014).

The challenge to predictive maintenance is that the implementation of the whole program is very expensive. Condition monitoring equipment can be costly, and in addition to that is the training of in-plant personnel to effectively utilize predictive maintenance technologies which will require considerable funding. Program development will require an understanding of predictive maintenance and a firm commitment to make the program work by all facility organisations and management (Sullivan *et al*., 2014).

2.3.4 Reliability Cantered Maintenance

Reliability cantered maintenance (RCM) is based on the philosophy that maintenance is a key function of the company. It is crucial for the expected functional performance and productivity goals to be achieved. Therefore, once production goals have been determined, RCM will identify maintenance requirement of a physical asset that meet the operational or production goals, then it optimizes the performance, with real results (Campbell, 2015). RCM recognizes that all equipment in a facility is not of equal importance to either the process or facility safety. It recognizes that equipment design and operation differ and that different equipment will have a higher probability to undergo failures from different degradation mechanisms than others.

It also approaches the structuring of a maintenance program recognizing that a facility does not have unlimited financial and personnel resources and that the use of both needs to be prioritized and optimized (Sullivan *et al*., 2014). In a nutshell, RCM is a systematic approach to evaluate a facility's equipment and resources to best mate the two and result in a high degree of facility reliability and cost-effectiveness. RCM is highly reliant on predictive maintenance but also recognizes that maintenance activities on equipment that is inexpensive and unimportant to facility reliability may best be left to a reactive maintenance approach (Sullivan *et al*., 2014).

2.3.5 Understanding Operations Failures

The choice of maintenance approach depends on the understanding of the equipment or process possible failures. O'Connor (2002:1) defines failure as the termination of an item's ability to perform a required function. In any operations there is always a chance that in the process of making the product or providing the service, things might go wrong. It is very important that operations managers should accept that failure will occur, and attempt should be made to minimize the failures. Organisation needs to prioritize the failures in terms of seriousness and pay particular attention to those which are critical to the rest of the operation (Singh and Pycraft, 2017).

Failure in an operation can occur because of number of reasons. The overall design of the operation could be the root cause of failure. The failures could occur because the circumstance under which the operation has to work was not expected. The design failures could be avoided by identifying the range of all circumstances under which the operation has to work and designing accordingly (Singh and Pycraft, 2017). If the stress applied exceeds the strength of the asset then failure will occur (O'Connor, 2002:5). The asset might be strong at the start of its life but become weaker with age (O'Connor, 2002:6). People failures can come in two types: errors and violations. Errors are mistakes in judgment, which a person should have done something different and the result is some significant deviation from normal operation. Violations are acts which are clearly contrary to defined operating procedure (Singh and Pycraft, 2017).

2.3.6 Patterns of Failure

Campbell (2015) emphasises that the key to select the correct maintenance is based on understanding how the failure happened, and how it can be prevented. Different equipment will follow a different pattern of failure. There are six known failure pattern, namely: Worst old or Wear out Failures: These failures are age-related, they normally increase rapidly at particular point of use. Routine maintenance based on time is very effective on worst old failures (Campbell, 2015); Bathtub: These failures are relatively high at the beginning and end of the asset life. The maintenance strategy must deal with early and end of life problems (Campbell, 2015); Slow aging: There is a steady increasing probability of failure with age. This type of failure is associated with continuous exposure to stress (Campbell, 2015);

Also, there are no failures when equipment is new, then failure becomes constant. Age-based routine maintenance is generally ineffective in these types of failures (Campbell, 2015); Constant or Random: These are random failures that are not age related. Age-based routine maintenance is generally ineffective in these types of failures (Campbell, 2015); Worst New or Early Infant: This is a most common failure in complex equipments. The probability of failure declines with age. Once the infant mortality problem is solved routine maintenance plays a minor role (Campbell, 2015). The different failures can be represented in the Bath curve as shown in Figure 2.2.6. below.

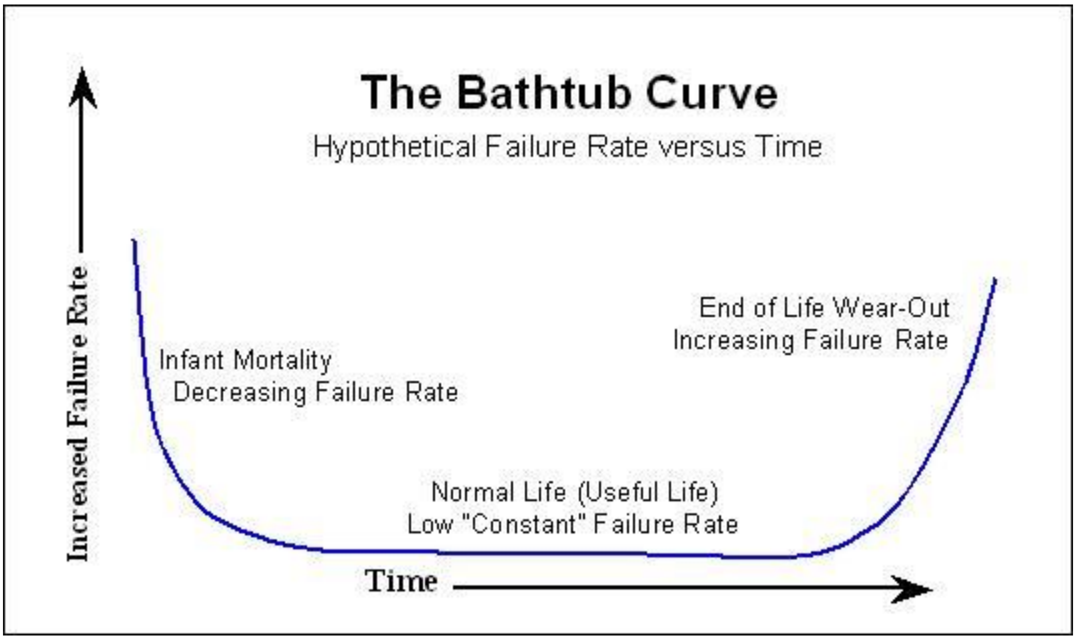

Figure 2.5: The Bathtub Curve (Wilkins, 2012)

2.3.7 Consequences of failures

A detailed analysis of any industry is likely to yield high number of failure modes. Each of these failures affects the organisation in some way, but the effect is different (Moubray, 2011:10). They may affect operations, production quality, safety and environment. Some will take time and money to repair. It is these consequences which strongly influence the extent to which failures are prevented. This means if the failure has serious consequences, means must be put in place to avoid it (Moubray, 2011:10).

The consequences analysis enables the organisation to focus the on-maintenance activities that have most effect on the performance of the organisation. Failure management techniques can be divided into 2 categories (Moubray, 2011:11).

Proactive tasks are tasks undertaken to prevent failures. Many people believe that the best way to improve plant availability is to do some kind of proactive maintenance in routine basis. This assumption is based on that most items operate reliably for certain period and then wear out (Moubray, 2011:11). Default actions are action taken after the failure mode is understood properly. It can be redesign (modifications change the capacity), run to failure (allow them to occur then fix them), fault finding (checking hidden function periodically to determine whether they have failed) (Moubray, 2011:14).

2.3.8 The challenges of maintenance improvement

Welch (2007a:1) highlights that even if the failure patterns and consequences are well understood, there will always be challenges in maintenance improvement. The effective maintenance is the one that can bring effective improvement in the way maintenance is performed. According to Welch (2007) the challenges to the maintenance improvement are as follows:

The ability of the utility to perform maintenance at low costs lies on the available skilled maintenance people. Finding, training and retaining the skilled maintenance people is one of the top challenges facing maintenance organisations ((Welch, 2007). Effective maintenance organisations needs leadership that is able to create an environment of change not commonly found in most maintenance teams (Welch, 2007). Effective maintenance has changed significantly in recent years. Maintenance today is far more technology based than it is a repair activity with need for greater emphasis on predicting and forecasting maintenance needs.

Now there is a great need to measure maintenance if improvement is required ((Welch, 2007). Welch (2007) argues that in maintenance, 85% of problems are process related and 15% are people related. Therefore, there is a great need to focus the efforts on process improvement. Maintenance must be able to demonstrate a measurable return on investment and must be able to justify its existence through reduction of machine downtime and reduced overtime. Maintenance excellence is the balance of performance risk and cost to achieve optimal solution (Welch, 2007). Maintenance managers have a challenge to increase output, reduce downtime and lower the maintenance costs, and do it with less risk to safety and environment. Then maintenance will be effective if it means all these factors (Campbell, 2015).

2.4 Theoretical Framework

2.4.1 Measuring and Benchmarking Performance

Management expert Tom Peters believe that what get measured it gets done. But what is measured and how is done are critical decisions (Campbell, 2015). Performance management is one of the basic requirements of the effective operation. Measurement is important in maintenance continuous improvement and in identifying and resolving conflicting priorities (Campbell, 2015).

Campbell (2015) uses the process approach to analyse and define the measurement factors that can be used in performance measurement. Figure 2.4 shows the 3 major elements of this equation: the inputs, the outputs and the conversion process.

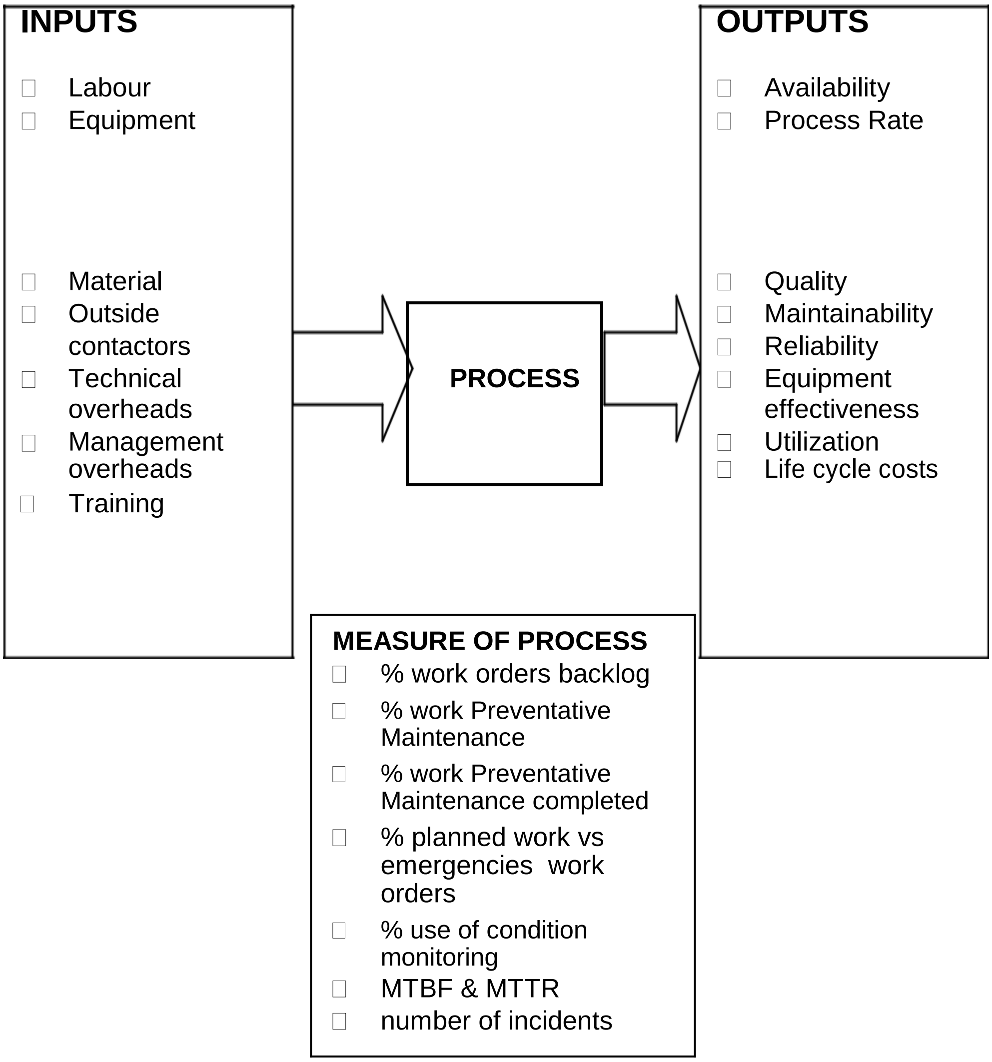

Figure 2.6: Maintenance as business process (Campbell, 2015)

One can look at maintenance as a business process that turn the inputs into useable outputs. Most of the input are readily measured such as labour costs, materials, equipment and contractors, but some are difficult to measure accurately and that includes experience, techniques, teamwork and work history yet each can have significant impact in the results (Campbell, 2015).

