UNIVERSITY OF KWAZULU-NATAL

Evaluation of a Preventative Maintenance System at an Automotive Weld Plant

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A dissertation submitted in partial fulfilment of the requirements for the degree of

Master of Business Administration

Graduate School of Business & Leadership

College of Law and Management Studies

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2016

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Acknowledgements

The journey to enlightenment can never be made alone. I wish to thank those who assisted me in developing this body of work and supporting me throughout the program. A special thanks to the following:

- My dearest wife, Prishani, for the emotional support and patience during the long study hours.
- My family members for their motivational support.
- My MBA colleagues: Poovan, Shah, Ntokozo, Shiraz, Stanley and Nokwanda.
- Management for permission to conduct the study.
- All participants who volunteered their time to support the research.
- Dr Muhammad Hoque, my supervisor, for his patience, encouragement and wealth of knowledge.

Abstract

The automotive industry is an organisation that competes globally with other organisations and internally with other plants. Through the implementation of various competitive strategies namely total quality management, just in time and production systems, these organisations have taken on the mantle of world-class organisations. To compete in this space, world class organisations must ensure that all aspects of the business are strategically aligned to the organisational goals. Total Preventative Maintenance is a strategy that world-class organisations use to ensure that maintenance activities are competitive by minimising costs and maximising production. The aim of the study is to evaluate the Preventative Maintenance System of an automotive weld plant to understand the struggle points that result in high repeat breakdowns. The study makes use of a quantitative study, for the evaluation of the plant, amongst 73 employees. The employees are from the maintenance and engineering sector of the weld plant and the information is gathered using a questionnaire. It is found that the respondents have limited resources with regard to staff size and that the organisation structure is a limiting factor in application of their tasks. It is also noted that skills and training are rated high amongst respondents. The main finding is the lack of a Preventative Maintenance (PM) management system and planners. This results in the lack of historical data and the lack of PM improvements. This is a contributing factor to poor maintenance and resultant equipment failure. It is recommended that management address the low morale by ensuring the organisation structure and staff complement is adequate. The best practices of Preventative Maintenance with information from equipment failures must be followed forming the base for further improvement to the PM system. This can only be done with accurate record keeping and daily planning. The implementation of a permanent planner is an essential factor in ensuring that PM is managed and updated to ensure repeat breakdowns do not occur.

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1 Chapter 1: Introduction

1.1 Introduction

World Class Organisations (WCO) have maintenance policies that form a part of the overall strategy which is geared to achieve efficiency and productivity. Preventative Maintenance and Predictive Maintenance are standard concepts in many organisations, however, what varies is the method of execution. The effective management of a system is important in ensuring that it helps in achieving the key performance goals of the department being served by the system.

The organisation under study is acclaimed to be a world class organisation as it operates in a global sphere against geographically diverse competitors for global customer base. This places enormous pressure for remaining competitive against changing global conditions and financial pressures (Kaur et al., 2012). The study focusses on the Maintenance aspect of the organisation in a specific plant. It is observed that the performance of the department, with regards to the uptime of equipment, is failing. This phenomenon should not occur based on the presence of an existing Preventative Maintenance System (PM).

This chapter discusses the research topic and the development of the research questions and objectives. Preventative maintenance is discussed based on the automotive sector and its importance emphasised as the role in ensuring a world class production facility. The implications are further discussed in the motivation for the study. The problem statement then contextualises the problem by providing information for the source of the issue and the impact thereof in terms of the business process. The environment in which the study takes place is explained and the focus of the study discussed. The chapter is closed with a summary.

1.2 Motivation for the study

The choice of the particular study stems from the large number of production failures of plant and machinery in the automotive plant understudy. The existence of the preventative maintenance system is then called into question. The study aims to examine the current system and compare with the established literature to understand the shortfalls. Preventative maintenance is a subject that is well

established and implemented by all world class production facilities in one form or another. The study aims to evaluate the existing PM system at the automotive weld plant and understand the causes of the system failure. The benefit of such a study is that the findings can result in practical recommendations. This will result in an improvement of the PM system, which further results in production equipment being available for longer periods with minimum failure. The problem statement discusses the issue and the source in more detail.

The results of the study can prove beneficial to the following stakeholders:

- The management of the organisation can utilise the findings for improving the PM system and the plant performance
- Support staff of the organisation can utilize the findings for facilitating improvements in their sphere of control.
- Similar organisations can utilise the information for improving their own systems and compare the same against scenarios in their own departments.
- Students or other interested parties can use the information for improving their understanding on the subject of preventative maintenance.

1.3 Focus of the study

The study held its target population to be the support and management staff at an automotive weld plant in the KZN region. The study focussed on gathering information on the current Preventative Maintenance system in relation to the theory of Preventative Maintenance best practices from the world-class organisations. The findings would aide management in identifying the struggle areas in the existing system.

1.4 Problem statement

Valuable production time is lost due to the equipment failure. It is important that machine up time be maximised during production time. Such results are not a yielded by the existing system. Repetitive equipment failures occur during

production time which results in a facility downtime. A high downtime further results in a low Operation Production Ratio (OPR), the target of which is set at 95 % to allow for a reasonable amount of downtime. The Weld plant is found to be struggling to achieve the targeted OPR due to a high amount of downtime. The analysis of the downtime revealed a pattern of repeated equipment failures and its countermeasures mention changes to PM activities. Failures continue to occur and are often due to similar faults but in different pieces of equipment. The evaluation of the system can help understand the problem areas in the system and recommendations can be made using theory and industry best practices.

1.5 Research Questions

The objective of the study was developed with the following research questions:

- Do the resources exist for the implementation of the system?
- What is the present level of skills of the personnel implementing the system?
- Does the necessary information technology exist for the facilitation of the system?
- What is the condition of the current Preventative Maintenance System?
- What planning and scheduling activities does the PM system involve?

1.6 Objectives

The main objectives of the study are:

- Determine whether or not the required resources are available for the implementation of the system.
- Establish the level of skills of maintenance personnel.
- To ensure that the necessary information technology is in place for facilitation of the system.
- Assess the current Preventative Maintenance System.

- To understand if the planning and scheduling activities are in line with PM system.

1.7 Limitations of the study

The following limitations are associated with the research:

- The research was based solely on one weld plant in the automotive group due to which it has a small population size. The aspect of generalizability to other plants is reduced because of this.
- Since the use of only the quantitative approach is done in this research, the study lacks the depth of a qualitative study. A qualitative study provides detailed nature of the respondents' behaviour and characteristics.
- The respondents comprise of the engineering and maintenance staff, thus, the study lacks input from operators.

1.8 Summary

This chapter discusses the problem under study that is the failure of the Preventative Maintenance System at a weld plant. One of the factors influencing the competitiveness of an organisation is the cost management. Maintenance is a large cost factor is an organisation and Preventative Maintenance Strategies assist in managing the cost of maintenance thereby ensuring the effectiveness of the production system. The motivation for the study and the research questions and objectives have been discussed in the earlier section. The possible limitations to the study were also listed above. A literature review of world-class organisations and Preventative Maintenance is presented in chapter two.

2 Chapter Two: Literature Review

2.1 Introduction

The chapter focusses on the research in the field of World Class Manufacturing (WCM) and how effective Preventative Maintenance plays a significant role in determining an organisation's competitive advantage.Yamashina (2000) in his article on The Challenge to world-class manufacturing, looks at the background of manufacturing and how consumer behaviour has led to the evolution of the manufacturing process. The author highlights the distinctness between the innovative nature of the west and the constant improvement principals of the east. Kaur et al. (2012) states that the challenges faced during the manufacturing process in particular Japanese organisations are the rate of competition among emerging markets and the economic factors.

This chapter also discusses in detail the concepts of just in time systems (JIT), Six Sigma, total quality management (TQM) and Total Productive Maintenance (TPM). These concepts are found to be followed by the World Class Organisations in an attempt to achieve a competitive edge in the market place by supplying the customer with the right quality at the right time (Singh et al., 2016). Preventative Maintenance systems are developed by using many of the WCM strategies which include Total quality management, Total Productive Maintenance and Six Sigma. Broad research on each of these concepts have shown how production can be improved by employing these concepts in the manufacturing process. The objective of this study revolves around understanding the five major components of a maintenance model: resource management, information management, equipment technology and planning and scheduling (Maletič et al., 2014).

2.2 World Class Manufacturing

The development of an effective maintenance model begins with the focus on world class manufacturing as the core structure (Brown et al., 2007). There is a large amount of literature and evaluations of WCM strategies is available that emphasises the strategic role it plays in providing competitive advantage to an organisation (Singh et al., 2016). The global competition has made the

organisations realise that productivity performance is accomplished only through the employment of world-class business strategies. TQM and TPM form the most widely used ones out of all such strategies (Seth and Tripathi, 2006). These business solutions have been studied in various organisations and in various studies by Brown et al. (2007) and later by Piechnicki et al. (2015) which show that from an operations management point of view, it enhances the performance of an organisation corresponding to its chosen goals. A world class organisation must have a manufacturing strategy that depicts the way in which the organisation would compete with its rivals in the marketplace (Kaur et al., 2012).

2.2.1 WCM concept

The concept of “World Class” was coined by Hayes and Wheelwright in the year 1984 to showcase the systems engineered by the Japanese and the German companies. The term “World Class Manufacturing” became a criterion to describe the organisations that were able to achieve success in global operations. WCM is a concept that focuses mainly on production activities and includes the following production techniques: total quality management(TQM), employee involvement(EI), just in time(JIT) and Total Productive Maintenance(TPM) (Eid, 2009). It was recognized that these principles served to be the basis for differentiating an organisation from the traditional ones. It made the organizations shift from the process of inventory management to the concept of production management (Smith, 2011). The concept of JIT in the available literature is seen to be discussed in conjunction with inventory management systems, however, it can be extended to identify and remove any non value adding elements in a process including plant maintenance (Chen and Tan, 2011).

These systems have common elements and mainly focus on work sharing and the development of personnel. An element of development in TQM and TPM involves creating work teams for sharing and solving problems. This creation of teamwork leads to employee involvement, which further leads to staff motivation and achievement of the organisational objectives. It can, therefore, be concluded that TPM is an element of TQM and a base for JIT (Chen, 2015).

2.3 Just in Time (JIT)

Just in time is the nominal inventory policy that manufacturing firms employ to control inventory holding. JIT was first used in the 1980s by the Japanese Management systems as a tool for reducing the cost of technology setup. It also improved the quality of the product, which in turn reduced buffers required in the processes giving rise to production efficiencies (Chen, 2015). It mainly focusses on lowering inventory to a level where the inefficiencies are exposed (Näslund, 2013). Prior to Just in Time, the manufacturing companies used mass production to deal with the market fluctuations (Bayo-Moriones et al., 2008). These fluctuations are considered to be inevitable scenarios in the production process by the JIT approach. It tried to balance out the demand and the production process. The objective of JIT is to reduce inventory size and hence eliminate the waste.

There are generally two approaches to JIT implementation. The first approach being the removal of excessive holding stock and the lot size reduction which negatively impacts the customer service time. The second is a broader approach that focusses on the philosophy of reducing waste in all the stages of the production process through a systematic and continuous approach(Chen, 2015).

In the maintenance model, we focus on the second approach, which takes into consideration all of the WCM concepts in order to improve the production process. Efficient manufacturing must have TQM, JIT and TPM (Singh et al., 2016). TPM places its emphasis on equipment while TQM emphasises on the systems that ensure product quality. Thus, TPM forms a component of TQM and the foundation of JIT.

2.4 Total Quality Management (TQM)

TQM drives continuous improvement involving all levels of an organisation (Sharma et al., 2006). It combines elements such as just in time approach to inventory management, work teams, total productive maintenance and statistical process control with the quality objective of the organisation.

The relationship between TQM and JT states that higher quality can be achieved by effective use of JIT systems (Smith, 2011). For present day manufacturing businesses, TQM acts as a facilitator of process performance. Amongst other

facets of the business, it focuses on equipment management and its impact on product quality (Seth and Tripathi, 2006).

Total quality management and JIT are two concepts that have been developed and are used together .(Ahuja and Khamba, 2008). JIT is essentially more based upon Kanban controls, planning and sets time reductions. TQM, however, involves more of the statistical controls , design and customer focus (Reis et al., 2009). Total Quality Management supports JIT by providing management of the process and reducing safety inventories, re-processing of goods and essentially speeding time to market (Chen, 2015).

There are a number of methodologies that can be utilized under the framework of quality management (Pun and Nurse, 2010).These are listed as follows:

The use of statistical tools such as six sigma, for controlling processes and reducing defect outflow (Näslund, 2013).

The partnership with suppliers and customers: This can improve supplies of materials and create a strong relationship between the suppliers and the organization where skills can be shared (Vanichchinchai and Igel, 2009). This results in better product quality and reduction of holding stock which is an important element of JIT(Bayo-Moriones et al., 2008). In terms of customers, a good relationship will allow for communication and feedback regarding quality. Panwar et al. (2015) emphasises that the involvement of suppliers is important while implementing JIT. It is important that companies have assessment programs that can provide assistance to suppliers. Chen (2015) indicates that there is a synergistic relationship between JIT and TQM and its positive impact on the manufacturing process. Studies by Chen and Tan (2011) have shown that implementing TQM processes is easier in plants that have already introduced JIT.