Likewise, some outputs are easy to measure and others are harder but very significant to overall maintenance performance. The task of maintenance department is to convert the maintenance inputs into required outputs. Because it not feasible to come up with the absolute conversion rate, benchmarking process is used by senior management as key indicator of good maintenance management (Campbell, 2015).

2.4.2 Maintenance Performance Measures

According to Campbell (2015), business approach to maintenance, a good combination of inputs must give the desired outputs. The desired output in maintenance is better equipment performance. Therefore, the measures on the outputs will highlight the effect of the inputs on the outputs. The measures can be divided into equipment performance measures, costs performance measures and process performance measures (Campbell, 2015).

2.4.3 Equipment performance measures

There are many ways in which one can measure the effectiveness of an asset is fulfilling its functions. Moubray (2011:293) and O'Connor (2004:8) highlighted the most common ones as follows:

Reliability: The ability of an item to perform a required function under stated conditions for stated period of time (O'Connor, 2004:1). A primary component of reliability analysis is referred to as failure rate, or the number of failures expected during a certain period of time. Calculation of equipment failure rate and its inverse – The Mean Time Between Failures (MTBF) for items which are repairable or Mean Time to Failures (MTTF) for non-repairable items is the basic of reliability predication (O'Connor, 2004:8).

Failure rate = Number of failures/Operating time

The Mean Time Between Failures (MTBF) is the expected time between two successive failures of the system (O'Connor, 2004).

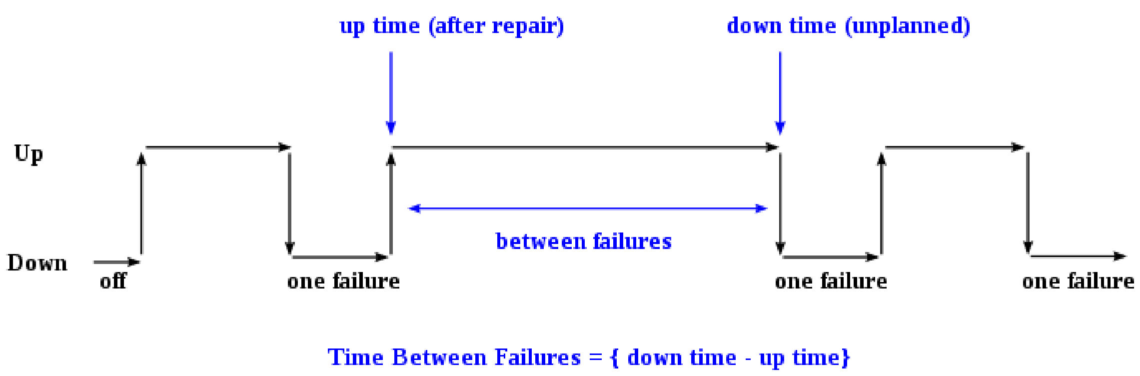

Figure 2.7: Illustration of Mean Time Between Failures (O'Connor, 2004)

The Mean Time to Failures (MTTF) is the expected time to failure of a non-repairable system (O'Connor 2004).

Maintainability: Campbell (2015) defines maintainability as the measure of ability to make equipment available after it has failed, or mean time to repair (MTTR). It is determined by:

$$MTTR = \frac{\text{Total downtime from failures}}{\text{Number of failures}}$$

The Mean Time to Repair (MTTR) is the expected time to recover a system from a failure. This may include the time it takes to diagnose the problem, the time it takes to get a repair technician onsite, and the time it takes to physically repair the system (Torell and Avelar, 2004:6). Similar to MTBF, MTTR is represented in units of hours.

Availability: It is the degree to which the operation is ready to work. An operation is not available if it has either failed or being repaired following a failure (Singh and Pycraft, 2017). Availability can be calculated as follows:

$$\text{Availability} = \frac{MTBF}{(MTBF + MTTR)}$$

where MTTR = mean time to repair (Torell and Avelar, 2004:6)

Therefore, MTBF impacts both reliability and availability. It is very clear that availability improvements can be achieved by improving the MTBF and/or MTTR (O'Connor, 2004:15). Availability is determined by a system's reliability, as well as its recovery time when a failure does occur. Availability is often looked at because, when a failure does occur, the critical variable now becomes how quickly the system can be recovered (Torell and Avelar, 2004:5).

MTTR impacts availability and not reliability. The longer the MTTR, the worse off a system is. Simply put, if it takes longer to recover a system from a failure, the system is going to have a lower availability. The availability equation illustrates how both MTBF and MTTR impact the overall availability of a system. As the MTBF goes up, availability goes up. As the MTTR goes up, availability goes down (Torell and Avelar, 2004:6). MTBF and MTTR do convey frequency of repair, and length of repair time.

According to Campbell (2015) availability is a measure of uptime, as well as the duration of downtime. It can be calculated as:

$$\text{Availability} = \frac{(\text{Schedule time} - \text{All unplanned delays})}{\text{Schedule time}}$$

$$\text{Downtime} = \frac{(\text{Unplanned delays})}{\text{Schedule time}}$$

The value of any of these measures has a lot to do with how the equipment is designed and built. The best test of equipment performance is often its performance trend over time. This will provide a good feedback and highlight changes in operating and maintenance practices (Campbell, 2015).

2.4.4 Costs performance measures

According to Campbell (2015) maintenance management is a business process as shown in figure 2.4, the maintenance costs are inputs into the process, and that means they can influence the outputs.

2.4.5 Process performance measures

Maintenance management is a business process with costs as inputs, equipment performance as outputs. In between the inputs and outputs there is a complex process of making sure the desired output is achieved (Campbell, 2015). The measures of the process can be any of the following:

Planned versus unplanned work: Unplanned work can be very costly, therefore there should be very little unplanned work in the effective maintenance management. Emergencies: Any immediate situation that affect safety, profitability or customer value, and that necessitate overtime is a true emergency. The impact and the costs of emergency can be measured.

The outsourcing client will use some of these of performance measurements to see if the suppliers are performing properly (Bragg, 2006:296). According to Welch (2007a:2), one cannot achieve maintenance improvement, unless performance measurements are in place. Welch (2007a:2) further emphasizes that maintenance should not be outsourced to the service provider who cannot demonstrate a history of collecting maintenance data and reporting metrics for continuous improvement. To ensure a continuous adherence to the agreed performance, performance measurements must be put in place.

2.6 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.* 2011:258, Ahuja and Khamba 2008:712-15, Lind and Muyingo 2012:18 and Kumar and Kapil 2013:3). 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.* (2012), Tsang (2012) 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.* 2012, 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, Simoes *et al.* 2011, Rolfsen Rolfsen and Langeland, 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 ,2012, Murthy *et al.* 2012, 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 (2013), Murthy *et al.* (2012), Al-Turki (2011) and Sharma and Yadava (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 (2013) 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 organisations. In a closed system manufacturing organisation, a maintenance function is perceived as a necessary manufacturing expense, whilst in the open system, the manufacturing organisation maintenance function is deemed as a strategic competitive resource (Simoes *et al.* 2011).

Closed system manufacturing organisations 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 organisations 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 and Yadava (2011:18), assert that there are two views of maintenance, namely the traditional and the contemporary views. Table 2.1 (a) below explains each view.

Table 2.1 (a) Traditional vs. Contemporary views of maintenance. (Sharma and Yadava, 2011:18)

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.

Maintenance evolution culminates to, *changing world of maintenance*, which is characterised by two paradigms, namely, old and new paradigm Moubray (2011).

Table 2.1 (b), below, serves to contrast the old and new paradigms of maintenance.

Table 2.1 (b) Comparison between Old and New paradigms in maintenance. (Moubray 2011)

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 optimise equipment availability	Maintenance impacts business operational performance areas, either positively or negatively

In a nutshell, 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.* 2012, 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.

2.4.7 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 and RCM.

2.4.9 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 (2016) and Nel (2014).
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.

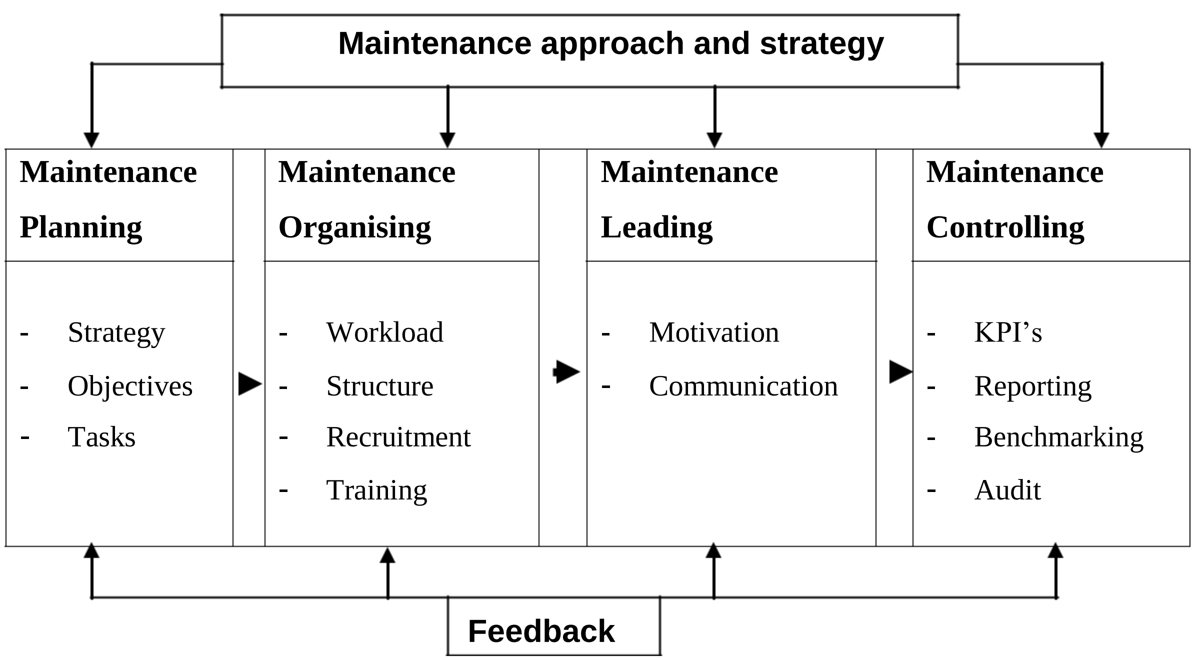

Figure 2.8: Maintenance Management Framework. (Nel, 2014:204)

The management function of any system which must be managed comprises the sub-functions of: planning, organising, staffing and controlling (Nel 2014). 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.

2.4.10 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 (Pintelon and Pinjala, 2015). 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 (2013) describes as myopic.

There is a plethora of research studies pertinent to the field of maintenance management (Reis *et al.* 2009:260). To this end, researchers, namely: Jonson (2017), Mitchel *et al.* (2002), Cholasuke *et al.* (2014), Pintelon and Pinjala (2015), Alsyouf (2013), 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 (2017) 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 (2013) 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.

2.4.11 The Theory and Practice of Preventive Maintenance

Preventive Maintenance (PM) has at its core the principle that periodic, often pre-scheduled, inspection and service of equipment is beneficial with respect to one or more aspects of ongoing equipment performance. These include equipment longevity, detection of future need for major service or replacement, maintenance of proper performance, prevention of downtime due to mal-performance or failure, reduction of repair costs, and/or the prevention of the equipment becoming hazardous in a way that it is not hazardous when in proper operating condition (Alsyouf, 2013).

Having access to the equipment for PM also offers the opportunity to make minor repairs that may not be part of the specific PM plan, and to identify other action items. To be effective this requires technicians that can go beyond simply following the specific work order. Equipment longevity can be strictly a financial issue in that premature failure generates the need to replace the device. However, longevity can also be a safety issue depending on how and when the device becomes unusable. Proper performance can be either a convenience or a safety issue, the latter taking precedence when degradation in performance can occur that is not obvious, and that can adversely affect patient outcomes. In some cases failure of one device may trigger failures of other devices, magnifying the consequences and cost (Alsyouf, 2013).

Note here that adverse patient outcomes are not limited to direct patient injury. Erroneous (but believable) clinical information that leads to a wrong or delayed treatment can be just as dangerous to a patient as a direct injury. Similarly, downtime can be an inconvenience, or directly or indirectly hazardous. An increase in the potential for a device to injure a patient (or other person) due to degradation presents a clear instance of a potentially preventable incident, if it can be detected in a reasonable and timely manner.

Even when PM has clear and targeted purposes, it must always be remembered that PM does not, and cannot, prevent all types of equipment malfunction, including malfunctions that may be the target of the PM. Many failures are effectively “random,” or at least unpredictable in time and undetectable in advance. Others may present only a limited window of pre-failure detection. In addition, failures may be unrelated to any specific PM procedure, or may be induced in the field in a way that was not predictable, or at least not predicted. In this regard the value of PM should not be over-stated. In the absence of rational, equipment-based reasons for PM procedures and intervals, PM might better be called “periodic maintenance,” since actually preventing anything will only be a random occurrence.

2.4.12 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.* (2015), Cholasuke *et al.* (2014) and Jonsson (2017) 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.* (2015). It is for that reason that it is adopted here for the purposes of this research study. In Table 2.5 below, structural elements pertain to maintenance resources, whilst infrastructural elements pertain to maintenance management (Pintelon *et al.* 2015).

Pintelon *et al.* (2015) 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.* 2015, Tedele 2007, and Alsyouf 2013). Wireman (2014) defines maintenance practices *as* … practices that enable the manufacturing firm to attain the competitive advantage over its competitors in the maintenance management process.

Table 2.2 Maintenance management frameworks. (Chinese and Ghirado 2010:158)

Pintelon *et al.* (2015:10)	**Cholasuke *et al.* (2014:7)**	**Jonsson (2017:236)**
Structural elements: 1. Maintenance capacity 2. Maintenance facility 3. Maintenance technology 4. Vertical integration – i.e. outsourcing ***Infrastructural elements:*** • Maintenance organisation • Maintenance approach • Planning and control • Human resources • Performance measurement	1. Maintenance organisation 2. Maintenance approach 3. Maintenance planning 4. Information management 5. Human resources 6. Spare parts management 7. Financial aspects 8. Continuous improvement	1. Goals and strategy 2. Human aspects 3. Support mechanisms 4. Maintenance tools 5. Maintenance organisation

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, 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 organisation, 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), assert that predictive maintenance is the most cost-effective maintenance approach. Predictive maintenance optimises plant reliability and availability (Prajapati *et al.,* 2012)).

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 (2014) 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, 2014). 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 2014).

The work order system controls and monitors maintenance planning and scheduling activities (Yam *et al.* 2013). Wireman (2014) 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.* 2014, 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.* (2014), 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, 2013, Wireman, 2014, 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. Lewis (2012) 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 organisation and staffing - Maintenance organisational structure is the backbone of the effective maintenance function in a manufacturing firm as it addresses all the issues pertaining to maintenance organisation, communication, problem-solving and decision-making (Simoes *et al.* 2011). Fore and Mudavanhu (2011) and Cholasuke *et al.* (2014) 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 (2014) 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 (2014) 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 (2017) 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.* 2014). 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 (2014) 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.* 2014). 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 organisations (Campbell, 2015).

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 (2014), 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. (2014) 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 (2014), 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, 2014). Sharma and Yadava (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).

2.4.12 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.

2.4.13 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). Aoudia *et al.* (2010) reminds 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, 2017, Dhilon, 2002, Pun *et al*. 2012, Cholasuke *et al.* 2014, Kodali *et al.* 2009 and Rachidi, 2013)

According to Pun *et al.* (2012:352): 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 organisation.

Jonsson (2017) 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.* (2014:7) 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 (2013:504): assert that the elements of effective maintenance are: general organisation, work method, technical follow up of the equipment, stock management of the spare parts, technical documentation, maintenance organisation and information management.

According to the maintenance strategy decision elements, cited in Pintelon *et al.* (2015), 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.* (2014) and Rachidi (2013) can are the main pillars of an effective maintenance strategy. According to Cholasuke *et al.* (2014) factors cited in Table 2.7.2 below are elements of an effective maintenance system with actions or deliverables associated with an effective maintenance system.

Table 2.3: Factors associated with effective maintenance system. (Cholasuke, *et al*. 2014:11)

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

2.4.14 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 Al-Najjar (2013), Alsyouf (2013), Aoudia *et al.* (2008), 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 (Aoudia *et al.* 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 (Jammine 2009). Those power cuts due to ineffective maintenance adversely affected the South African economy, as millions of Rands were lost subsequently (Jammine 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).

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.

2.5 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).

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.

2.5.1 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 (2015) define TPM as an organisation-wide machine management program with a great emphasis on the involvement of machine operator in first equipment maintenance and continuous improvement in plant effectiveness.

2.5.2 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 2.8.2 below.

Table 2.4: Practices to be executed in each TPM pillar. (Ahuja and Khamba 2008:722)

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.

2.8.3 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 (2016) validate the contribution of TPM in maximization of Overall Equipment Effectiveness (OEE) in manufacturing plants. According to Garg and Deshmukh (2016), 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 2.5 below illustrates TPM's contribution towards each operational area.

Table 2.5: Manufacturing operational performance areas realized through TPM. (Ahuja and Khamba 2008:719)

Manufacturing goals	TPM contribution
Productivity (P)	-Reduction of unplanned machine breakdowns -Improved machine availability and plant throughput
Quality (Q)	-Reduction of quality problems due to unreliable machines -Decrease in product failures due to improved quality.
Cost (C)	-Effective and efficient maintenance
Delivery (D)	-Enhanced delivery efficiency, speed and machine reliability. -Enhanced production capacity, availability and throughput.
Safety, Health and Environment (SHE)	-Improved workplace environment -Minimal absenteeism and occupational injuries and diseases -Zero occupational accidents and incidents
Morale (M)	-Increased problem-solving capability and autonomy -Employee involvement and empowerment -Increased employee skills and technical know-how

2.5.4 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* demonstrate 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 organisations 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.

2.5.5 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 2.5 below.

Table 2.6: Critical Success factors for implementing TPM Adapted from Panneerselvam (2012:6)

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

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.

2.5.6 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, organisational, cultural, technological, departmental, financial and operational. Table 2.8.6, below summarises each impediment.

Table 2.7: Impediments to successful TPM implementation Adapted from Panneerselvam (2012:5)

Behavioural Impediments	**Organisational Impediments**
-Resistance to change and stern mindset -Issues with working on cross-functional teams	-Absence of top management commitment and communication -Unions and Industrial relation
Cultural Impediments	**Departmental Impediments**
-Lack of motivation: top-down -Resistance from shop floor employees to adopt autonomous maintenance activities	-Lack of coordination between departments - ‘Us and Them’ mentality between production and maintenance departments
Financial Impediments	**Operational and Technological Impediments**
-Minimal investment in TPM initiatives -Scarcity of resources (financial, human, time and technological) to support TPM	-Inadequate training on maintenance improvement methods. -Inadequate usage of Computerized Maintenance Management System (CMMS)

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

CHAPTER 3: RESEARCH METHODOLOGY

3.0 Introduction

This chapter presents the research design and methodology employed by the study. The chapter covers the research philosophy for the study and the overall design. In addition, the research strategy, target population, sampling strategy, the research instrument, administration of the questionnaire as well as the data analysis techniques are presented.

3.1 Research Design

Research design influences the choice of data sources; the types of data collected and provide the context for identifying the relationships amongst variables (Cooper and Schindler, 2003:146). The research design used for this study was the descriptive study, as it sought to investigate the contribution of planned maintenance on plant performance at Richards Bay Transnet Port Terminal.

3.2 The Research Philosophy

Wiid and Diggines (2010) highlights two widely recognized research approaches referred to as the positivist and phenomenological. The positivist paradigm also known as the quantitative and the phenomenological as qualitative or interpretivist. According to Keele (2011), the approaches depicts two ends of a continuum with a combination of the two models occurring in varying shades of emphasis along the continuum. The quantitative methods draw from the positivistic approach, which assumes that the world is socially constructed and that research exist external to the problem, hence require scientific methods to solve the problem. Braun and Clark (2006) argue that in quantitative methodology, numbers are used with measurements and calculations employed to reach a finding.

The method has the advantage of providing objective results (Wiid and Diggines, 2010). Gray (2013) posits that the qualitative methodology is quality driven, thus the approach relies on in-depth descriptions by participants with the aim to understand the problem. The qualitative methodology is considered to be systematic and subjective in nature towards problem solving and tends to be less structured than quantitative research (Keele, 2011).