In a study conducted by (Bayazit, 2003) on the implementation of TQM in Turkish Manufacturing Organisations , it was found that there was an increase in customer satisfaction, quality improvement, profitability and market share and a decrease in prices. The implementation time took around five to seven years and the success relied on the support from all the members in the organisation who made use of the tools of TQM. It is also observed that implementation of any of these systems

requires strong commitment from management and motivation to solve the problems that occur (Singh et al., 2016).

2.5 Total Productive Maintenance

TPM was initially introduced and developed in Japan in 1971(Ireland and Dale, 2001). It has been categorised as a strategy that utilises team based structures that optimise employee productivity to maximise facility availability (Bayazit, 2003). This is done by generating a maintenance system that is comprehensive spanning all equipment related fields (Sharma et al., 2006). Nakajima (1988) elaborated on the concept of TPM and listed the basic components as the following:

- Maximisation of Equipment.
- Creation of a procedure of PM for the lifespan of equipment.
- Implementing a maintenance strategy that involves multiple departments.
- Involvement of employees throughout the organisational structure.
- Improvement of the equipment design that results in reliability and quality.

Case study by Bartz et al. (2014) studied the implementation of Total Productive Maintenance (TPM) based on the maintenance model and found that significant improvements in production output and quality were derived post the deployment of TPM. TPM should be seen as a strategic tool as it aims to achieve continuous improvement as it attempts to improve waste, develop personnel, production processes and quality of the product (Maletič et al., 2014). TPM requires an environment that encourages changes and continuous improvement thus influencing the culture and structure of an organisation. This is done by investing in people through training. Efficient leaders and managers must be created to empower the personnel working under them. The strong development of people is crucial to the implementation of TPM as was emphasised in a study by (Jain et al., 2014).

A study by Ireland and Dale (2001)concluded that competitive manufacturing can be achieved by implementing TPM strategies . These are obtained by:

- Involving employees in basic maintenance tasks and creating ownership.
- Developing the problem-solving capabilities among employees.
- Developing further preventative and predictive maintenance activities.
- Analysing and creating awareness about consistency and maintainability aspects.
- Promoting the use of cross-functional teams. These teams should include employees from all the departments and levels within the organisational structure. This improves the speed and accuracy of problem solving.
- Improvements should be standardised.

The role of TPM in WC manufacturing is to ensure that quality goods are produced at the required rate (Singh et al., 2016). This is achieved by ensuring production equipment is maintained well in advance to be available when required to deliver the desired quantity and quality (Jain et al., 2014). TPM and TQM have been shown to be linked to lean manufacturing as it eliminates waste by ensuring the longer functioning of equipment (Seth and Tripathi, 2006). A key element of TPM is the blending of roles where operators take up some of the maintenance tasks (Lazim and Ramayah, 2010). Such an involvement of employee creates benefits in terms of increased equipment reliability and improved product quality.

Piechnicki et al. (2015) discussed the eight pillars of TPM and then listed them as follows:

Pillar 1 5S: This involves the cleaning and organising of the workplace. This enables problems to be seen and the processes to be visualized. The definition in English is Sort/Clean, Set in order, Shine, Standardise and Sustain. Once this step is done the other TPM pillars follow.

Pillar 2 Autonomous Maintenance: It involves enabling of operators in the maintenance of mundane tasks. This allows maintenance staff to focus on activities that are more critical. The aim is to maintain equipment to function optimally at all times through the consistent application of simple maintenance tasks.

Pillar 3 Improvements or Kaizen: Kaizen is the application of Improvement tools used for achieving small improvements in a process with minimum of investment. It is a continuous process that aims at achieving zero loss with regard to small stoppages. Nakajima (1988) classified losses into six areas namely: losses during start-ups, speed loss during production, losses due to small breakdowns, losses due to adjustments/setups and losses due to equipment failures.

Pillar 4-Planned Maintenance PM: The aim of this pillar is to have equipment that can produce products at the desired quantity and the desired quality is the one that exceeds the customer's expectations. To achieve this, maintenance can be broken down into varies categories: preventative, breakdown (reactive), corrective maintenance and maintenance prevention. PM strategy involves ensuring the availability of equipment, optimising maintenance cost, reducing spares inventory and increasing equipment reliability.

Pillar 5 Quality Maintenance: This aims at improving customer satisfaction by delivering defect free products. This is done by ensuring that the equipment produces products that are free from errors.

Pillar 6 Training: The aim is to develop multi skilled personnel with high morale by providing training to develop members and create a factory full of experts.

Pillar 7 Office TPM: This follows after the other pillars have been engaged and looks after the administrative functions and aims to improve them.

Pillar 8 Environment, health and safety: This pillar aims at creating a safe working environment which should be headed by a senior manager and maintained by a committee that ensures there are zero incidents.

The author observed that in order to deploy TPM successfully for forming an orderly systematic process, these pillars must be interlinked. This has been described in Figure 1

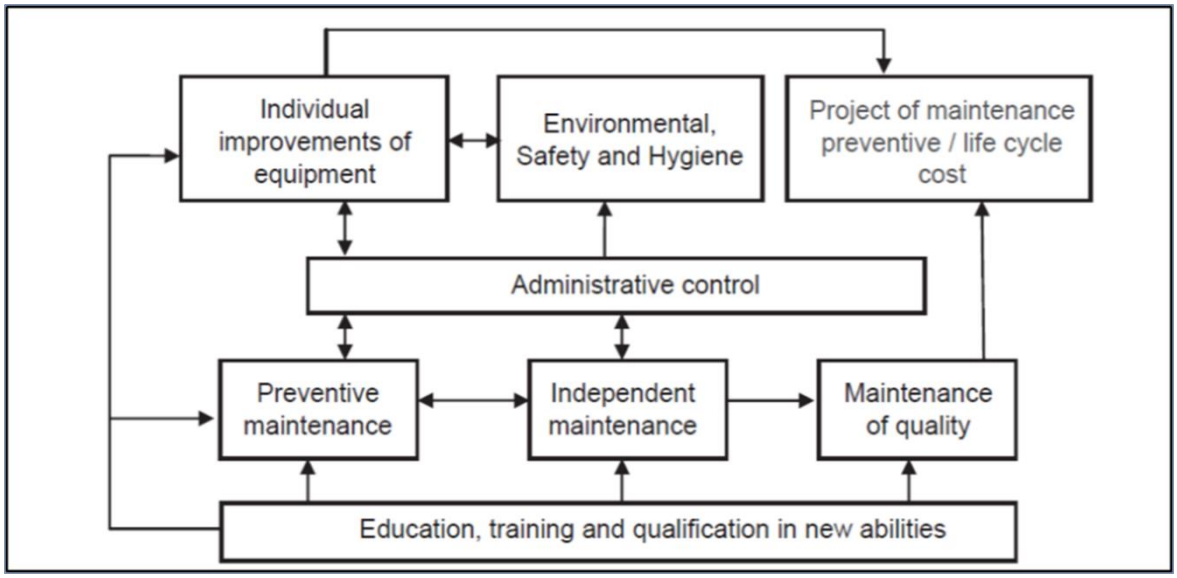

Figure 1 : Interconnection between the phases of TPM. Adapted From (Piechnicki et al., 2015)

2.5.1 Process Performance Improvement through Maintenance KPI Tracking

Lazim and Ramayah (2010) suggest three basic steps in developing a maintenance strategy that suits the organisation: The first is to design a plan for each component. The second is for procuring the resources (human and material) and the last step involves the implementation.

The implementing of a maintenance strategy is not complete without an evaluation of its performance. Bartz et al. (2014) have discussed through the reference of other authors that the use of key performance indicators (KPI) motivate the implementation of new models for maintenance. KPI applies a measure of control and aims at continuous improvement. Ahren and Parida (2009) have shown that KPIs for maintenance are a strategic factor for businesses. They further point out that measurement identifies improvement points in the system. The KPI must be well defined and well understood if it is intended to be effective.

The performance indicators used by maintenance must be based on the strategies of the organisations (Parida et al., 2015). This enables the company to justify

funding the maintenance improvement activities. This will also lead to improvement of health and safety in the work environment.

A model for maintenance management was proposed by Marquez et al. (2009) (Figure 2) which comprises of 8 sequential blocks. Maintenance effectiveness is evaluated in Phase 1 to Phase 3, Phase 4 and 5 ensure efficiency, Phase 6 and 7 cover equipment life cycle and Phase 8 deals with the continuous improvement.

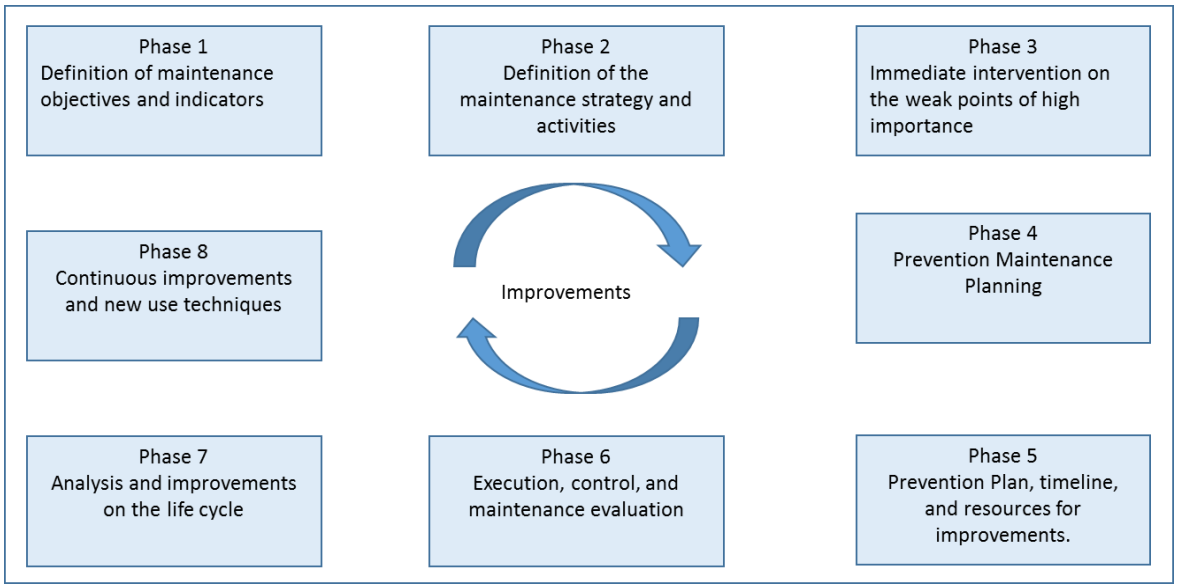

Figure 2 : Maintenance Management Model. Adopted from Marquez et al. (2009).

2.5.2 Types of Maintenance Strategies

In search of competitiveness, it was found that maintenance management is critical in achieving organisational goals (Verron et al., 2010). To achieve effective PM management many techniques and strategies have been suggested. Among the strategies being employed are the reactive maintenance, corrective maintenance, predictive maintenance, preventative maintenance, and proactive/reliability centred maintenance (Jain et al., 2014).

Reactive and correct maintenance should only be employed in cases where Preventative Maintenance becomes costly (Bartz et al., 2014). Jain et al. (2014) described corrective maintenance as a means to restore basic functionality of equipment that had earlier suffered failures. This is also referred to as reactive maintenance.

Preventative Maintenance can be divided into policies that revolve around a time base and condition-base(Meselhy et al., 2009). In the present environment where flexibility and reliability are not always a mutually required attribute, strategies called as reliability–centred maintenance are used(Gupta and Mishra, 2016). Such a strategy is dependent on what is necessary to maximise equipment availability.

Moubray (2000) presented in his book four phases of maintenance. The first phase began in the period from 1940 to 1950 with corrective maintenance. This phase moved on to Preventative Maintenance around 1950 to 1980. The third phase from 1980 to 2000 involved TPM, the then reliable centred maintenance. The author proposed that organisations should be in the phase that employs proactive maintenance, which works in line with the strategic goals of the organisation.

Maintenance strategies are segmented as follows:

- Strategies with logical steps and planning resulting in achievable action plans with computed results.
- Strategies with no prior planning.

Pun and Nurse (2010) state that planning allows for a scientific approach to maintenance with controlled activities and examination of performance.

Maletič et al. (2014) proposed in their paper on Total Productive Maintenance the concept of condition-based maintenance strategy. Condition-based maintenance allows equipment to run just before failure which is accomplished using the two defence lines. The first being the proactive maintenance which involves activities that detect and correct failures. The second is predictive maintenance which involves monitoring the condition of equipment to determine when is it likely for a failure to occur (Maletič et al., 2014). This strategy involved integrating the maintenance activities with the essential activities of the plant. These activities are Quality Control, Production and environmental conditions. This integration enables a user belonging to any of the organisational levels to acquire reliable information about the state of the production facility whenever required. This can be extended to the following types of information that can be made available:

- The condition of equipment at an early stage where control can be affected to reduce failure.
- The financial feasibility of the replacement times of the component.
- The allowable level of wear before failure.
- The remaining useful working life of the equipment where the operation is deemed acceptable.
- The statistics relating to product quality and lead time to failure.
- Documentation relating to modes of failure and its root causes. This needs to be done with accuracy by comparing measurements to occurrences of failure.
- Strategies to understand if the use of additional monitoring variables will result in improvement in functioning of the system.