This study seeks to investigate the management challenges facing taxi operators gathering data from a relatively large sample derived from the taxi operators employing quantitative methods as the suitable design for the study. Krause (2005) argue that quantitative method allows the collection of data from a large population then process the results into findings that could be generalized to the entire population. This aligns with the focus of the study, where data gathered from the sample could be inferred to the entire Durban taxi operators.

3.3 Research Strategy

A research strategy is the plan of action that the researcher will follow in answering the research questions (Saunders *et al.,* 2012:173). The research strategies associated with the positivist approach are the experimental design, quasi-experimental design and survey methods. The experimental design is not commonly used in business research due to the challenges of maintaining the required level of control involved with organisational behaviour (Bryman and Bell, 2007:44). The experimental strategy is more appropriate in a laboratory setting than a field study, according to Saunders *et al.* (2012:176). Quasi-experiments are similar to the experimental design, with the difference being that the researcher does not randomly allocate participants to each group (Saunders *et al.,* 2012:175).

Quasi-experimental designs do not meet the full criteria to be experimental designs as they do not meet all the internal validity requirements as found by Bryman and Bell (2007:50). The survey method is primarily linked with the quantitative research approach (Saunders *et al.,* 2012:163). This method consists of a cross sectional design in which data is collected simultaneously at a specific point in time usually by means of a questionnaire (Bryman & Bell, 2007:55-56).

The survey strategy is cost-effective and enables the collection of uniform data from a large population according to Saunders *et al.* (2012:177). The survey method was found to be the most suitable for the current study due to the nature of the data required for this, therefore, through a survey method data was collected using the structured questionnaire.

3.4 Research Approach

The two main research methods available for use in research studies are quantitative and qualitative. Quantitative research aligns with the positivistic paradigm, whereas qualitative research is most closely aligned itself with the phenomenological paradigm (Keele, 2011; Gray, 2013). Quantitative research relies on numbers, measurements and calculations, and tends to be more highly structured and scientific in approach than qualitative research (Wiid and Diggines, 2010). In contrast, qualitative research relies on detailed description by respondents to gain insight into a particular problem (Wiid and Diggines, 2010).

The quantitative approach was considered more suitable for this study. This was because the kind of data gathered needed to be measured and analysed using statistical tools of a quantitative nature. Further, the nature of the objective, which sought to *determine* as well as *establish* could only be measured using quantitative methods. Quantitative research is generally used with a deductive approach where data is collected to test a theory (Saunders *et al.,* 2012:162). The study sought to investigate the to investigate the contribution of planned maintenance on plant performance at Richards Bay Transnet Port Terminal.

Thus, it was necessary to obtain extensive coverage of the Transnet employees to answer the research question. The benefits of the quantitative approach are that, it allows the use of probability sampling techniques which enables the results to be generalizable to the population (Saunders *et al.,* 2012:163).

3.5 Target Population

Krause (2005) defines population as the individuals, members or employees that fall under the organisation being studied. In the context of this study, population entails, all the all the technicians at Richards bay Transnet. In total, there are approximately 350 arcticians and technicians at Richards bay Transnet. Babbie and Mouton (2009) warn researchers not to include the entire population into the study, as it will create difficulty in managing large samples. Researchers are thus advised to select study sample that are manageable. Saunders *et al.,* (2012) highlights that sample for quantitative studies usually require relatively large sample while the qualitative rely on relatively smaller samples.

3.6 Sampling Strategy and Sample Size

Sampling is defined by Babbie and Mouton (2009) as the process of choosing the study participants from population using specific sampling methods. The sampling methods exists in two types referred to as probability and non-probability techniques (Wiid and Diggines, 2010). According Kolb (2008), probability technique selects participants using the statistical probability approach aligned to quantitative and positivistic research methods. Since this study is quantitative in nature, the probability technique will be employed to select participants using mathematically proven methods. The advantage of this technique is that it selects samples that are representative of the population.

According to Curry, Nembhard and Bradley (2009), non-probability sampling techniques represent deliberate ways of subjectively choosing participants capable of providing answers to the satisfaction of the researcher. According to Cooper, Donald and Chindler (2006) data collected using non-probability, sampling techniques are not generalisable to entire population. The non-probability techniques were not considered for the study, instead a probability sampling method was used. A sample of 95 employees, from all hierarchical levels at TRP, participated and responded to the questionnaire.

3.7 The Research Instrument

The two most commonly used primary data collection methods are the questionnaire and the interviews (Babbie and Mouton, 2009). All research is generally concerned with obtaining answers to questions (Chambliss and Schutt, 2012). The questionnaire and interview are data collection instruments that enable the researcher to pose questions to subjects in his/her search for answers to the research questions. Both these instruments, however, have distinct features that have a bearing on the correct and appropriate use of each for specific data collection purposes (Babbie and Mouton, 2009). An interview is a form of data collection that is very common in exploratory research but can also be used to collect valid and reliable data in other types of research (Chambliss and Schutt, 2012).

The two most commonly used primary data collection methods are the questionnaire and the interview Babbie and Mouton (2009). All research is generally concerned with obtaining answers to questions (Chambliss and Schutt, 2012). The questionnaire and interview are data collection instruments that enable the researcher to pose questions to subjects in his/her search for answers to the research questions. Both these instruments, however, have distinct features that have a bearing on the correct and appropriate use of each for specific data collection purposes (Babbie and Mouton, 2009).

Interviews are a form of data collection that is very common in exploratory research but can also be used to collect valid and reliable data in other types of research (Chambliss and Schutt, 2012).

Questionnaires are most widely used in surveys with a descriptive focus. Questionnaire are also effective experiment designs as well as case study research strategies. The appropriateness of questionnaires as research tools, however, must be carefully examined in the context of each study. Saunders *et al.* (2012:280) maintain that it is generally good practice not to rely solely on questionnaire data but to use the questionnaire in conjunction with at least one other data collection instrument, however combining the two could be too involving.

This study employed close ended questionnaires that circumscribe the respondents' range of responses to questions that are better suited to questionnaires as they readily lend themselves to coding and quantitative analysis (Chambliss and Schutt, 2012). In this study, questions were designed to facilitate the computer analysis as this allows for rapid computation, statistical analysis and graphical presentation of data. Depending on the needs of the research topic and the range of data required for comprehensive coverage of the research objectives, the typical question format for this study followed the Likert rating scale rating. The questionnaire structure included the biographical sections, which will gather data on age, gender race and expertise.

3.8 Questionnaire Construction

Mindful of the fact that the study employed quantitative methods; the questionnaire was the most appropriate tool to for the study (Wagner *et al.*, 2012:102). For this study, the questionnaire was designed in view of the objectives, the research questions and the literature reviewed.

Direct questions, which required participants to list their views, formed all the questions in section to gather data on biographical information. Closed statements on the Likert scale type format were used also. The Likert-type of question required participants to state their level of agreement with given statements (Saunders *et al.*, 2012:436). The Likert scale included strongly disagree (1) disagree (2) neutral (3) agree (4) and strongly agree (5).

3.9 Pilot Study

As Cooper and Schindler (2003:76) and Saunders *et al.*, (2012:305) note, the data-gathering phase of the research process usually begins with pilot testing. The purpose of the pilot test is to detect weaknesses in design and instrumentation. It should draw subjects from the target population and simulate the planned procedures for data collection and data analysis. In this study, plant operators were selected to respond to the questionnaire, upon which corrections were made so that the fully-fledged study employed the revised questionnaire (Saunders *et al.,* 2012:305). Participants who participated in the pilot study were excluded from the main study (Schindler, 2003:76)

3.10 Data Analysis

Data analysis refers to the processing of research data to meaningful information. (Saunders *et al.*, 2012:280). In quantitative research, such as this study, data analysis refers to a conversion of numerical values, ranging from the numerical frequency of occurrences to complex presentation of data in terms of graphs and charts towards conveying meaning within the framework of the study (Babbie and Mouton, 2009). In short, collecting and analysing data with quantitative techniques includes understanding the relationship among variables utilising descriptive and inferential statistics (Chambliss and Schutt, 2012). The descriptive data for this quantitative study will be gathered through the questionnaire with the analysis done by capturing the data onto a Microsoft excel spreadsheet as well as the SPPS tool to convert that data into meaning (Braun & Clarke, 2006).

3.11 Elimination of Bias

Wilkins (2012) define bias as any tendency that prejudices are visibly considered. In the context of research, bias occurs when a systematic error is introduced into sampling or testing by the researcher to influence the results to generate a particular outcome. According to Shuttleworth (2009) there are various types of research bias that includes design bias, measurement bias, sampling bias and procedural bias. By using the quantitative approach for the study, an attempt was made to eliminate bias by triangulating data Shuttleworth (2009). The question items were aligned to the objectives and the literature.

3.12 Validity and Reliability

All research requires validity and reliability in order to obtain accurate and objective results. Validity refers to the extent to which the research findings accurately and adequately reflect real meaning of the concept under consideration (Collis and Hussey, 2003; Babbie & Mouton, 2009). Research reliability refers to the ability to obtain the same results if the research were to be repeated by any other researcher (Collis and Hussey, 2003). Wagner *et al.* (2012:80) state that there are various kinds of validity, which includes face validity, content validity construct and criterion validity. All these are discussed in detail below

3.12.1 Validity

Face validity refers to appropriateness of the research instrument to be applicable or relevant to participants in the study. This was ensured by asking individuals within the target population to make some sense on the relevance of the questions during the pilot study. Under this part, participants provided very useful comments, which were used to improve the structure of the instrument.

Content validity refers to a situation where the researcher seeks expert opinion on the relevancy and appropriateness of the questions as opposed to face validity, were non-experts views are sought. Cooper *et al.* (2008:290), noted that content validity entails the extent to which the data collection tool covers the subject under investigation. Construct validity refers to the degree to which the research measures the actual occurrence of those concepts that the researcher intended to measure (Saunders *et al.,* 2012:193; Wagner *et al.,* 2012:81).

Criterion-related validity is about ensuring the accuracy of the predictions made (Saunders *et al.*, 2007:366). In this study, all validity issues were addressed and ensured, the research was free from bias and was contextually relevant, which is a positive step towards criterion related validity.

3.12.2 Reliability

Reliability implies that the data collection methods and analytical procedures would produce consistent findings if they were repeated by another researcher or duplicated on another occasion (Saunders *et al.,* 2012: 429). Reliability is concerned with the stability of the measure which can be established through re-testing according to Bryman and Bell (2007:162), as well as internal reliability and inter-observer consistency (Bryman and Bell, 2007:163).

3.13 Limitations of the study

Saunders *et al.* (2012:42) point out that all research projects have limitations and that these limitations derive from the conceptual framework and design of the study. The limitations of the study included the following: Limited time frame, where respondents were given only minimal time to complete and return the questionnaires. The reason for the short period was due to the nature of their jobs. Also, number of respondents where the number of respondents was limited due to the time factor and the number of employees who were capable of understanding and completing the questionnaires. The research was also limited to Transnet in Richards Bay and thus the findings may not be able to be generalised across other plant operations countrywide.

3.14 Ethical Considerations

Ethical considerations in research imply that researchers ought to respect the research participants as well conduct research in ways, which do not harm the environment. Saunders *et al.*, (2012:305) highlights that researcher must indicate the fundamental ethical considerations that guided the study.

According to Saunders et al. (2012), anonymity in research means that the names of the research participants should not be exposed to anyone else or to the public. If this happens, the participants may be harmed. In this study names of participants were not revealed. This aspect was explained well in the participant letter attached to the questionnaire. Wild and Diggins (2013) define confidentiality as using the data information only for the purpose for which it was primarily gathered. This means that data collected for research should be used for the particular study only. In this study, the study ensured that the data gathered was used specifically for the study and nothing else. Saunders et al. (2012) state that recruitment in research is about how participants are invited to complete the questionnaire or answer the interview In this study, the researcher invited participants on a meeting convenient to inform organisations that the study of this nature was conducted in the interest of finding solutions to the business management challenges. Phone calls and email were also be used to invite participants. This study did not harm participants, instead, participants had a chance to benefit from the findings which will be communicated to participants and the entire industry

3.15 Conclusion

The research methodology chapter laid down the foundation for the study. The study employed the positivist philosophy aligned to the quantitative method using structured questionnaire. Efforts were made to ensure that the questionnaire is valid and reliable by aligning it to the objectives and literature relevant to the study. The chapter also outlined the data collection process and administration. The following chapter presents the results, discussions and interpretations of findings.

CHAPTER 4: RESULTS, DISCUSSION AND INTERPRETATION OF FINDINGS

4.0 Introduction

Chapter 4 presents the results of the study. The sections covered include the response rate, demographic data and results based on the objectives of the study. In addition, the chapter discusses and interprets the results with an attempt to link the findings to the literature reviewed in chapter 2.

4.1 Response Rate

Taking into account that the questionnaire was distributed during the meeting held in Durban, the entire 120 questionnaires were successfully completed and returned on the same day giving a response rate of 100%. According to Saunders *et al.* 2012:341), a high response rate gives hope for successful study findings.

4.2 Demographic profile of a sample

Table 4.3, below, is the tabular presentation of the respondents' demographic information.

From Table 4.3, it can be gleaned that males constituted the majority of respondents (77%) compared to females (23%). As shown in Table 4.3, 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 TRP for a period of less than 5 years. Table 4.3 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 TRP. Table 4.3, revealed that 36% of respondents were working in the lubricants filling department. That can be attributed to the fact that 71% of TRP'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 4.3 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

4.4 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.

4.4.1 Objective one: To establish the effectiveness of the current maintenance structure at Richards Bay Transnet Port Terminal.

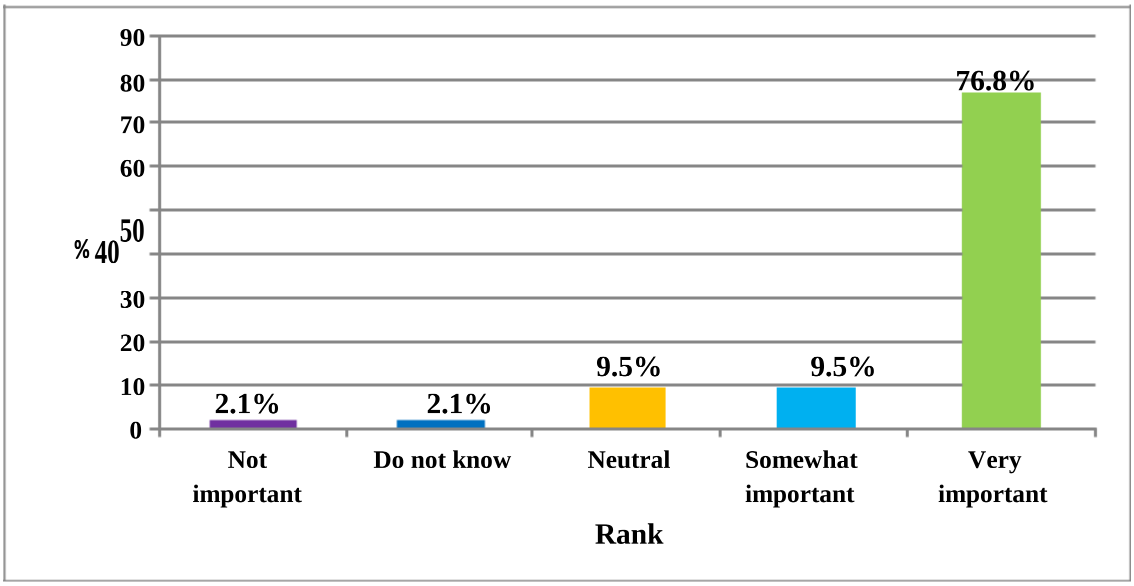

Figure 4.4.1 Frequency distribution for ranking the importance of maintenance function at TRP

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 TRP. 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.* 2014). 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 2017, and Chinese and Ghirardo 2010). Furthermore, the empirical result in Table 4.3.1(a), also suggests a characteristic of an open system organisation (Simoes *et al.* 2011:129).

Table 4.4.2 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 4.4.2 Respondents perceived status of maintenance function at TRP

Statements	N	Likert Scale Rating (%) StronglyDisagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Deviation
I know about different maintenance types used at TRP	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 TRP	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 4.4.2, above, are summarized below:

It is evident from Table 4.4.2, that majority of respondents agree that they are aware of different maintenance types at TRP (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 4.4.2 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, 2017). In contrast with this finding, Lazim and Ramayah (2010:387), Al-Turki (2011), Simoes *et al.* (2011), Rolfsen and Langeland, (2012) and Maletič *et al.* (2012) are in agreement that maintenance function is a strategic imperative and an integral part of manufacturing.

Table 4.4.2 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 4.4.2, that majority of respondents (Mean = 3.87 and SD = 1.08) agreed that the maintenance management function contributes positively to the company's profitability. Sharma, Kumar and Kumar (2016), 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 centre. 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 4.4.2 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 TRP is perceived as being a very important functional management area; there is a paradigm shift in TRP'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 that a paradigm shifts 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.* 2012).

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

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

Table 4.4.3 Perceived shortcomings of the maintenance function at TRP

		Likert Scale Rating (%)						
Statements	**N**		**Disagree**	**Neutral**	**Agree**		**Mean**	**Std. Deviation**
Machines are repaired only when they are broken at TRP	95	10.5	24.2	10.5	28.4	26.3	**3.36**	1.375
Maintenance planning is effective at TRP	95	14.7	20	20	31.6	13.7	**3.09**	1.289
Maintenance scheduling is effective at TRP	95	12.6	24.2	38.9	21.1	3.2	**2.78**	1.023
Predictive maintenance is practiced at TRP	95	20	32.6	27.4	13.7	6.3	**2.54**	1.147
Planned maintenance is practiced at TRP	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 TRP are well understood	95	15.8	22.1	34.7	17.9	9.5	**2.83**	1.182
There is a maintenance planner at TRP	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 4.4.3, above, are summarized below:

It is evident from Table 4.4.3, that majority of respondents (Mean = 3.36 and SD = 1.37) agreed that at TRP, 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 2014).

It is evident from Table 4.4.3, that majority of respondents (Mean = 2.54 and SD = 1.14) disagreed that predictive maintenance is practiced at TRP. 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 4.4.3, revealed that majority of respondents (Mean = 2.42 and SD = 1.217) disagreed that there is a maintenance planner at TRP. Wireman (2014) 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 (2014) the exclusion of the maintenance planner in the maintenance organisational structure is a major impediment to effective maintenance planning and scheduling.

From Table 4.4.3, majority of respondents (Mean = 3.09 and SD = 1.28) agreed that maintenance planning at TRP 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 2014). 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.* (2014) and Alsyouf (2013) are in agreement that ineffectiveness maintenance planning and scheduling impedes the maintenance function from accomplishing its goals. According to Wireman (2014), 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 4.4.3, 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 TRP employees' perceptions regarding the level of effectiveness of the maintenance function at TRP.

Summary of the statements are shown in Table 4.4.4 below.

Table 4.4.4 Perceived level of maintenance effectiveness at TRP

		Likert Scale Rating (%)						
Statements	**N**		**Disagree**	**Neutral**	**Agree**		**Mean**	**Std. Deviation**
I am aware of TRP 's maintenance strategy and policy	94	20.2	38.3	22.3	14.9	4.3	**2.45**	1.103
TRP '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 TRP 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 TRP 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 4.3.3that majority of respondents (Mean = 2.45 and SD = 1.103) disagree that they are aware of TRP'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.* 2014:8, and

Wireman 2014). 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 TRP 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 TRP is perceived to be very low and therefore ineffective.

Alsyouf (2013), 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.* (2010), 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 TRP employees' views about Total Productive Maintenance (TPM)'s contribution towards improving TRP's operational performance areas.

Figure 4.4.4(a) revealed that majority (42.1%) of respondents describes TPM as a combination of strategy, philosophy, approach, concept, and best practice.

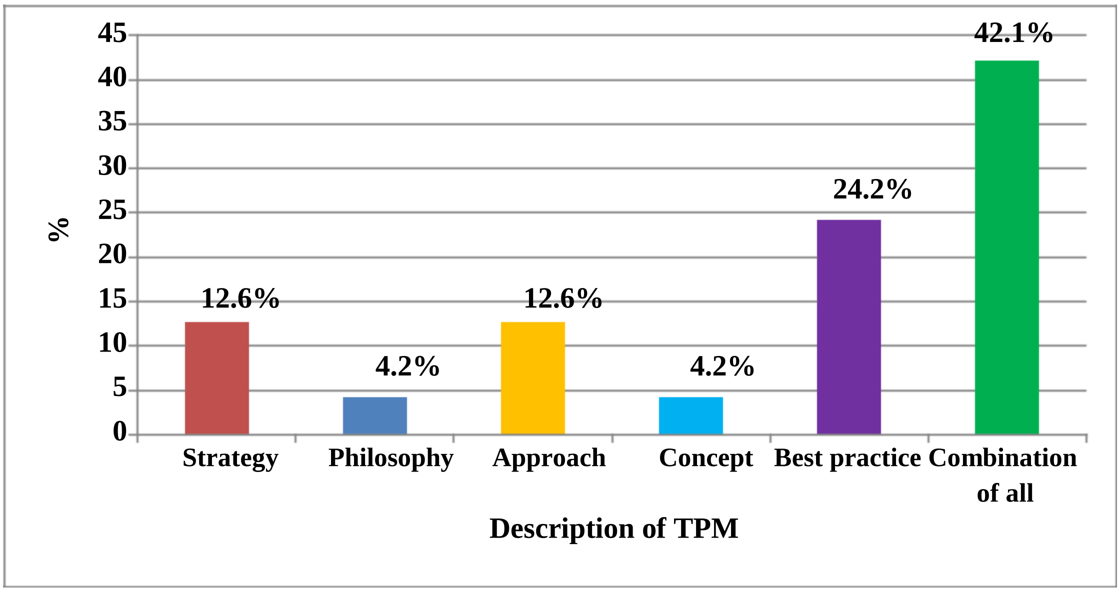

Figure 4.4.4(a) Description of TPM by TRP employees

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

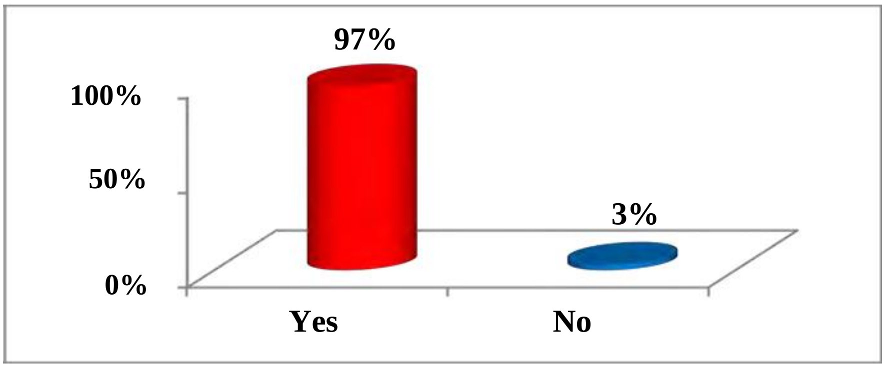

Figure 4.4.4(b) TPM can improve maintenance effectiveness

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 4.4.4

Table 4.4.4: Total productive maintenance at TRP

		Likert Scale Rating (%)						
Statements	**N**	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**		**Mean**	**Std. Deviation**
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 4.4.4 above are summarized below:

Analysis of responses in Table 4.4.4 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 4.4.4 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 4.4.4 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.* (2016), assert that TPM could increase manufacturing efficiency and effectiveness in manufacturing plants

Analysis of responses in Table 4.4.4 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, organisational, 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) and Lack of motivation (Mean = 3.97 and SD = 0.914)

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

Tables 4.5 (a) and Table 4.5 (b) depicts comparison of average TPM score by gender, age group, position and educational level. It is evident from Table 4.5 (a) that females had the higher average score however this was not statistically significant: *p* = 0.352.

Table 4.5 (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 4.5 (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 4.5(b): 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.						

4.6 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 4.6, below, elucidates reliability tests for this study.

Table 4.6: Reliability Tests

Perceived status of maintenance function at TRP		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
0.824	0.828	9
Maintenance effectiveness level at TRP		
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 TRP		
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

Table 4.6 (a) below 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 4.6(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**	***p*-value**	**Sum of squares**	**df**	**Mean square**	**F**	***p*-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			

4.7 Chapter summary

The research question for this study was: *How can the effectiveness of the plant maintenance function at TRP 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 next chapter is the discussion on recommendations pertinent to the findings of this research study.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

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 Transnet 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 Findings from the Study

This section documents the findings from the study. The findings are in 2 parts which include findings from literature and from primary study.

5.2.1 Findings from the Literature Review

The inferences drawn from the analysis of the empirical results for this study are:

i) Maintenance function at TRP is perceived to be an important business management function that contributes positively towards the company's overall objectives and profitability.

ii) Characteristics of the maintenance function at TRP are: secondary function and first generational perspective maintenance approach.

iii) TRP is a closed system manufacturing organisation with a cost centre view towards the maintenance function.

iv) The perceived shortcomings of the maintenance function at TRP 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.

v) The perceived shortcomings of the maintenance function negatively affect the maintenance function's effectiveness level.

vi) 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.

vii) Resistance to change, lack of motivation, poor communication and lack of resources were identified by respondents as being the potential impediments to TPM implementation.

5.2.2 Findings from the Primary Study

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 TRP employees' perception towards the maintenance management function. The results revealed that, the maintenance function at TRP 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 Transnet SA's profitability. Sharma et al. (2016), 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 TRP. The results revealed that the perceived shortcomings of the maintenance function at TRP 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 (2014) reports that an empirical study conducted within US manufacturing plants, concluded that only one-third of manufacturing plants employ a maintenance planner. Wireman (2014) 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 TRP. The empirical evidence indicated that the effectiveness level of the maintenance function at TRP 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 TRP's maintenance function ineffective.

The fifth objective of the study was to solicit TRP employees' views about Total Productive Maintenance (TPM)'s contribution towards improving TRP's operational performance areas and effectiveness of the maintenance function. The study results confirmed that the majority of TRP employees are of the opinion that TRP'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 TRP 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

Transnet SA's strategic objectives is to increase in efficiency and profitability. That strategic objective is underpinned by optimization of all Transnet SA's business units, including TRP, 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 TRP's maintenance perspective is a closed system manufacturing organisation. The fact that TRP is the only manufacturing business unit under Transnet SA, further compounds this finding.

According to Simoes *et al.* (2011:128), in a closed system manufacturing organisation, 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 TRP'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 TRP'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 Transnet 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 TRP. The results revealed a gap between TRP's maintenance system and when compared with the characteristics of an effective maintenance system. On the basis of the foregoing, TRP's maintenance function is ineffective. It is against that background that the researcher outlines recommendations of how to improve TRP's maintenance effectiveness.

The perception towards the maintenance function in manufacturing plants has a profound impact on the effectiveness of the maintenance function (Wireman 2014). Issues pertaining to Health, Safety and Quality are held at high regard at Transnet 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 TRP, 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:

i) Senior executives of Transnet South Africa must play an active role in TRP'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, Transnet 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.

ii) TRP management team must also advocate and drive for pursuance of an organisation 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

iii) TRP management must enhance the level of maintenance management awareness to all employees at TRP about more in particular about its role and significance to the Transnet 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 TRP employees' maintenance training needs.

iv) TRP management must ensure transparency and full comprehension of maintenance KPI's and how those link to TRP's and Transnet SA's overall objectives. Cholasoke *et al.* (2014), 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 TRP'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).

v) The fundamental premise for maintenance effectiveness within manufacturing plants depends on the prudent adoption and replication of maintenance best practices (Alsyouf, 2009). Such initiative can be realised and accomplished by considering the short-term interventions such as immediate recruitment of a maintenance planner. According to Wireman (2014) the exclusion of the maintenance planner in the maintenance organisational structure is the major impediment to effective maintenance planning and scheduling.

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 (2014) 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 (Transnet SA) procedures. Benchmarking of maintenance best practices is a vital tool and a necessity for ensuring continuous improvement of maintenance function (Tsang, 2015, Wireman, 2014, 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 TRP 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 TRP.

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 TRP. 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 TRP, notwithstanding the low effectiveness level of that function, which adversely impact both TRP’s and Transnet SA’s operational performance.

The findings of this study further revealed that, the maintenance function at TRP 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 TRP's maintenance function ineffective. The study also revealed TRP is a closed system manufacturing firm with a cost centre view towards the maintenance management function.

The perceived shortcomings of TRP'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 TRP'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 TRP. TPM implementation at TRP 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 TRP to improve both maintenance effectiveness and the manufacturing operational performance areas.

REFERENCES

Adale, MA 2009, Evaluation of maintenance management through benchmarking in geothermal power plants. *MSc Thesis*, United Nations University.

Ahren, T and Parida, A 2009, Maintenance performance indicators (MPIs) for benchmarking the railway infrastructure. *International Journal of Quality and Reliability Management*, vol. 16, no. 2, pp. 247-258.

Ahuja, IPS and Khamba, JS 2008, Assessment of contributors of successful TPM initiatives towards competitive manufacturing. *Journal of Quality Maintenance Engineering*, vol. 14, no. 4, pp. 356-374.

Ahuja, IPS and Khamba, K 2008. Total productive maintenance: literature review and directions. *International Journal of Quality and Reliability Management*, vol. 25, no. 7, pp. 709-756.

Al-Najjar, B and Jacobson, M 2013, A computerised model to enhance the cost effectiveness of production and maintenance dynamic decisions. A case study of Fiat. *Journal of Quality in Maintenance Engineering*, vol. 19, no. 2, pp. 114-127.

Alsyouf, I. 2013, Measuring maintenance performance using a balanced scorecard approach. *Journal of Quality in Maintenance Engineering*, vol. 12, no.2, pp.133-149.

Alsyouf, I 2009, Maintenance practices in Swedish industries: survey results. *International Journal Production Economics*, vol. 1212, pp. 212-223.

Al-Turki, U 2011, A methodology for strategic planning maintenance. *Journal of Quality Maintenance Engineering,* vol. 17, no. 2, pp. 150-162.

Amaratunga, D, Baldry, D, Sarshar, M and Newton, R 2002, Quantitative and qualitative research in the built environment: Application of Mixed Research Approach, *Work Study*, vol. 51, no. 1, pp. 17-31.

Aoudia, M, Belmokhtar, O and Zwingelstein, G 2010, Economic impact of maintenance management and ineffectiveness of an oil and gas company. *Journal of Quality in Maintenance Engineering,* vol.14, no.3, pp. 237-261.

Arca, GJ and Prado, PCJ 2008, Personnel participation as a key factor for success in maintenance program implementation. *International Journal of Production and Performance Management*, vol. 57, no. 3, pp. 247-258.

Arsovski, S, Pavlovic, A, Arsovski, Z, Kalinic, Z and Rankovic, V 2011, Strategic Approach to Maintenance Management : A case Study, Strojarstvo. *Journal of Quality in Maintenance Engineering* vol. 53, no. 5, pp. 341-352.

Arts, RHPM, Knapp GM and Mann Jr L 1998, Some aspects of measuring maintenance performance in the process industry. *Journal of Quality in Maintenance Engineering*, vol.4, no.1, pp.6-11.

Aspinwall, E and Elgharib, M 2013, TPM implementation in large and medium size organisations. *Journal of Manufacturing Technology Management*, vol. 24, no. 5, pp. 688-710.

Bamber, CJ, Sharp JM and Hides, MT, 1999 Factors affecting successful implementation of total productive maintenance. A UK manufacturing case study perspective. *Journal of Quality in Maintenance Engineering*, vol.5, no.3, pp.162-181.

Bamber, CJ, Sharp, JM and Castka, P, Third party assessment: the role of the function in an integrated management system. *Journal of Quality in Maintenance Engineering*, vol.10, no.1, pp.26-36.

Biggam, J, 2008, *Succeeding with your Master's Dissertation*. 2nd edition . New York, McGraw Hill, USA.

Blumberg, B, Cooper, DR and Schindler, S 2005, *Business Research Methods*, New York: McGraw Hill.

Bryman, A and Bell, E 2007, *Business Research Methods*, 2nd Edition, New York: Oxford University Press Inc.

Campbell, JD 2015, *Uptime: Strategies for excellence in maintenance management*. 2nd edition. New York: Productivity Press.

Chinese, D and Ghirardo 2010, Maintenance management in Italian manufacturing firms. matters of size and matters of strategy. *Journal of Quality in Maintenance Engineering*, vol. 16, no.2, pp. 156-180.

Cholasuke,C, Bhardwa,R and Antony J,2014, The status maintenance management in UK Manufacturing organisations: results from a pilot survey. *Journal of Quality in Maintenance Engineering*, vol.10, no.1, pp.5-15.

Coetzee, JL 2016, A holistic approach to the maintenance problem. *Journal of Quality in Maintenance Engineering*, vol. 5. No. 3, pp. 276-280.