2.5.3 Six Sigma

Six sigma, similar to TPM, is a strategy utilized to increase performance in manufacturing (Thomas et al., 2008). It is a tool created for solving problems in the business environment and has the same basic principles as of TPM. It differs in its structured five-phased approach to problem solving, define, measure, analyse, improve and control (DMAIC). Nachiappan et al. (2009) argued that the six sigma approach to quality problem solving has an improved success rate as compared to TPM although the systems were fundamentally the same. The Six Sigma Maintenance model (SSM) was developed to enhance the performance indicators of a company generally termed as safety, quality, production, personnel development and cost (Thomas et al., 2008). SSM involved the inception of teams comprising of cross-functional members. These teams then tackled the issues that affected the quality of maintenance. This resulted in significant savings of the company by using existing resources to improve the process (Näslund, 2013).

2.5.4 Developing an effective Maintenance Model

Parida et al. (2015) discussed the importance of linking the development of a maintenance model with the strategic goals of the organisation. Panesar and Markeset (2008) proposed the idea that maintenance should be a profit generating structure. This could be attained by balancing costs and critical maintenance to maximise return on investment.

Tam and Price (2008) developed a decision making framework that prioritised maintenance tasks for delivering the best return on investment. To accomplish this the budget constraints and the expected risk versus each asset class must be known. Establishing a maintenance system that does not depend on reaction maintenance yields improved results in quality and equipment reliability (Jain et al., 2014).

TPM is a management system that helps to improve the manufacturing efficiency by distributing the workload to increase equipment availability. It also requires the collection of records which form the basis of risk analysis for critical processes (Narayan, 2012). A successful implementation of TPM requires the acceptance of continuous change and consistent monitoring of the process (Singh et al., 2016).

2.6 Resource Planning

2.6.1 Organisational Structure to achieve PM Implementation

The implementation of the system relies on existence of support structure. The organisational structure must be in place that understands from a strategic level the goals of the organisation and how to translate that into the necessary key performance indicators(Lazim and Ramayah, 2010).

The shift among world class production facilities is from reactive maintenance to preventative maintenance. In order to achieve this a department must be able to handle the following simultaneously:

- Preventative Maintenance
- Corrective Maintenance
- Emergency Maintenance

Most organisations without proper structures end up sacrificing planned maintenance to address emergency maintenance(Jain et al., 2014). This leads to the failure to complete critical PM and creates a cycle where an organisation is lead towards a reactive behaviour.

Why are these three maintenance services important? The importance of preventive and planned corrective maintenance is that these two systems are primarily responsible for moving organizations from a reactive mode to a proactive mode. In order to address preventive maintenance, though, we have to spend time focusing on preventive maintenance. In order to address corrective maintenance, we likewise have to focus our attention on corrective maintenance. At the same time, we must also respond to emergency work. Preventive, planned corrective and emergency work has an egalitarian relationship; they pull equally against our resources and we act in kind by trying to cover all the bases while in a crisis mode. We must, however, be prepared to and structured to address all three at the same time.

Traditionally, a maintenance organization takes on a centralized or decentralized structure. A centralized organization places the maintenance department outside the functional centre of production, where all needs are met from a separate and common base. At least in a decentralized structure there is an attempt to divide up the elephant and give each section of the plant a focused effort. Neither is as effective in the 21st century as they could be, and as a result, we sometimes morph versions of these traditional structures.

2.7 Skills and Training

A preventative maintenance system relies on properly skilled and educated workforce to implement the work. Hiring based on academic qualifications provides a good base to find the suitable staff. The highly technical nature requires a blend of highly skilled artisans and suitably qualified engineers and automation specialists.

The challenge has always been to ensure that maintenance staff remains skilled and continually skilled to deal with the changing technology and best practices.

2.7.1 Development and Training

Training and development is a crucial factor in ensuring that maintenance is done effectively and efficiently. Training and Development is an HR issue that affects many industries and departments and is not just a maintenance issue. Maintenance training requires training both in OJT and class modules . Training is one the pillars of TPM and is mentioned consistently in the literature as a fundamental to any world class organisation.

2.7.2 Mentorships

The automotive industry requires artisan skills that are generally gained over time through on the job training. This skill is generally passed on to young apprentices with the use of journeymen, or skilled senior artisans. The availability or retention of skilled senior staff has always been an issue. In an industry reliant on skilled labour training program that produced new skills artisans in essential to see the organisation into the future.

Many industries unable to retain their skilled workforce and establish apprentice programs rely of third party training organisations to supply such labour. This solution is not always favoured unless the organisation creates training situations linked with the actual operations in the specific plant. It is best to create training for new members within the organisation. This helps to institute the organisation culture and values of the organisation.

2.7.3 Scheduled Training

People Development must be part of the key performance drivers of any department. This ensures that managers and personnel make consistent efforts to ensure that the required training is being done. Scheduled training programs must be developed according to a training framework. The training framework must be based on needs analysis performed on the department and requires frequent testing to remain relevant.

Scheduled training must be emphasised and not be passed over in response to other work pressures. Managers must ensure that the required training is followed. Training and development has an impact of moral and the effectiveness amongst

employees. Employees feel empowered and this translates to an effective workforce.

2.7.4 The important of health, safety and Environment

In any training regimen is it important to include aspects of Health and Safety and Environmental Management. In many organisations this is mandatory and part of the policy and procedures. The principles of TPM include 4S . This is an aspect relating to safety more than actual workplace tidiness. The two are however interrelated. 4S in a deeper concept that can be integrated in to every work aspect. In any piece of work employees must be trained to work in a logical manner that emphasised order and results in a safe process.

This behaviour translated into better employee moral and results in plant quality .

2.8 Total Quality Maintenance

World Class Organisation can leverage the various improvement models (JIT and TQM) to gain a competitive advantage against their competitors(Yang et al., 2010). Competition is ever increasing and it is important that every business unit within the organisation strives to achieve the strategic goals set out by the organisation. The factors that are generally recognised as priorities are : sustainability, flexibility, quality, customer delivery satisfaction and demand (Phusavat and Kanchana, 2008). Lollar et al. (2010) argued that the management processes must be in place for facilitation of these factors.

Maintenance is a crucial function to any organisation with a large amount of production assets which require continuous operation for maintaining product outflow (Eid, 2009). Maintenance was, in the past, seen as only a support sector but is now considered to be a strategic factor in a business due to its impact on performance through equipment operation (Ahuja and Khamba, 2008). In a competitive environment, the organisation must ensure a strategic vision for maintenance that focusses not only on equipment health but on customer satisfaction as well (Farinha et al., 2013). Models such as JIT and TQM are used to achieve the ideal goal of zero failure (Bartz et al., 2014). Clearly though every product or service will eventually fail, it is important to choose a maintenance policy that best suits the organisation (Reis et al., 2009). Cost effectiveness is a

criteria which must be considered carefully while selecting the appropriate maintenance strategy (Maletič et al., 2014).

Computer integrated manufacture (CIM) integrates all production systems and often excludes maintenance systems (Singh et al., 2016). Today's business environment requires the equipment to be constantly available while maintaining finance targets (Gulledge et al., 2010). Focus has been put on integrating maintenance systems with production and marketing to form a complete process management tool. It should include feedback systems for improving productivity, quality and reliability (Eid, 2009). A number of factors are required to control the tolerances and the quality of manufactured items which are illustrated in Figure 3.

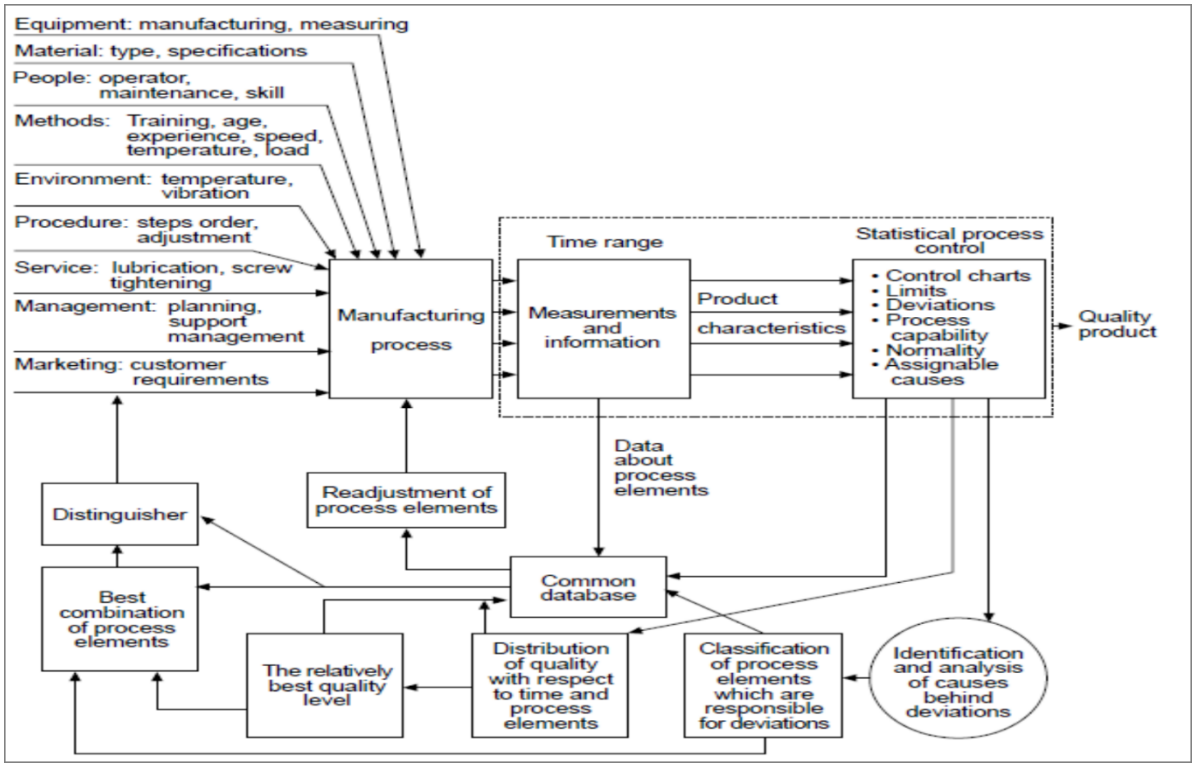

Figure 3 : Total Quality Maintenance. Adapted from (Maletič et al., 2014)

The figure above contains the basic elements of a manufacturing process and can be summarised as: the manufacturing equipment, policies for monitoring the plant and maintenance, employees and the environment, standards for production, quality tolerances, raw material, store inventory levels, purchasing agreements, and feedback for marketing.

Figure 3 shows that the condition of the production process is governed by the status of each element (Maletič et al., 2014). A process where the equipment has

degenerated will more than likely produce goods of lower quality shortly before stoppages and after repairs. It is also unlikely that the process will operate with a high overall equipment effectiveness (OEE). Manufacturing downtime due to mechanical or facility breakdowns causes production losses to accommodate for rejected products that have failed the quality standards (Al-Najjar and Alsyouf, 2000). Continuous improvement can only be ensured by measurement (Rajiv Kumar et al., 2006). The analysis of variables is necessary for evaluating the impact of TPM activities. Overall equipment effectiveness(OEE) provides a means to measure the variables of a TPM system to judge the effectiveness of the system (Piechnicki et al., 2015):

$$\boldsymbol{OEE = availability \times performance\ efficiency \times quality\ rate}$$

OEE interrogates the machine or integrated system values. Availability is made up of equipment losses, which comprises of losses from breakdowns, set-up, reduced production speeds and start-up. The measure of the effectiveness of the system by processing the total losses is established through OEE value (Singh et al., 2016) .

The disintegration of equipment can be caused by the external causes, for e.g. misuse, high environment vibration, bad servicing or temperature levels. In order to minimise these conditions, these parameter should be monitored and controlled. Most facilities are prone to failure the reason being the maintenance which is usually performed after hours or holidays as this after hour maintenance increases the cost of a PM. This however may still be cheaper than a failure during production hours. In most of the plants, the problem is further exacerbated by the fact that the facility is in operation for more than one shift and even during holidays. The implementation of a TPM system has been noted to reduce failures, but not to zero (Bartz et al., 2014).

2.9 Conclusion

Total Productive Maintenance and Total Quality Maintenance are terms that are used interchangeably but as per literature, they are considered to be separate approaches. TQM is primarily focussed on the quality of goods while TPM focusses of the equipment used in production. TPM associates with TQM by ensuring quality goods by maintaining the quality of the equipment as the breakdown of equipment can cause defective product quality.

Traditional Maintenance strategies namely corrective maintenance have been replaced with data driven strategies that use IT systems linking production, quality and to some extent the market demand. This enables a flexible and reliable maintenance management system that is aligned with the organisation's objectives. Maintenance performance indicators, which are also linked to organisational goals assist to measure and improve the maintenance systems. OEE gives the measure of TPM.

Regardless of the maintenance strategy, using TPM is a fundamental necessity for every organisation aiming to be globally competitive. TPM implementation requires senior management support to drive a mind-set to accept change to improve and create better work processes (Bartz et al., 2014). Implementation is a process which does not show immediate results and requires constant effort on part of all the members within the organisation. Integrated systems are necessary to form a comprehensive database to help in taking maintenance decisions. Planning is a fundamental activity and is vital for any strategy to succeed. The focus of TPM is on work teams, education and training, and it requires competent leaders and managers. Staff must be motivated in order to sustain an environment of continuous improvement.

3 Chapter Three: Research Methodology

3.1 Introduction

This chapter focuses on the methodology of the business research conducted in evaluating the Preventative Maintenance system of an automotive weld plant. The aims and objectives of the research are discussed, and a detailed strategy is explained systematically that gathers the information required to answer the research questions posed thereof. The research methods focus on the research design, locality of the participants, population and sample size, construction of the survey and instrument and its reliability. The researcher discusses these aspects in this chapter and its impact on shaping the process of creating an instrument for gathering the required data.

3.1.1 Aim and Objectives

Efficient Manufacturing relies on equipment and facilities to be online and functional during scheduled production runs. Equipment failures result in downtime which impacts the efficiencies and the cost effectiveness of the operations.

Preventative Maintenance (PM) systems are a part of world-class manufacturing concepts and suggest a set of planned maintenance procedures to keep equipment functional and minimize the occurrence of breakdowns during production intervals. Preventative Maintenance also influences product quality and overtime costs. It is an integral part of any Manufacturing plant for ensuring consistency of output.

The problem under study is the occurrence of breakdowns in a Weld Manufacturing Plant in the presence of an existing Preventative Maintenance system. This study aims to evaluate the current system and identify, in line with industry, the best practices for the improvements necessary to minimize the unscheduled facility stoppages.

The main objectives of the study are:

- Determining whether the required resources are available for implementing the system.

- Establishing the level of skill of maintenance personnel.
- To understand whether or not the necessary information technology is in place to facilitate the system.
- Evaluate the current Preventative Maintenance system.
- To understand if the planning and scheduling activities are in line with the PM system.

3.1.2 Participants and Location of Study

Sekaran and Bougie (2012) define the term population as a group of people, events, or things of interest that the researcher wishes to investigate. They further explain that the target population is defined on the basis of three criteria, the elements, the geographic location and the time. The target population for this study comprised of 73 employees from among Engineers and Maintenance personnel from a Weld Automotive Plant. The automotive plant is located in KZN and is a division of a major automotive company. The company manufactures a range of vehicles from sedans to trucks. The company consists of a number of divisions (Press, Weld, Paint and Assembly) with each its own Maintenance division.

3.1.3 Research Design

In developing the research study, it is important to understand the purpose of the study and the type of study that is necessary. The purpose of a study can be either exploratory, descriptive or setup to test hypotheses (Sekaran and Bougie, 2012). An exploratory study is undertaken when the field of research is new and not much is known about the situation. This type of study favours a qualitative approach in the form of interviews for gaining a comprehensive understanding of the problem in hand. Hypothesis testing is used for explaining the relationships amongst groups or variables. It can make use of either qualitative or quantitative data. A descriptive study has variables that the researcher will describe in context to a particular situation. Sekaran and Bougie (2012) state that a descriptive study should be undertaken when the researcher requires a deeper understanding of a variable in a known situation. The goal is to offer a profile of relevant aspects of a

situation of interest. Descriptive studies therefore use quantitative data in terms of frequencies, standard deviations and means.

In this study, the purpose of the study is descriptive in nature. The characteristics of a PM system are known, but in the organisation under study, a deeper analysis is required for understanding which aspects are non-functional or are performing poorly.

A study can be either causal or correlational. In a causal study, a researcher wants to determine a cause and effect relationship between the two variables. Causal studies generally involve a high degree of researcher interference in the normal flow of work. Researchers often setup experiments for causal types of investigations for establishing variable relationships. These experiments are normally in a contrived study setting. Correlational study types occur in non-contrived situations and are called to be the field studies. This study type aims to cause minimum interruption to the normal work process. Correlational studies are undertaken when the researcher needs to understand the factors influencing a particular problem.

This particular study is correlational; the performance of the PM system under evaluation is impacted by many factors of interest. The study was undertaken in a field study and there was no requirement to alter the behaviour patterns of the respondents.

Unit of analysis refers to the level of accumulation of the data collected during the subsequent data analysis stage (Sekaran and Bougie, 2012). In this study, we are accumulating data about the system from the individuals. The time horizon of this particular study is known as a one-shot. The study was conducted once over a period of weeks.

3.1.4 Research Approach

The method of data collection is important as it affects the information gathered from the data. There are two data collection strategies discussed by Sekaran and Bougie (2012) which are Quantitative and Qualitative methods. The choice of methodology develops the questions posed and the design of the data collections

instruments. It is then important to understand the difference between the two and select the most appropriate for the study.

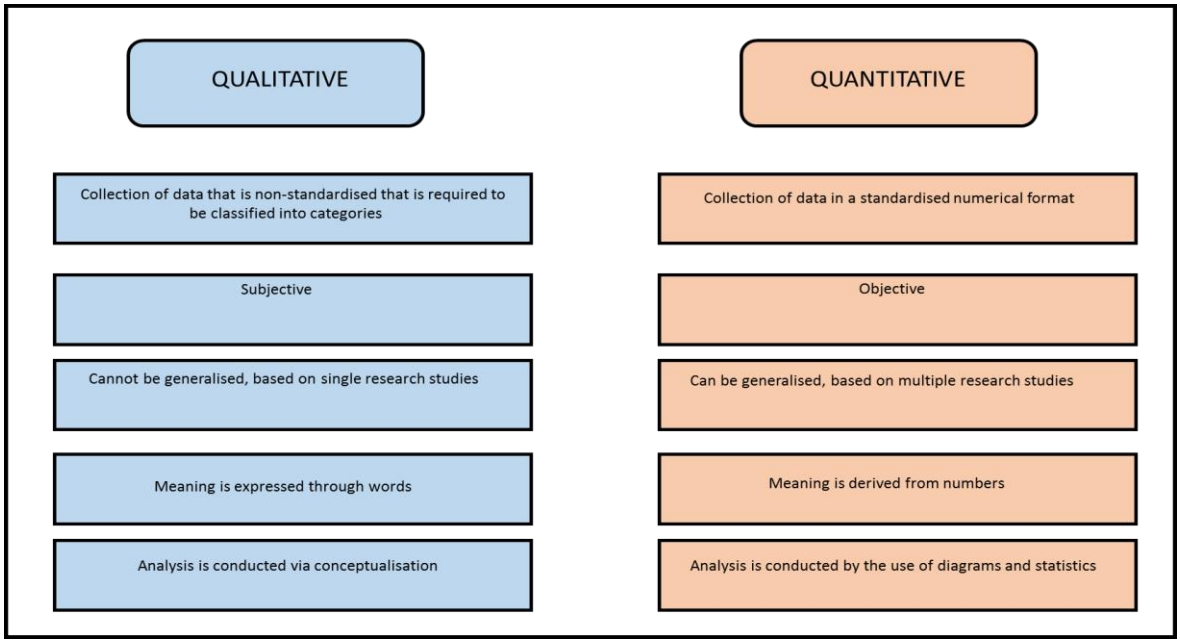

Figure 4 : Differences between qualitative and quantitative methods. Adapted from (Sekaran and Bougie, 2012)

The differences between qualitative and quantitative methods can be visualised in Figure 4. Quantitative methods are objective, and rely on controlled observations during the data collection activity, and are generalizable. Qualitative methods rely on uncontrolled observations, are subjective, and are non-generalizable (Sekaran and Bougie, 2012).

The study conducted utilised quantitative analysis and primary data was obtained via a survey questionnaire from the target employees of the automotive weld plant under study. The advantages of a questionnaire are that they are easier to manage, confidentiality of the respondent is easier to maintain and the cost is lower as compared to the use of electronic media.

3.2 Sample Size

The target population for this study comprised of 73 employees among which 21 were Engineers and 52 were Maintenance personnel from a Weld Automotive Plant. The sample size calculated was 61 (Research, 2014). This is based on simple random sampling techniques.

3.2.1 Sampling

In a study where there are large population sizes, it becomes impractical and costly to survey. Sampling is a technique of selecting a suitable representation of the population for determining the characteristics of the entire population. This technique allows inferences to be drawn from the sample for the entire population (Sekaran and Bougie, 2012). For selecting a sample from the target population of 73 employees, the study made use of simple random sampling.

3.2.1.1 Description of the population

The study focussed on engineers and maintenance personnel at an automotive weld plant and focusses primarily on salaried employees at the organisational level that would have the most relevant input in terms of the maintenance system at the plant.

3.2.1.2 The sampling design

The choice of which sampling design to use depends up on the generalizability required. There are two major types of sampling designs: probability and non-probability sampling (Sekaran and Bougie, 2012). The elements in a non-probability sampling design do not hold a known or predetermined chance of selection as subjects. Probability sampling on the opposite is when elements have a known or predetermined chance of being selected as subjects (Sekaran and Bougie, 2012). Probability sampling designs are chosen when it is important that the sample represents the population closely, essentially having greater generalisability. In certain studies there are other factors such as time that are of greater importance than generalisability, in those instances a non-probability sampling design is appropriate.

The study undertaken necessitated that the sample be representative of the sample with good generalisability. The elements of the population have a known chance of being chosen as subjects in the sample. The sampling design then calls for a form of probability sampling.

3.2.2 Sampling Methods

A probability sampling design can either be unrestricted (simpler random sampling) or restricted (complex probability sampling) in nature (Sekaran and Bougie, 2012). Complex probability sampling or a restricted sampling further expands to the following sampling designs: systematic sampling, stratified random sampling, cluster sampling, area sampling, and double sampling. The types of sampling are discussed below to provide reasoning for the design selected for the study.

Simple random sampling – All elements in the population have a known and equal chance of selection. There exists the least bias and the best generalizability

Systematic Sampling- This method involves elements to be drawn from the population starting with a randomly chosen element between one and n. The element drawn is then every nth element. Requires a sample frame and can allow systematic bias.

Stratified Random Sampling – This particular sampling method is appropriate for studies where the population is required to be grouped. The grouping is made indispensable by requisites of the study for improving the meaning of the data. The sample is then selected on the basis of proportionate or disproportionate random sampling. Proportionate sampling selects members from each group proportionate to the total population. Disproportionate random sampling is used when situations demand specific information from groups that require sample redistributions not based on the original population numbers. This method of sampling produces better representation of data than the previously discussed methods. This is due to the segmentation or stratification of the population into meaningful groups. It is, however, more time consuming and needs a sample frame.

Cluster Sampling – This method as the name suggests involves segmenting the population into clusters. A random sample of clusters are then drawn and then either all the elements from the selected clusters are included or only a sample of elements. This method provides greater heterogeneity within groups and homogeneity among groups. This method has the greatest bias, as the groups can be more heterogeneous than being more homogeneous.

Area Sampling – A form of cluster sampling that is dependent on a sampling frame called an area.

Double Sampling – This method is used when a secondary sample is required from a study where information has already been obtained. It provides further information about the study.

The study conducted made use of simple random sampling techniques to sample the target population as all the elements in the population had a known and equal chance of selection.

3.3 Data Collection

There are some primary data collection techniques. These are interviews (telephone, face to face, video conferencing, face time), questionnaires and observation (Thomas, 2011). This study employed the questionnaire survey as a means of collecting the primary data. This method was chosen due to its efficient speed, cost and benefit of anonymity to the subject. The questionnaire was created by using QuestionPro. The responses were collected on the hard copy of questionnaire as some respondents did not have full computer access.

3.3.1 Data Collection Tool

The questionnaire (Appendix A2) was created by using guidelines that were suggested by Leedy and Ormrod (2014). The following criteria was used: simple short questions, no ambiguity, clear language, avoiding questions that led to a response, clear instructions, minimal open ended questions, checks for consistency and rationale for any item the purpose of which may be unclear.

3.3.2 Survey Tool Construction

The questionnaire was created keeping objectives in mind to ensure that the relevant data was sourced to ensure the purpose of the study was achieved. The questionnaire was divided into five sections:

Question A 1 – 4:

Demographic Data. This was used to identify the employee demographics, the level of management, department and educational background.

Question O1: 1–7:

These questions examined the availability of resources for implementing the maintenance system.

Question O2: 8-12:

These questions examined the skills of the employees relative to the implementation of maintenance system.

Question O3: 13-21:

These questions examined the state of the information technology systems present and whether they were cable of managing the maintenance system.

Question O4: 22-33:

These questions examined the present Preventative Maintenance system.

Question O5: 34-44:

These questions examined the extent of planning with regards to the maintenance system.

The question was based on closed-ended questions in the form of multiple choice questions and questions using the Likert's scale. The multiple-choice questions were used to obtain demographic data at organisation level and provided nominal scale data, which can be used to create groups if there be need.

A Likert's scale is a non-comparative scaling technique (Leedy and Ormrod, 2014). Individuals are given a number of statements that are in relation to a similar subject. The respondent on a five-point range can then indicate the level of agreement or disagreement. The scale consists of the following five categories:

1 = Strongly Disagree

2 = Disagree

3 = Unsure

4 = Agree

5 = Strongly Agree

3.3.3 Reliability and Validity

The concept of validity in designing a research tool looks at the accuracy of the tool in measuring the conditions or concept we had initially set out for measuring (Sekaran and Bougie, 2012). For testing this, there are a number of validity tests available: content validity, face validity, criterion-related validity and construct validity. Content Validity is achieved by ensuring that there are enough scale items that represent all the dimensions of a particular concept (Thomas, 2011). Face validity examines whether items actually measure what they indicate they should measure. Criterion validity is achieved by using a criterion variable which is predicted by a measure that differentiates correctly (Thomas, 2011). Construct validity established if the measurement tool was able to test the concepts as the theory suggested.