Cooke, FL, 2003, Plant maintenance strategy: evidence from four British manufacturing firms, *Journal of Quality in Maintenance Engineering*, vol.9, no3, pp.239-249.

Marquez, A and Gupta, JND 2006, Contemporary maintenance management: process, framework and supporting pillars, Omega, *The Journal of Management Science*, [online]. Available at http://www.sciencedirect.com [Accessed 2 October 2013].

Marquez, A, Moreu de Leon, P, Gomez Fernandez, JF, Para Marguez, C and Gonzalez, V 2009, The maintenance management framework: a practical view to maintenance management, *Journal of Quality Engineering*, vol. 15, no.2, pp. 167-178.

Da Silva, CMI, Cabrita CMP, and de Oliveira Matias JC 2008, Proactive reliability maintenance : a case concerning maintenance service costs. *Journal of Quality in Maintenance Engineering*, vol.14, no.4, pp. 343-355.

Deac, V, Carstea, G, Bagu,C and Parvu, F 2010, The modern approach to industrial maintenance management, *Informatica Economica*, vol.14, no.2. pp. 35-67.

De-Groote, P. M 1995, Maintenance Performance Analysis: A practical approach. *Journal of quality in maintenance engineering*, vol.1, no. 2, pp. 4-24.

Dilanthi, MGS 2013, Improving productivity with maintenance function in manufacturing industry in Sri Lanka: Literature review. *International Journal of Education Research*, vol. 1, no. 4. pp. 13-23.

Duffuaa, SO, Ben-Daya, M, Al-Sultan KS and Andijani AA, 2015, A generic conceptual simulation model for maintenance systems, *Journal of Quality in Maintenance Engineering*, vol. 7, no.3, pp.207-219.

El-Akruti, K and Dwight R 2013, A framework for the engineering asset management system, *Journal of Quality Maintenance in Engineering*, vol. 19, no. 4, pp. 398-412

El-Thalji, I and Liyanage, JP 2012, On the operation and maintenance practices of wind power asset. A status review and observations. *Journal of Quality Maintenance in Engineering*, vol. 18, no. 3, pp. 232-266.

Farinha, TMJ, Glar, D, Fobseca, IA and Kumar, U 2013, Certification of maintenance providers: a competitive advantage, *Journal of Quality Maintenance in Engineering*, vol. 19, no 2, pp. 144-156.

Farrero , JMC, Tarres, LG and Losilla BC 2002, Optimization of replacement stocks using a maintenance programme derived from reliability studies of production systems. *Journal of Industrial Management and Data systems*, vol. 102, no. 4, pp. 188-196.

Fernandez, O, Labib, AW, Walmsley, R and Petty DJ 2003, A decision support maintenance management system: development and implementation. *International Journal of Quality and Reliability Management*, vol. 20, no. 8, pp. 965-979.

Fore, S and Mudavanhu T 2011, An application of RCM for a chipping and sawing mill.

Journal of Engineering, Design and Technology, vol. 9, no. 2, pp. 204-226.

Forza, C 2002, Survey research in operations management: a process based perspective.

International Journal of Operations and Production Management, vol. 22, pp. 152-194.

Garg, A and Deshmuk, SG, 2016, Maintenance management: literature review and directions, Journal of Quality in Maintenance Engineering, vol.12, no.3, pp. 205-238.

Gebauer, H, Putz, F and Fischer, T. 2008, Exploring maintenance strategies in Chinese product manufacturing companies. *Management Research News*, vol.31, no.12, pp. 941-950.

Ghayebloo, S and Shahanaghi, K 2010, Determining maintenance system requirements by viewpoint of reliability and lean thinking: a MODM approach. *Journal of Quality in Maintenance Engineering* vol. 16, no. 1, pp. 89-106.

Graisa, M and Al-Habaibeh 2011, An investigation into current production challenges facing the Libyan cement industry and the need for innovative total productive maintenance (TPM) strategy. *Journal of Manufacturing Technology Management*, vol. 22, no. 4, pp. 541-558.

Hair, J, Babin, B, Money, AH and Samouel, P 2005, *Essentials of Business Research Methods*, John Wiley & Sons Inc, Hoboken, America.

Holmgrem, M 2005 Maintenance related losses at the Swedish Rail. *Journal of Quality in Maintenance Engineering*, vol. 11, no. 1. pp. 5-18.

Holmgren, M 2005, Maintenance Related Losses at the Swedish Rail, *Journal of Quality in Maintenance Engineering*, vol.11, no. 1, pp. 5-18.

Hyde, K 2000, Recognising deductive processes in qualitative research. *Journal of Qualitative Market Research*, vol. 3, no.2, pp.82-89.

Ionescu, D 2013, Predictive maintenance for intensive energy consuming plants, serviced by under-qualified staff. Case study. *International Conference on Renewable Energies and Power Quality* (ICREPQ'13).

Jammime, A 2009, Eskom's power crisis : Reasons, impact and possible solutions.*International Maintenance Excellence Conference*.

Jonsson, P, 2017, The status of maintenance management in Swedish manufacturing firms, *Journal of Quality in Maintenance Engineering*, vol.3, no.4, pp.233-258.

Karim, R, Soderholm, P, and Candel, O 2009, Development of ITC-based maintenance support services, *Journal of Quality in Maintenance Engineering*, vol. 15, no. 2, pp. 127-150.

Kaur,M, Singh, K and Ahuja, IS 2013, An evaluation of the synergic implementation of TQM and TPM paradigms on business performance. *International Journal of Productivity and Performance Management* , vol. 62, no. 1, pp. 66-84.

Khazrei, K and Deuse J 2011, A strategic standpoint on maintenance taxonomy. *Journal of Facilities Management*, vol. 9, no. 2, pp. 96-113.

Kodali, R Mishra, PR and Anan, G 2009, Justification of world class maintenance systems using analytical hierarchy constant sum method. *Journal of Quality Maintenance Engineering*, vol.15, no. 1 pp. 47-77.

Koochaki, J, Bokhorst, J, Wortmann, H and Klingenberg, W, 2011, Evaluating condition based maintenance effectiveness for two processes in series. *Journal of Quality in Maintenance Engineering*, vol. 17, no.4, pp. 398-414.

Kovac, G and Spens, KM 2006, A content analysis of research approaches in logistics research. *International journal of physical distribution and logistics management*, vol. 36, no. 5. pp. 35-44.

Kumar, GR and Kapil, M 2013, Maintenance: from total productive maintenance to world class maintenance. *International Journal of Scientific Research and Review*, vol. 2, no.1, pp.1-23.

Kumar, U, Galar, D Parida, A, Stenstrom , C and Berges L 2013, Maintenance performance metrics: a state of the art review. *Journal of Quality In Maintenance Engineering*, vol. 19, no. 3, pp. 233-277.

Kutucuoglu, KY, Hamali, J Irani, Z and Sharp, JM 2001, A framework for managing maintenance using performance measurement systems. *International Journal of Operations and Production Management*, vol. 21, no. ½, pp. 173-194.

Labib, AW 2004, A decision analysis model for maintenance policy selection using a CMMS. *Journal of Quality in Maintenance Engineering*, vol. 10, no.3, pp.191-202.

Lazim HM and Ramayah, T 2010, Maintenance strategy in Malaysian manufacturing companies: A total productive management (TPM) approach, *Business Strategy Series*, vol. 11, no. 6, pp. 387-396.

Leedy, PD and Ormond JE 2005, *Practical Research; Planning and design*. 8th Edition. New Jersey, Pearson Prentice hall.

Leedy, PD and Ormrod JE 2001, *Practical Research*. 7th Edition. New Jersey: Prentice Hall.

Lewis A, Elmualim,A and Riley, D 2012, Linking energy and maintenance management for sustainability through three American case studies. *Journal of Facilities Management*, vol. 29, no. 5/6 pp.243-254.

Lind, H and Muyingo, H 2012, Building maintenance strategies: planning under uncertainty, *Journal of Property Management*, vol.3, no.1, and pp.14-28.

Liyanage PJ 2007, Operations and maintenance performance in production an manufacturing assets. The sustainability perspective. *Journal of Manufacturing Technology Management*. vol. 18, no. 3, pp. 304-314.

Lofsten, H, 1999, Management of industrial maintenance-economic evaluation of maintenance policies. *Journal of Quality in Maintenance Engineering* vol. 19, no. 7, pp716-737.

Macchi, M and Fumagalli, L 2013, A maintenance maturity assessment method for the manufacturing industry. *Journal of Quality in Maintenance Engineering*, VOL. 19, no.3, pp.295-315.

Madu, CN, 2000, Competing Through maintenance strategies. *Journal of Quality in Maintenance Engineering*, vol. 17, no.9, pp.937-948.

Maletic, D, Maletic, M and Gomiscek, B 2012, The relationship between continuous improvement and maintenance performance. *Journal of Quality in Maintenance Engineering*, vol.18, no.2, pp. 30-41.

Marttonen, S, Monto, S, and Karri, T 2013, Profitable working capital management in industrial maintenance companies. *Journal of Quality in Maintenance Engineering*, vol. 19, no. 4, pp. 429-446.

Mitchell, E, Robson, A and Praabhu, VB 2002, The impact of maintenance practices on operational business performance. *Manufacturing Auditing Journal*, vol. 17, no. 5, pp. 234-240.

Moayed, FA and Shell, RL 2009, Comparison and evaluation of maintenance operations in lean versus non-lean production systems. *Journal of Quality in Maintenance Engineering*, vol. 15, no.3, pp.285-296.

Moseki, LK, Tembo E and Cloete CE 2011, The principles and practice of facilities maintenance in Botswana. *Journal of facilities management* vol. 13, no. 1, pp. 48-63.

Moubray, J 2011, *Reliability-centred maintenance*. 2nd Edition. New York: Industrial Press.

Muchiri, P and Pintelon, L 2008, Performance measurement using overall equipment effectiveness (OEE): literature review and practical application discussion. *International Journal of Production Research*, vol. 46, no.13, pp.3517-3535.

Murthy, DNP, Artens, A and Eccleston, JA, 2012, Strategic maintenance management, *Journal of Quality in Maintenance Engineering* vol.8, no.4, pp. 287-305.

Muthu, S Devadsan, S. Ahmed S, Suresh, P and Baladhandayuthan R 2000, Benchmarking for strategic maintenance quality improvement. *Benchmarking : An international Journal*. vol 7, no. 4, pp. 292-303.

Narayan, V, 2012, Business performance and maintenance; how are safety, quality, reliability, productivity and maintenance related? *Journal of Quality in Maintenance Engineering*, vol. 18, no. 2, pp. 183-195.

Naughton, DM, Hardinam, F and Mansbridge, E 2013, Maintenance practices in an economic down turn: the Irish experience survey results, *Journal of Facilities Management* vol. 11, no. 4, pp. 289-305.

Nel, W, 2014, *Management for Engineers, Technologists and Scientists*. 2nd edition . Cape Town, Juta, South Africa.

Panneerselvam, A. 2012, Measuring maintenance performance: a holistic approach. *International Journal of Operations and Production Management*, vol. 19, no.7, pp. 691-715.