Reliability refers to a measure that is stable and consistent. It is an identification of the degree to which the measure is error free (without bias). A stable measure remains the same over time despite uncontrolled testing conditions. A consistent measure offers homogeneity of the items in the measure and helps assess the goodness of the measure.

Pretesting was employed for ensuring that the survey results have credibility. Pretesting is a method that betters off the reliability and validity of a study. Pretesting allows the tool to be tested on a small batch of respondents to address any problems before it is sent out to the actual respondents. Problems such as language, interpretation, wording and sequencing can be addressed before the tool is actually administered.

3.3.4 Time frame

The current study is cross-sectional or a one-shot study. This indicates that the study was administered just once (Ruane, 2016). Longitudinal studies are undertaken at various time intervals depending on the need of the researcher. In this study, the questionnaires were administered from mid-April 2015 to the end of

June 2015. The feedback in terms of completed questionnaires was slow and at times lead to additional reminders.

3.3.5 Pre-Testing and Pilot

A pilot study ensures that the research tool (in this case, questionnaire) is tested before being distributed to all the respondents. The feedback from a pilot study helps in checking for errors and issues pertaining to the relevancy of the questions, completion time and appearance of the questionnaire. This ensures the validity and reliability of the research tool. Five managers were selected from engineering and maintenance departments for the pilot study and the following comments where noted and corrected:

- The respondents found certain terminology inconsistent with the ones used in the plant .Explanations were added to the questionnaire.
- Errors in grammar were found and corrected.
- The completion time of fifteen minutes was adequate for survey.
- The respondents found that the questions were related to the objectives presented in the study.

3.3.6 Administration of the Questionnaire

The research tool once created and checked was setup on the online research tool QuestionPro. It was possible to email the survey link to the respondents but a large number of respondents were unable to access the link due to the lack of internet access. Copies of the questionnaires were then emailed along with the consent letter (Appendix A1). In certain instances, the questionnaires were printed and manually administered. Once the questionnaires had been collected, the responses were recorded onto QuestionPro.

3.3.7 Ethical Issues and Considerations

The researcher has responsibilities concerning data collection and the management of confidential data. Prior to proceeding with the data gathering, it is essential that the necessary permissions are sought out. Authorization to conduct the research at the organisation was requested and granted. It was requested that

the organisation remains anonymous. Ethical clearance was requested from the University of KwaZulu-Natal Humanities and Social Sciences Research Ethics Committee on the 25th March 2014 (Protocol Reference Number: HSS/0130/013M) (Appendix A3). It is unethical to conduct research without the participant's knowledge or consent. A letter of consent was drafted and distributed with every questionnaire. The letter of consent contained information regarding the purpose of the study along with the contact details of the researcher. The letter also clearly explained that participation was voluntary and the participant had the right to terminate the process at any stage.

3.3.8 Data Analysis

The captured data was entered into QuestionPro, which coded the responses and allowed statistical inferences to be made. Graphical frequency analysis of the data was conducted.

3.3.9 Summary

This chapter discussed the theory of research methodology and the application to the study parameters. The aim, objectives, sampling design, research tool design were discussed. The differences between qualitative and quantitative methods were discussed. The structure of the research tool was discussed along with the validity and reliability tests. The data collection methods were then discussed along with the most suitable method for the study. Pre-testing and pilot studies were discussed. The findings were discussed. The next chapter presents the discussion on the results of the current study.

4 Chapter 4: Results and Discussion

4.1 Introduction

This chapter is a presentation of the primary data that was collected from the employees from an automotive weld plant. The findings are summarised and further discussed. The data is represented though graphs and tables. The first section explores and portrays the demographics of the employee profile. The second part represents the relation of findings with each of the five objectives. In the conclusion, the overall findings are reflected.

4.2 Description of the sample

The total population comprised of 73 employees at the Weld plant. This can be broken down into 21 Engineers and 52 Maintenance staff. Fifty nine respondents completed the survey and the responses. The sample made use of a confidence interval of 95% and a margin of error of 5%.

4.2.1 Demographics

Section A of the study questioned the employees on their demographic characteristics. The demographic information provides an understanding of the attributes and environment in which the sample was taken. The questions have been summarised below:

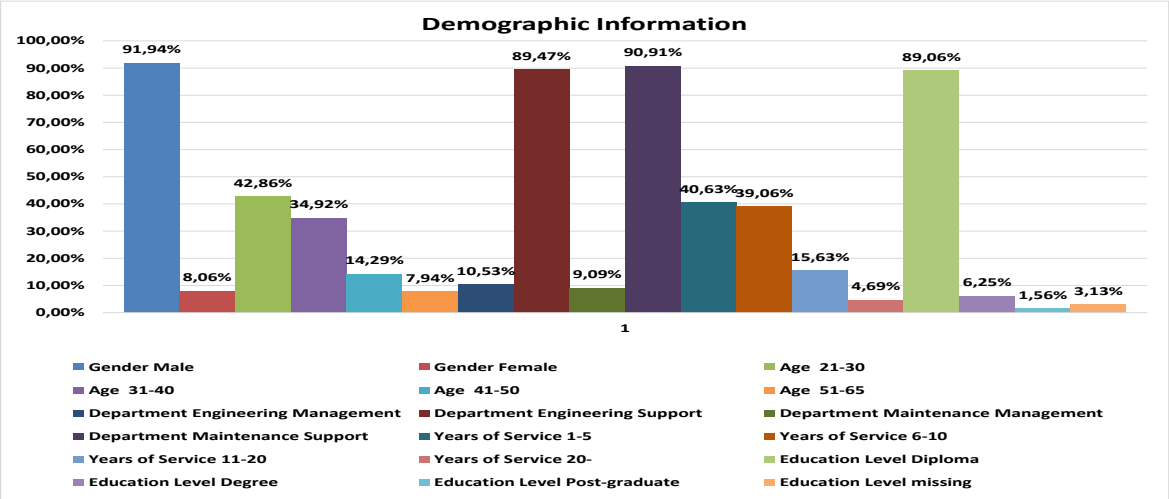

Figure 5 : Overall demographic information of respondents

The graph in represents the entire response regarding the demographic data obtained. The information is further broken down in the subsequent sections for analysis and discussion.

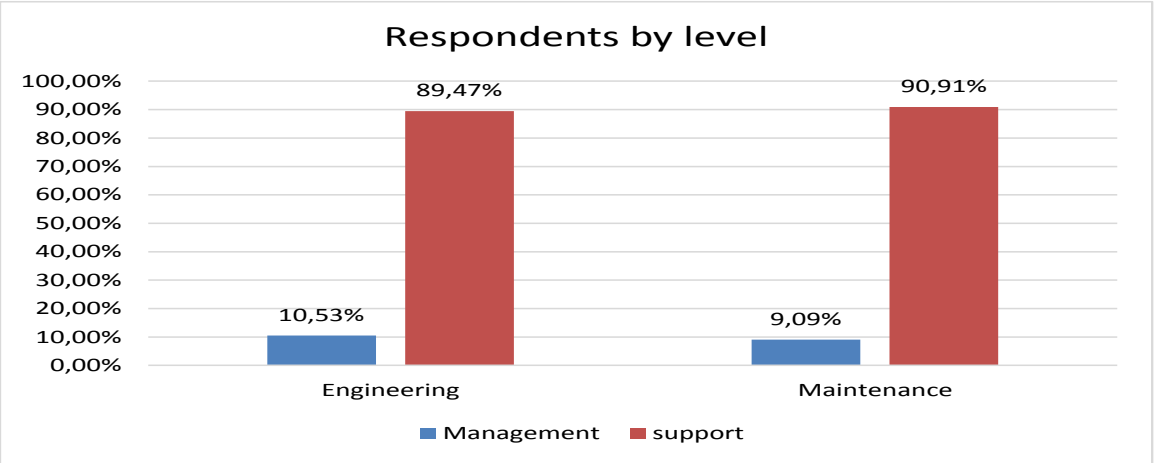

Figure 6 : responses by organisational structure

The above graph represents the respondents by department and support level.

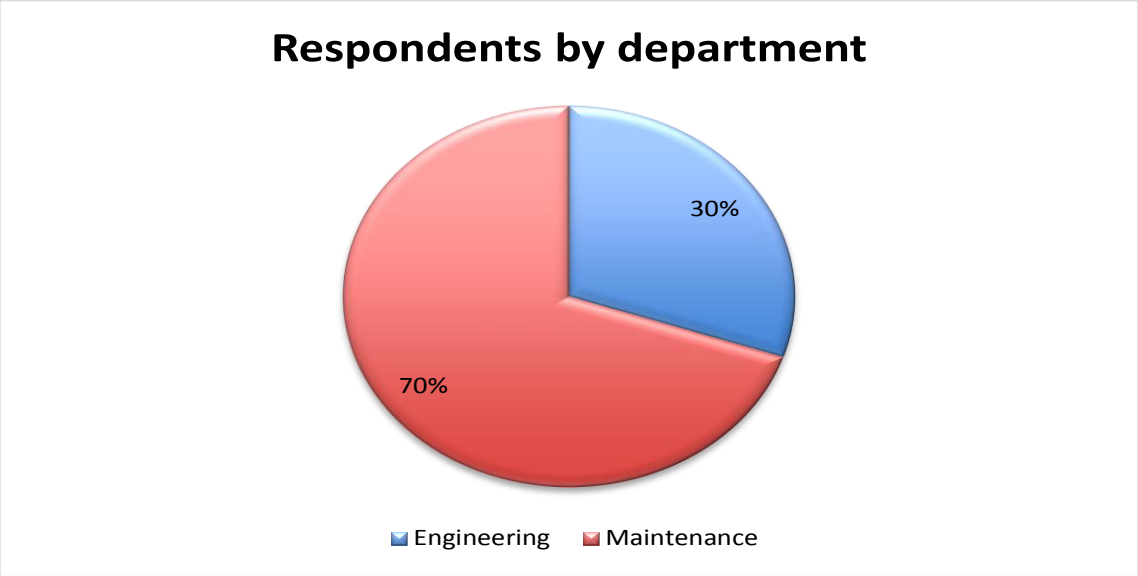

Figure 7 : Respondents by department

Seventy percent (70%) of the respondents were from the maintenance departments and the remainder were from the engineering sector. Ninety percent of the Maintenance respondents were support staff and the other 11% were at some designated management level. Engineering respondents were roughly around the same percentage.

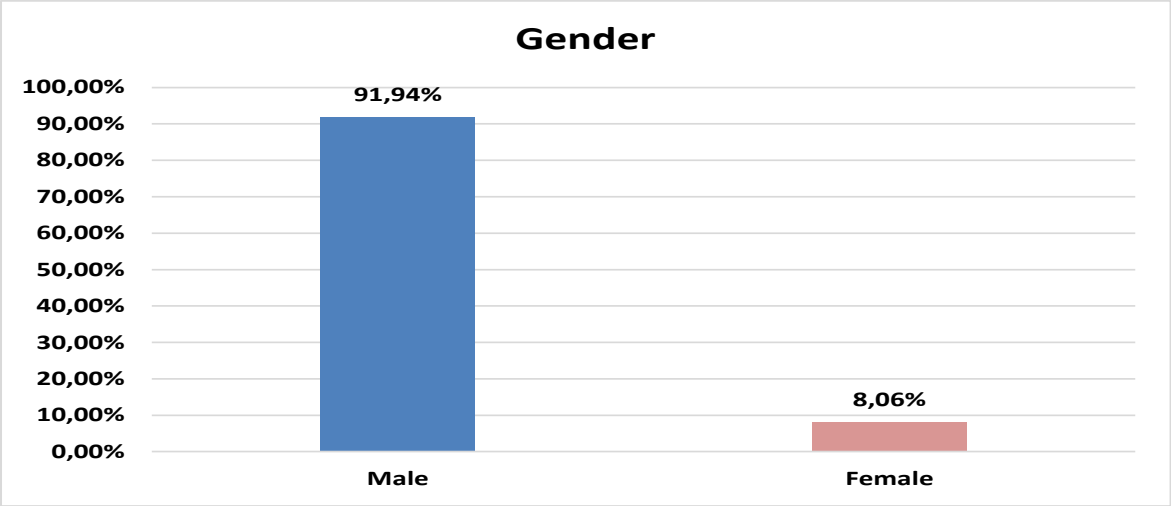

Figure 8 : Gender Demographic

It is evident from that there is a significant disparity between male and female respondents with 92% being male and only 8% female. This information has no specific impact on research questions but may prove useful for further studies were gender roles in a technical field are relevant. The study focusses on the evaluation of the Preventative Maintenance system. The findings relating to years of service and education level might be the most valuable in understanding some aspects of the workforce skill.

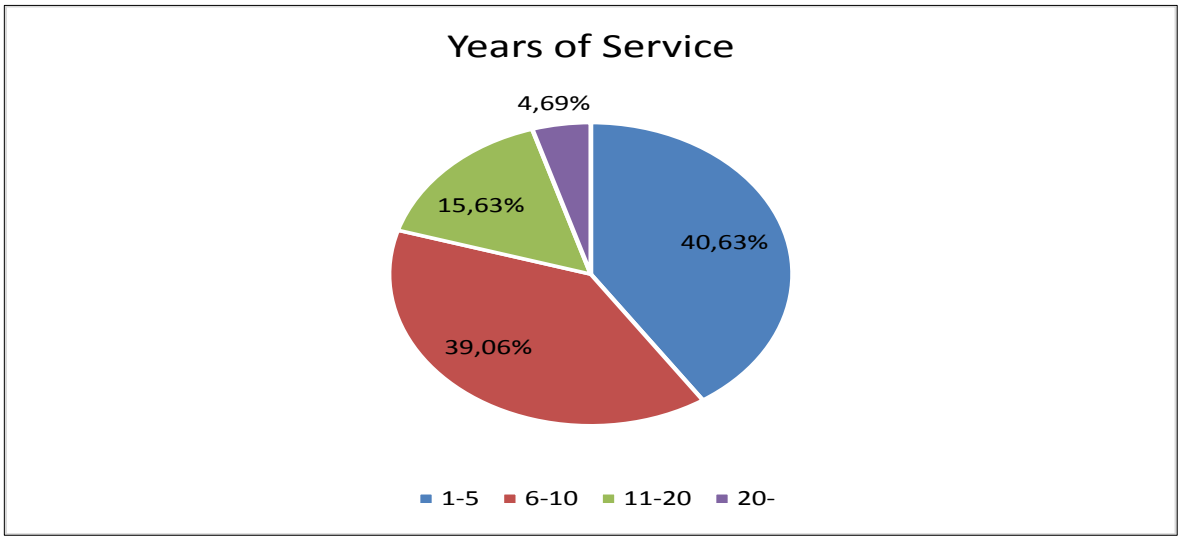

Figure 9 : Years of Service

The majority of the employees were aged between 21 and 40 years of age, with 21 to 30 comprising of 43% and 31 to 40 comprising of 35%. 8% of the population was between 51 and 65 years of age represents the findings concerned with the years of service, where 79% of respondents have less than 10 years of

experience. Forty one percent (41%) of those have less than 5 years of experience.

This may be an indication of loss of expertise in the industry. However, provided the organisation have strong training and mentorship programs, this can be mitigated (Singh et al., 2016). The automotive industry , as discussed in chapter 2, relies heavily of skilled artisans. The plant in particular relies on steel fabrication and design skills. The maintenance and repair of jigs and fixtures are generally skills picked up through years of experience. The loss of experienced staff has an impact of the development of younger employees as knowledge is passed on.

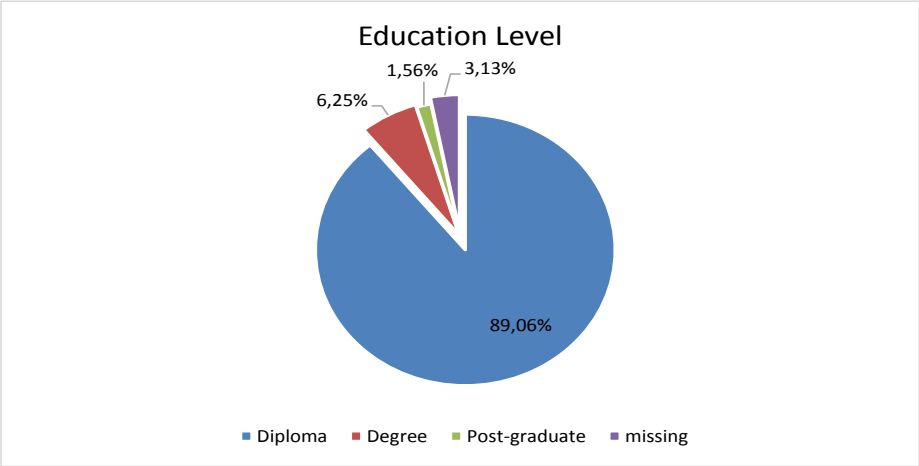

Figure 10 : Educational Qualification of Respondents

The education levels indicate that 89% of respondents have a diploma, 6 % a degree, 1.5% a postgraduate qualification and 3% gave no response to the question. The findings indicate that majority of the respondents have above matric qualification. This is not unusual as all respondents are from either engineering or maintenance background. Generally, a qualification relating to the field of work is a requirement for employees. Employees with years of service may not necessarily require this. The 3% non-participation does not necessarily indicate that those members do not possess any qualification, but some other reasons might be responsible for the lack of response.

A large number of respondents have at minimum a diploma and this emphasises that the workforce is well educated. This together with the ‘on the job training’ and ‘skills reinforcement’ indicate that the skill level of maintenance personnel is sufficient to manage the current PM system. Nakajima (1988) and later Maletič et

al. (2014) highlight that main component of TPM is a skilled workforce and training through cross functional teams and improvements. This process of worker development encourages further learning and development of problem solving techniques.

4.2.2 Objective of the study

The questions used in the research tool where linked to each of the objectives to gather the relevant information and answer the research questions. The summary below shows the relationship between the Objectives and the questions:

Table 1 : Questions per Objective

#	Objective	Questions
1	Determine if the required resources are available to implement the system.	1-7
2	Establish the skill level of maintenance personnel.	8-12
3	To understand if the necessary information technology is in place to facilitate the system.	13-21
4	Evaluate the current PM system.	22-33
5	To understand if the planning and scheduling activities are in line with PM system.	34-44

4.2.2.1 Objective 1: Determine if the required resources are available to implement the system.

Questions 1–7: These questions examined the availability of resources to implement the maintenance system. Respondents were asked seven questions to ascertain if the necessary resources were present to implement the maintenance system. The questions revolved around staffing, organisational structure, motivation, support by other teams and management support to assist in accomplishing objectives.

Table 2 : Questions relating to Objective 1

No:	Question
1	Do you feel maintenance is staffed to do its job ?
2	Does the overall structure of the maintenance organisation seem to be logical
3	Does the organisation help to remove barriers maintenance encounter in their jobs that are beyond their control, which prevents them from doing a good job?
4	Does management encourage maintenance to meet the needs of production?
5	Does management encourage production to help maintenance in doing its job?
6	Are cross-functional (production and maintenance) teams used to identify and resolve issues that affect both departments?
7	Does management encourage maintenance and production operators to work together on issues?

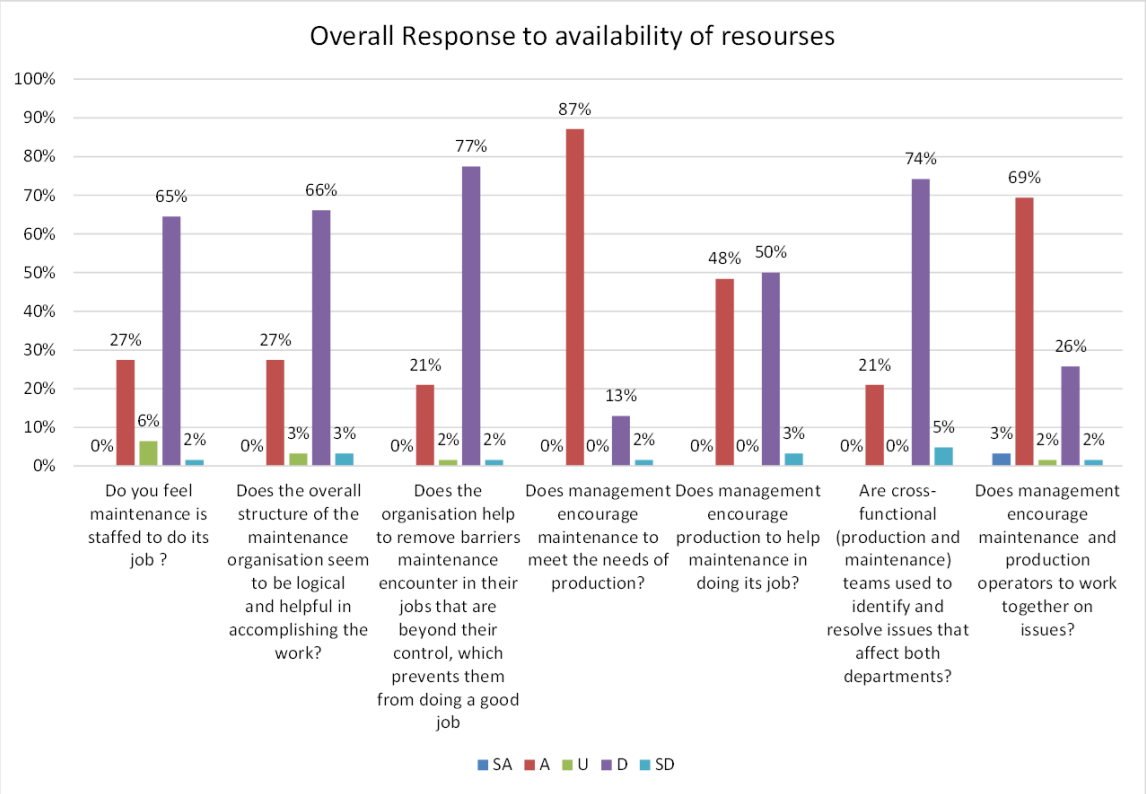

Figure 11 : Availability of resources to implement the PM system.

The responses indicate that the majority of the respondents disagree in each of the questions posed. Responses from questions one, two and three correlate. Question 3 which looks at the support from management shows a stronger majority in disagreement. This may indicate that the organisation structure and staffing are those factors that relate to the struggles while implementing the PM system.

Question 4 and 7 do not follow the trend with a majority of the respondents agreeing that the management encourages maintenance to support production issues and team work between departments. These questions refer to the instruction on firstly, meeting the needs of production and secondly, working together as a team. It is clear that the emphasis on teamwork is present, however, the response in question 6 indicates that it is poorly perceived.

Question 5 posed the question on management's direction on production support to maintenance. Fifty two percent of the respondents disagreed. This together with the previous responses indicates that the support from a production perspective is lacking.

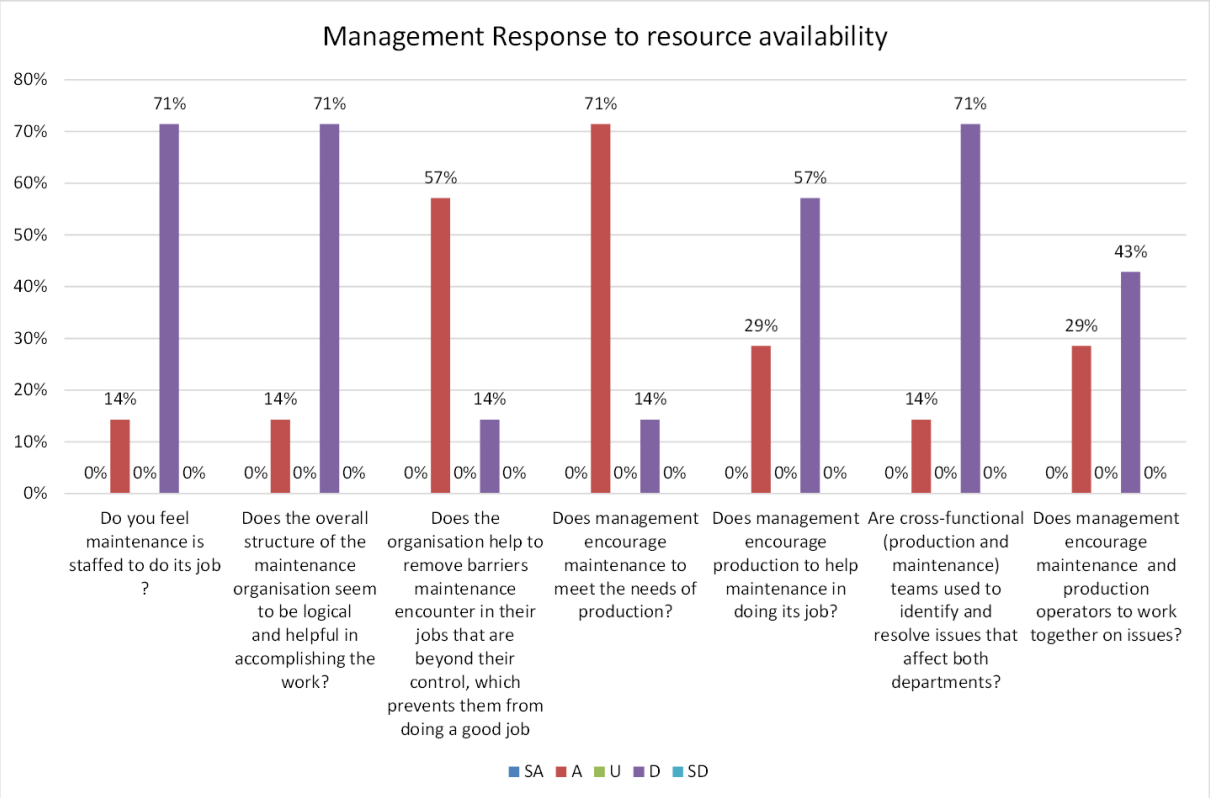

Figure 12 : Response of Management regarding resource availability

shows an extraction of the responses from the management. The responses correlate with that of the overall response except for questions three and seven. Question 3 which shows a strong disagreement in , is based on the above representation of the view held by the support staff. Management show strong agreement, which indicates that senior management, is providing the necessary

support. This means a problem exists between the support staff and their direct management.

The result gathered from the response of question 7 agrees that from a support level production and maintenance are encouraged to work together. The disparity from the management result indicates a disharmony at the management level, with regards to the organisational objectives. This lends to the majority feeling that the required resources are not available.