Pintelon, L, Preez, N and Puyvelde van , F 2015. Information technology: opportunities for maintenance management. *Journal of Quality in Maintenance Engineering*, vol. 5, no.1, pp. 9-24.

Portioli-Staudacher, A and Tantardini, M 2012, Integrated maintenance and production planning: a model to include rescheduling costs. *Journal of Quality in Maintenance Engineering* vol. 18, no. 1, pp. 42-59.

Prajapati, A, Bechtel, J and Ganesan S 2012,Condition based maintenance: a survey. *Journal of Quality in Maintenance Engineering*, vol. 18, no.4, pp.384-400.

Pretorius, PG and Visser, JK, ND, Investigation of the maintenance organisation for hot rolling mills, Department of Engineering Technology Management, University of Pretoria.

Singh, K and Prycraft, M, 2017, *Operations Management*. Cape Town: Pearson Education.

Pun, KF, Chin, KS, Chow, MF and Lau, HCW 2012, An effectiveness centred approach to maintenance management. A case study. *Journal of Quality in Maintenance Engineering*, vol. 8, no. 4, pp.346-368.

Rachidi, AHC 2013, Strategic dimension of maintenance management. *Journal of Quality in Maintenance Engineering*, vol.8, no.1, pp.7-39.

Raouf, A and Ben-Daya, M 2015, Total maintenance management: a systematic approach. *Journal of Quality in Maintenance Management Engineering*, vol. 1, no. 1, pp. 6-14.

Razak IHA, Kamaruddin, S and Azid, IA, 2012 An empirical study in Malaysisa of a model of maintenance workforce performance evalution. *International Journal of Productivity and Performance Management*, vol.61, no.1, pp. 24-45.

Razak, IHA, Kamaruddin, S and Azid IA 2012, Workforce competency model (WFCM) An empirical study in Malaysia of a model for maintenance workforce performance evaluation. *International Journal of Productivity and Performance Management*, vol. 61, no. 1, pp. 88-109.

Reis, ACB, Costa, APC and Almeida, AT de 2009, Planning and competitiveness in maintenance management. An exploratory study in manufacturing companies. *Journal of Quality in Maintenance Engineering*, vol. 15, no.3, pp. 259-270.

Riis, JO, Luxhoj, JT, Thorsteinsson, U 1997, A situational maintenance model. *International Journal of Quality and Reliability Management*, vol. 14, no. 4, pp. 349-366.

Rolfsen, M and Langeland C 2012, Successful maintenance practice through tea autonomy. Employee Relations. *International Journal of Productivity and Performance Management* vol. 34, no. 3, pp. 306-321.

Salonen, A and Bengston, M 2011, The potential in strategic maintenance development. *Journal of Quality in Maintenance Engineering*. vol. 17, no. 4, pp. 337-350.

Salonen, A and Deleryd, M 2011, Cost of poor maintenance. A concept for maintenance performance improvement. *Journal of Quality in Maintenance Engineering*, vol. 17, no. 1, pp. 63-73.

Sari, E and Shaharoun, AM 2012, A proposed maintenance performance measure for manufacturing companies, *Proceedings of the Asia Pacific Industrial Engineering and Management Systems Conference*.

Saunders, M, Lewis, P and Thornhill, A 2000, *Research Methods for Business Students*. 2nd edition . Great Britain , Prentice Hall.

Savsar,M 2011 Analysis and modelling of maintenance operations in the context of an oil filling plant. *Journal of Manufacturing Technology*, vol. 2, no. 5, pp. 679-697.

Sekaran, U and Bougie, R 2010, *Research Methods for Business A skill building approach*, 5th Edition, Wiley Production.

Sharm, RK, Kumar, D and Kumar, P 2006, Manufacturing excellence through TPM implementation: a practical analysis. *Industrial Management and Data Systems*. Vol. 106, no. 2, pp. 256-280.

Sharma, A and Yadava, GS 2011, A literature review and future perspectives on maintenance optimization. *Journal of Quality in Maintenance Engineering*, vol.17, no1, pp. 5-25.

Sharma, RK, Kumar, D and Kumar, P 2016, Manufacturing excellence through TPM implementation: A practical analysis. *Industrial management and data systems*, vol. 106, no. 2, pp. 256-280.

Sherwin, D 2000, A review of overall models maintenance management. *Journal of Quality In Maintenance Engineering*, vol. 6, no. 3, pp.138-164.

Simoes, JM, Gomes, CF and Yassin, MM 2011, A literature review of maintenance performance measurement: a conceptual framework and directions for future research, *Journal of Quality In Maintenance Engineering*, vol. 17, no. 2, pp. 116-137.

Soderholm, P, Holmgren, M and Klefso B. 2007, A process view of maintenance and its stakeholders. *Journal Of Quality In Maintenance Engineering*, vol. 13, no. 1, pp. 19-32.

Stenstrom, C, Parida, A, Kumar, U and Galar, D 2013, Performance indicators and terminology for value driven maintenance. *Journal of Quality in Maintenance Engineering*, vol. 19, no. 3, pp. 222-232.

Srivastava, G and Mondal, T 2013, *Benchmarking of Best Maintenance Practices*, 2nd Edition. New York; Industrial Press.

Sullivan, M., Weck, K.H. and Roth, M. (2014) 'Assessing the impact of maintenance strategies on supply reliability in asset management methods', *Proceedings of the 40th CIGRE Session of August, 2004*, Paper C1-108.

Tahboub, KK 2011, An assessment of Maintenance practices and problems in Jordanian industries. *Journal of Mechanical and Industrial Engineering*, vol.5, no. 4, pp.315-323.

Tsang, AHC, 2012. A strategic approach to managing maintenance performance. *Journal of Quality In Maintenance Engineering*, vol. 4, no. 2, pp. 87-94.

Tsang HC, Jardine AKS and Kolodny, H 2013, Measuring maintenance performance: a holistic approach. *International Journal of Operations and Production Management*, vol. 19, no. 7, pp. 691-715.

Tsang, A.H.C., 2015. Maintenance performance in capital intensive organisations, *PhD Thesis*. University of Toronto.

Tsarouhas, P 2007, Implementation of total productive management in food industry; a case study. *Journal of Quality in Maintenance Engineering*, vol.13, no. 1, pp. 5-18.

Uysal, F and Tosun, O 2012, Fuzzy tops is-based computerized maintenance management system selection. *Journal of Manufacturing Technology Management*, vol. 23, no. 2, pp. 212-228.

Uzun, A and Ozdogan, A 2012, Maintenance parameters-based policies optimization. *Journal of Quality in Maintenance Engineering*, vol. 18, no. 3, pp. 295-310.

van der Wal, RWE and Lynn D 2002, Total productive maintenance in a South African pulp and paper company: a case study, *The TQM Magazine*, vol. 14, no. 6, pp. 359-366.

Veldman, J, Klingenberg, W and Wortmann, H 2011, Managing condition-based maintenance technology. A multiple case study in the process industry, *Journal of Quality in Maintenance Engineering*, vol. 17, no. 1, pp. 40-62.

Visser, JK and Kotze, RLM 2010, Maintenance performance indicators: An analysis in the mining industry. *International Maintenance Excellence Conference*. University of Pretoria

Visser, JK and Pretorious, MW 2003, The development of a performance measurement system for maintenance. *South African Journal of Industrial Engineering*, vol. 14, no.1, pp.83-97.

Wang, CH and Hwang, SL 2004, A stochastic maintenance management model with recovery factor. *Journal Of Quality In Maintenance Engineering*, vol. 10, no. 2, pp. 154-164.

Wireman, T 2014, *Benchmarking of Best Maintenance Practices*, 2nd Edition. New York; Industrial Press.

Yam, RCM, Tse, P, Ling, L and Fung F 2013, Enhancement of maintenance management through benchmarking. *Journal of Quality in Maintenance Engineering*, vol.6, no.4, pp. 224-240.

Zaim, S, Turkyilmaz, A, Acar, MF, Al-Turki, U and Demirel, OF 2012, Maintenance strategy selection using AHP and ANP algorithms; a case study. *Journal of Quality in Maintenance Engineerin*g, vol. 18, no. 1, pp.16-29.

Zuashkiani, A, Rahmandad, H and Jardine, AKS 2011, Mapping the dynamics of overall equipment effectiveness to enhance asset management practices. *Journal of Quality in Maintenance Engineering*, vol.17, no.1, pp.74-92.

Appendix A: Letter of Permission to Conduct the Study (from the organisation under study);

(To be attached)

Appendix B: Draft Covering Letter (to respondents, informing them of the aim of the study and any ethical

Appendix 3 Final Questionnaire

Put an 'X' on the most appropriate answer

Section A Biographical data	
1. Age	
21-30	
31-40	
41-50	
50+	
2. What is your race?	
African	
Coloured	
Indian	
White	
Other	
4. How long you been operating	
1-5 years	
6-10 years	
11-20 years	
20+ years	
5. Indicate your highest level of education	

Below Matric
Matric
Certificate
Diploma
Post graduate Diploma
Degree qualification
Above degree qualification

Section B: To establish the planning related challenges faced by Richards Bay Transnet Port Terminal

Please indicate the extent to which you agree with the following statements

	Strongly Agree (5)	**Agree (4)**	**Neutral (3)**	**Disagree (2)**	**Strongly Disagree (1)**
1. Richards Bay Transnet Port Terminal has operational plans in place for all departments					
2. Richards Bay Transnet Port Terminal has dedicated planning office					
3. Richards Bay Transnet Port Terminal's planning is sufficiently funded					

4. Richards Bay Transnet Port Terminal plans are implemented as per plan					
5.I There is always plan B to support the initial plan					
6. Outline other planning related challenges at Richards Bay Port Terminal					
Section B: To determine the planning practices employed by Richards Bay Transnet Port Terminal					
Section C: To determine the factors which affect planning at Richards Bay Transnet Port Terminal Please indicate the extent to which you agree with the following statements					
	Strongly Agree (5)	**Agree (4)**	**Neutral (3)**	**Disagree (2)**	**Strongly Disagree (1)**
7. Richards Bay Transnet Port Terminal has a planning department					
8. The departmental plans are part of the overall organisation plans					
9. Richards Bay Transnet Port Terminal has a planning committee					

10. Richards Bay Transnet Port Terminal's planning committee lays down the organisation's initial plans					
11. There are control measures to ensure that plans are followed					
12. Richards Bay Transnet Port Terminal has a dedicated plan implementation officer					
13. Outline the other factors which in your view affect planning at Richards' Bay Port Terminal					

Section D: To establish the impact of planning on organisational performance at Richards Bay Transnet Port Terminal

Please indicate the extent to which you agree with the following statements

	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)
14. Planning has managed to enhance the equipment maintenance system leading increased performance					
15. Vessel turnout at Richards' Bay Port Terminal has improved due to planning					

15. Planning improves equipment maintenance at Richards' Bay Port Terminal					
16. Current equipment maintenance has improved as a result of good planning					
17. Plant availability has improved due to good planning					
18. Plant breakdown has reduced due to good planning					
19. Departments always achieve their planned goals					
20. Through planning Richards Bay Transnet Port has managed to meet its performance goals					
21. Explain what you can do to ensure that planning enhances performance at Richards' Bay Port Terminal					