The literature review discusses resources as the support provided by management and production (Marquez et al., 2009). Parida et al. (2015) discuss the role of management in ensuring that the resources are used effectively to achieve the performance targets. It is essential that the direct management are supportive and motivating towards the implementation of the PM activities.

Preventative Maintenance relies on the move away from reactive maintenance and towards corrective maintenance. Emergency Maintenance situations must not detract from preventative maintenance tasks. This is a cyclical problem tha if indulged can lead to PM failure. Proficient leaders and managers must be created to empower the people under them. The strong development of people is crucial to TPM implementation, as was emphasised in a study by (Jain et al., 2014).

Development occurs through the involvement of employees in cross functional teams for problem solving(Maletič et al., 2014). Sharma et al. (2006) emphasised that a successful PM strategy involves a team based approach encompassing multiple disciplines. This ensures that all resources are available to implement preventative maintenance.

Resources in terms of labour must be structured accordingly to cater for Planned maintenance and emergency maintenance. Ideally a successful PM system will have minimal unplanned stoppages but still requires a dedicated team.

World class companies achieve competiveness by ensuring that the organisational structures are aligned to achieve the strategic objectives(Brown et al., 2007). Lazim and Ramayah (2010) suggests three basic steps in developing a maintenance strategy that suits the organisation: Formulate a plan of what needs

to be done for each component, acquire the resources (human and material) and finally the implementation. It is then important for any maintenance strategy that the organisational structure and staff be available to support such a strategy.

The disparity between support staff and management, the lack of overall production support and the lack of cross functional teams indicate that the current PM system is lacking the resources as defined in the outlined theory regarding a model of an ideal PM system.

4.2.2.2 Objective 2: Establish the skill level of maintenance personnel to the implementation of the Preventative Maintenance system.

Question O2: 8-12: These questions examined the skills of the employees relative to the implementation of the maintenance system. Respondents are asked about training, current workforce skills, motivation and safety adherence. Figures 13 to 17 represent the responses received.

Table 3 : Objective 2 questions

No:	Question
1	Have Maintenance personnel received training to help them do their jobs?
2	Are maintenance in your plant properly skilled to do their jobs?
3	Are maintenance in your plant properly motivated to do the best possible job?
4	Do maintenance follow safety policies and procedures?
5	Does management follow-up and review housekeeping with maintenance?

Table 3 above represents the questions posed to respondents aimed at answering objective 2.

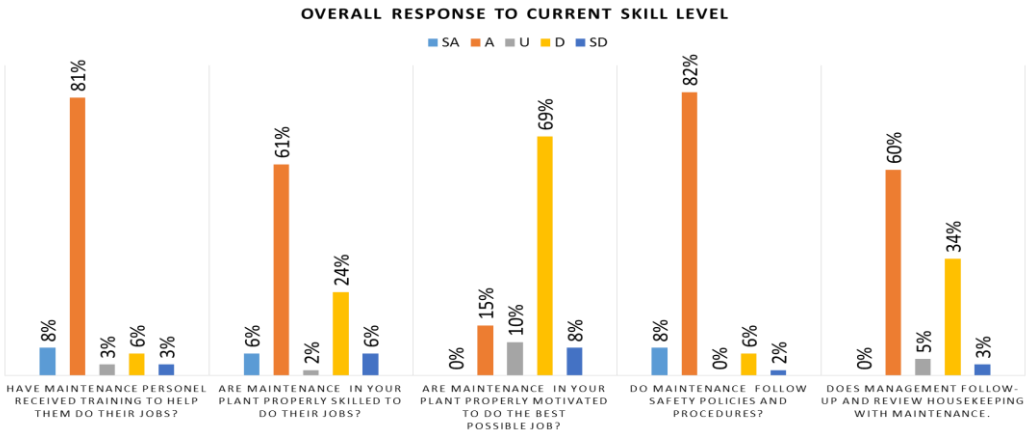

Figure 13 : Overall response regarding the current skill level.

A majority of the respondents agree that personnel receive the training to accomplish their work and that they are properly skilled. Bartz et al. (2014) have shown in their research on TPM implementation, that training and skill development is essential in any TPM. Investment in people is important and proficient leaders and management must be created.

In chapter 2 training and development is highlighted as a critical feature of any PM system. Scheduled training linked to performance management ensures that training is followed by employees and managers are tracked on that metric. Training often is neglected in cases of high reactive maintenance where repairs take priority. Managers must ensure training is followed. Motivation and moral has been shown to improve in employees that follow training programmes.

Question 3 asked respondents if they were properly motivated. A strong percentage was in disagreement. Motivation is acquired when employees use their personality to fulfil a mission that is meaningful to themselves. This results in Work Related happiness. This is something that should be noted by management as motivation is a predictor to performance (Michael, 2013).

The results indicates the educational level together with , represents the skill level, and provides strong data to indicate that the skills levels to implement the PM system are adequate.

4.2.2.3 Objective 3: To understand if the necessary information technology is place to facilitate the system.

Question O3: 13-21: These questions examine the state of the information technology. The questions posed to the respondents form an image regarding the use of maintenance related information in the plant. The processing of data and the use of the data to manage the Preventative Maintenance activities.

Table 4 : List of questions relating to objective 3

No:	Questions
1	Do you make use of a computerised system for maintenance activities (CMMS) ?
2	Is every piece of equipment tagged with an equipment or asset number ?
3	Does your organisation update its computerised maintenance system ?
4	Have maintenance members been trained to use the computerised maintenance system ?
5	Does Weldshop maintain accurate history records on equipment ?
6	Are the maintenance stores computerised ?
7	Does WeldShop track its total maintenance expenditures and costs ?
8	Are the management decisions made from the CMMS reports ?
9	Is the time maintenance personnel spend on TPMs or jobs tracked and recorded ?

The table above represents the questions relating to objective 3.

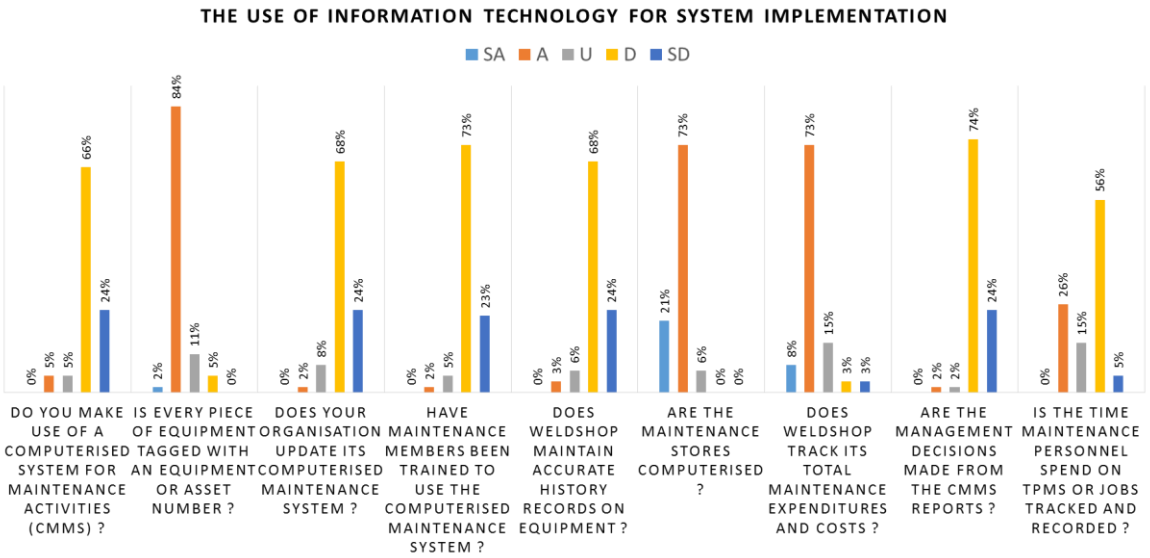

Figure 14 : Response regarding the use of information technology to implement preventative maintenance.

The results from question one, three, four, five and eight show strong correlation and indicate that there is no computerised system for tracking the maintenance activities. Questions 8 and 9 indicate that no decisions are made from the tracking

of maintenance problems. A strong majority also shows that the TPM activities are not recorded.

Question two, six and seven, which deal with asset tracking, spare component tracking and expenditure tracking, show that there is a system in place. The tracking of assets and spares are not just a component of a maintenance system but also of financial due diligence.

The literature discussed various maintenance strategies and based on the description by Moubray (2000) the current PM system follows that of corrective maintenance. Corrective Maintenance is a strategy that is currently not competitive, and extremely costly based on the high level of investment that automation represents (Singh et al., 2016). Reactive and correct maintenance should only be employed in cases where the Preventative Maintenance becomes costly (Bartz et al., 2014). Jain et al. (2014) described corrective maintenance as a means to restore basic functionality of equipment that had suffered failures. This is also referred to as *reactive maintenance*. The organisation, however, maintains a Preventative Maintenance system and should not be practicing reactive maintenance. A fundamental attribute to a PM system is the measurement, storage and analysis of data. Continuous improvement can only be verified by measurement (Rajiv Kumar et al., 2006). The measure of the impact of TPM on the variables must be analysed. Overall equipment effectiveness(OEE) provides a means to measure the variables of a TPM system to judge the effectiveness of the system (Piechnicki et al., 2015).

A system should be in place similar to the one presented by Maletič et al. (2014) in Figure 3. This represents the manufacturing process which is interlinked by a common database. This CMMS system must gather production , quality and maintenance information and generate updated work orders. Marquez et al. (2009) eluded to a model on PM (Figure 2) that is made up of a number of components. The lack of a CMMS system and historical records results in no continuous improvement, which is the final phase indicated in the model. Computer integrated manufacture (CIM) integrates production systems and neglects maintenance information systems (Singh et al., 2016). Today's business environment requires that facility and equipment be available at all production times (Gulledge et al.,

2010). Focus has been given to integrating the maintenance information systems with the plant information systems and marketing systems, in order to to create an effective management tool with the necessary feedback systems to improve productivity, quality and reliability(Eid, 2009). The presence of a CMMS system is then fundamental, and the lack of any system indicates a gap in terms of attaining future improvement.

The main driver of such an intervention is the management (Kaur et al., 2012, Singh et al., 2016). It needs to be driven as a requirement for operations, and linked to the department's key performance indicators (Ahren and Parida, 2009). This must be followed up to prevent the failure of the system. Systems and change point management usually fails, due to the lack of the management's support and follow up(Bartz et al., 2014).

The results illustrate that no computerised tracking is in place for the maintenance activities. There are no training programs for such a system. There are little or no records for changes or TPMs on equipment. This, then strongly shows that there is no information technology in the form of a computerised maintenance system present in the plant.

4.2.2.4 Objective 4: Evaluate the current Preventative Maintenance system.

Question O4: 22-33: These questions examine the current Preventative Maintenance system at the Weld Plant.

Table 5 : Questions relating to the current Preventative Maintenance system at the Weld Plant.

No :	Questions
1	Does Weld Shop use work orders for Preventative Maintenance Activities?
2	Does Maintenance periodically review PMs for accuracy, revision, increase/decrease, training needs ,etc. ?
3	Does Weld Maintenance use dedicated personnel solely for PMs ?
4	Do operators help with minor PMs such as cleaning, lubricating, adjusting and inspecting ?
5	Does Weld Use Predictive Maintenance (PdM), i.e., vibration, oil analysis, infrared or thermal technology, ultrasonic, or optical or laser alignment ?
6	Does Weld track PM and PdM costs ?
7	Does Production allow maintenance to access the equipment for scheduled PMs?
8	Does Weld Shop try to prevent breakdowns and failures from recurring ?
9	Are production operators and maintenance people involved in equipment selection decisions?
10	Are the people responsible for operating new equipment trained well ?
11	Are the people responsible for servicing and maintaining new equipment trained well ?
12	Does weld track how much it costs (Life Cycle Cost) to maintain equipment ?

The above table lists the questions posed to respondents to develop an image of the current PM system.

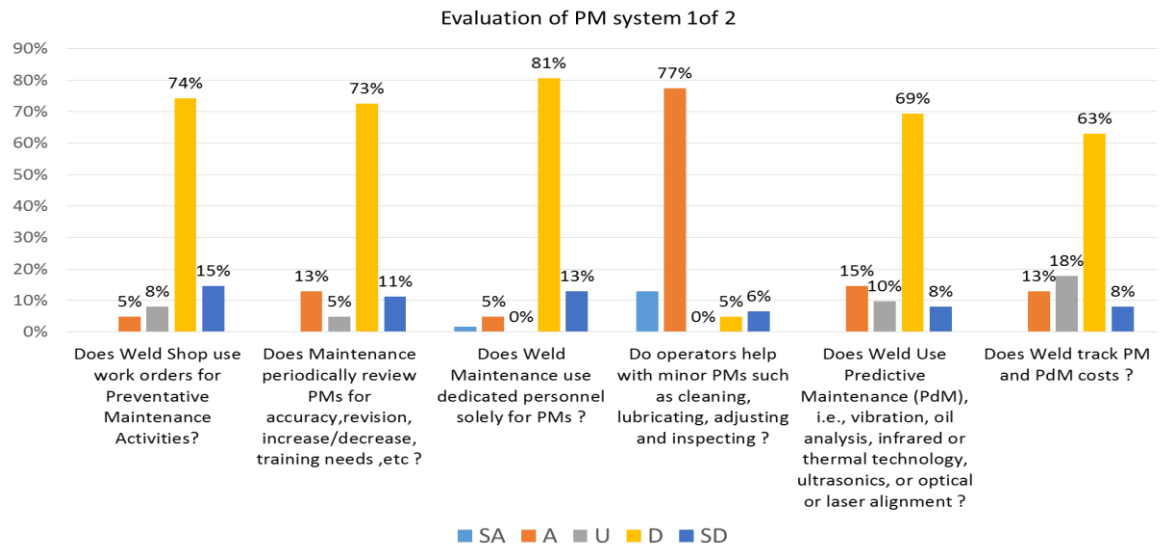

Figure 15 : results relating to PM system part 1

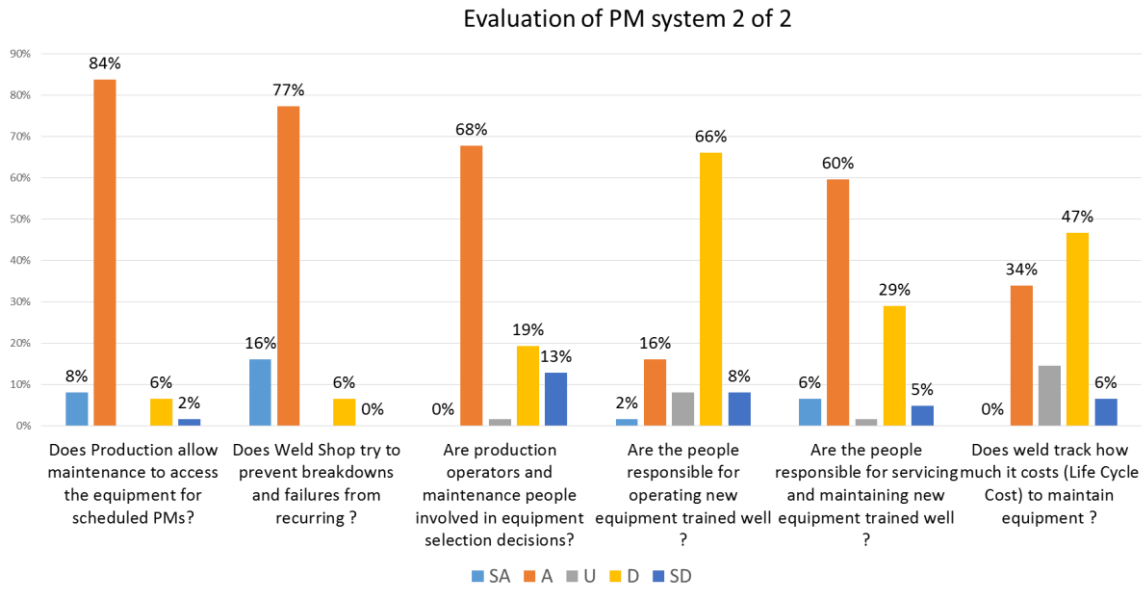

Figure 16 : Evaluation of PM system part 2

The results indicate that the respondents do not use work orders. Work orders are job requests that are generated and logged. PM activities are not reviewed, and if so, then minimally. This correlated with the results from objective three, regarding the collection of equipment history. Respondents also indicated that predictive maintenance is not used. This explains the indication from the respondents' response regarding the tracking of PM and PDM costs. Maintenance personal also

feel that operators are not well trained well enough, on the new equipment. Question eleven () found that a majority agrees that training is adequate. This corresponds to the findings in objective 1 .The findings indicate that the current PM system lacks in regards to the PM tracking, use of PDM methods, cost tracking of PM and equipment life cycle costs. These are however, the fundamental elements discussed in the theory.

A Majority of respondents did agree, that the operators assist in minor maintenance activities which is fundamental for TPM (Bartz et al., 2014). It was also found that the maintenance is allowed access to the equipment to perform PM, and that both maintenance and operators are involved in new equipment selection. This is crucial to the improvement of equipment design, as discussed by Ahuja and Khamba (2008).

The literature review develops a model for a maintenance system. The theory of operation of a successful PM system discussed by (Piechnicki et al., 2015) and (Marquez et al., 2009) consider the fundamentals of TPM (Figure 1), and develop them further into a system for organisational implementation Figure 2. This shows that all building blocks must be place appropriately for a sustainable and effective PM system. The five major components of any maintenance model are namely, resource management, information management, equipment technology and planning and scheduling (Maletič et al., 2014). The questionnaire evaluated the current system with reference to the key concepts discussed in the theory. The basic concept of TPM, as discussed Nakajima (1988), still holds valid, and those elements make up the preventative and corrective maintenance procedures which are tested. Work orders are generated from a Preventative Maintenance system based on the feedback from production, quality and previous PM reports. This is traceable and manageable, and is driven for PM improvement, and hence, equipment sustainability in the long term(Bartz et al., 2014).

Predictive Maintenance involves monitoring equipment condition to determine when a failure is likely to occur (Maletič et al., 2014). This strategy involved integrating the maintenance activities with the essential activities of the plant. These activities are Quality Control, Production and environmental conditions. This enables a user from any organisational level to, on demand, acquire reliable

information about the state of the production facility. The lack of PDM, as indicated in the findings correlated with the results regarding work orders and the tracking of costs. This is highlighted in the theory as a necessity for a PM system to function (Gupta and Mishra, 2016).

The evaluation of the current system indicates a lack of Administrative control and management of information. Administrative control, as discussed byPiechnicki et al. (2015), is a pillar of TPM and is interlinked. This has an impact on the PM system and ultimately the production process.

4.2.2.5 Objective 5: To understand if the planning and scheduling activities are in line with the PM system.

Question O5: 34-44: These questions examine the extent of planning with regards to the maintenance system.

Table 6 : questions posed to respondents regarding planning of PM activities.

No:	Questions
1	Are priorities set for maintenance job tasks ?
2	Does the department use work orders for maintenance work activities ?
3	is the system of how maintenance work orders are requested, planned and estimated effective?
4	Does your organisation control overtime?
5	Does your organisation record information from a work order into equipment history?
6	Are maintenance personnel assigned to job tasks based on their specialised knowledge and abilities?
7	Are non-emergency jobs well-planned before work begins?
8	Does your organisation use maintenance planners to plan and prepare scheduled maintenance work such as major repairs and shutdowns?
9	Does your organisation use contractors to handle excessive workloads and specialised skill applications?
10	If you have planners, do they prepare a job plan before a job is scheduled to begin?
11	Are shutdowns and major repairs planned in advance?

The table above represents the questions that aim to determine the extent of planning and scheduling that goes into the current PM system.

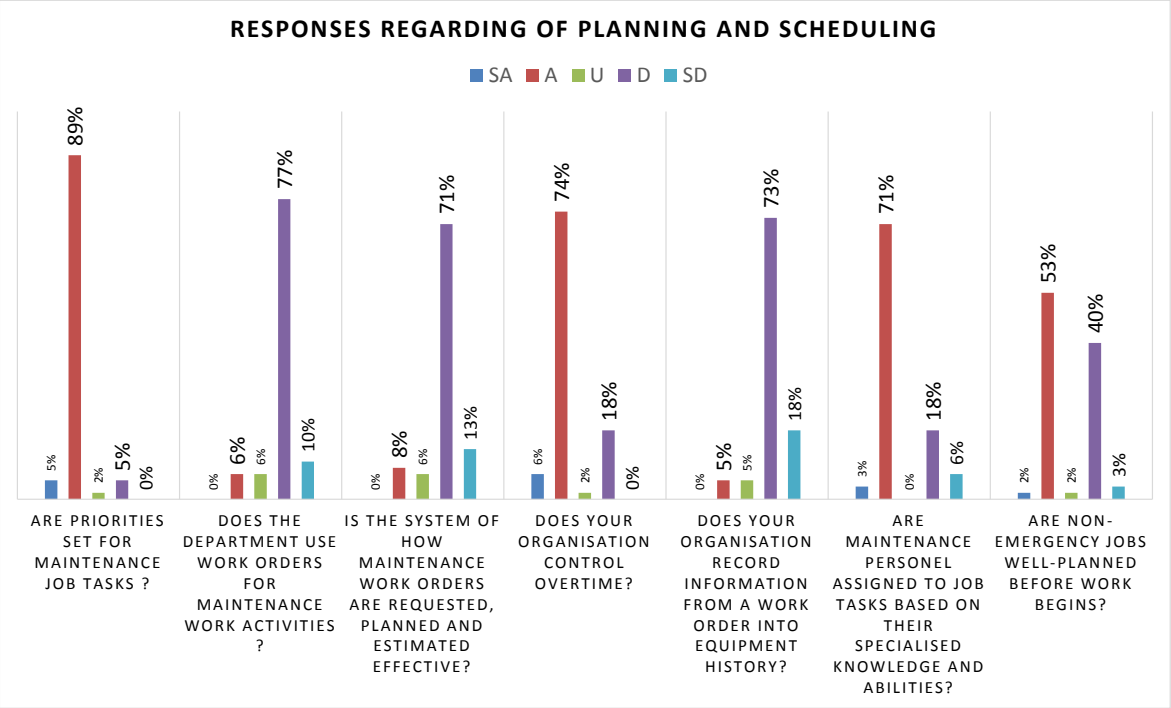

Figure 17 : Responses regarding the planning and scheduling of the current PM system.

The responses gathered are categorized into either majority ‘agree’ or ‘disagree’. This categorization gives a good understanding about the actual situation in the plant. The response regarding planning clearly indicated that work orders generated from maintenance schedules are not used. There are no specific planners who generate the maintenance as well as shutdown plans. Question seven, which looks at the planning of non-emergency work, generated a response of 55 % agreeing and 45% dis-agreeing. This unclear majority can also indicate that there are no specific planners. Response to shut down work planning and major repairs (question 11) shows that planning is undertaken for these activities.

The literature review discusses ‘planning’ as a key part of any PM system. Marquez et al. (2009) discussed planning in the model of a system (Figure 2) Phase 4 after goal setting is planning and scheduling. This allows the organisational goals to be translated into activities. It also enables the feedback to result in actual improvements. Pun and Nurse (2010) state that planning allows for the adoption of a scientific approach for maintenance to be carried out with control and performance analysis. A Maintenance system relies on schedules being drawn up, and PM plans setup to ensure the completion of task as well as tracking of activities (Meselhy et al., 2009). Maintenance strategies are segmented into strategies with logical steps and planning resulting in achievable action plans with

calculated results, and those without (Abdelhadi et al., 2015). This is the key to management, and also ensuring the work is done relating to equipment maintenance.

The results indicate that a reactive maintenance policy is being implemented, based on the lack of response regarding planning. The results of objective 4 indicate a failure in the administrative system, and this forms a facet of that structure. It has thus been realized from the findings that planning function which is extremely crucial, has failed.

4.2.3 Summary

The study entails significant findings about the Preventative Maintenance system at the weld plant. The findings relating to objective 1 show, that a majority of the respondents feel that staffing and organisational structure is an issue. There is also a perception held by the majority that the organisation is not being supportive. The results tend to indicate a mismatch between the support staff and middle management. The skills and training of maintenance staff were presented as satisfactory. Majority of respondents agreed that they are adequately trained, and possess the required skills for the job. Motivation amongst support staff was found to be needing an increased focus from the management. It was found that the plant, although managing assets and tracking financial costs of maintenance, did not track the maintenance activities. Further, it was also reported that there is no system to track and record PM. This indicates that problem solving can be a problem if no records of faults are kept. The evaluation of the current PM was found to be lacking the major elements of a world class PM system, Planning, scheduling, and the existence of a work order issuing system being key. Planning does exist for major items and shut downs. The next Chapter (Chapter Five) concludes the study and provides the recommendations.

5 Chapter 5 – Recommendations and Conclusion

5.1 Introduction

The research into the evaluation of the Preventative Maintenance system at a weld plant was brought about to address the failures of the system. The objective of the study covered five major areas of a Preventative Maintenance system. The literature review in chapter 2 discussed these major areas and brings forth the relevant theory. Chapter 4 discussed the findings. This chapter will discuss those findings in context to the research questions and together with the relevant theory make recommendations for the improvement of the system. The limitations of the study as well as possibilities for further research will also be discussed.

5.2 Resolution of Research Questions

The answers to each of the research questions, which each of the objectives are based are discussed in detail below:

5.2.1 Research Question 1: Determine whether the required resources are available for implementing the system.

The first research question attempts to understand if maintenance personnel are provided with the resources to implement a Preventative Maintenance system and effectively do the work required.

The majority of the respondents felt that they were not supported effectively and not provided with the proper aides. The common understanding between the management and support staff is found to be that the organisations structure and staff does not support the proper functioning of the department. It was also observed that the participants felt that production was not supportive although it was clearly felt that management emphasised production support.

5.2.1.1 Recommendation

The recommendation in light of these findings is that the direct management above the support structure be re-evaluated for supporting the organisational objectives. The organisational structure should be such that it upholds the number of staff present to manage the various sub sections. This will enable management

for gathering information effectively about the functioning of the plant and make decisions regarding the management of the department. The disparity between management and support staff may be due to information not being fed effectively to management and hence making problem resolution ineffective and slow. This has the effect of discouraging the staff and providing limited motivation for kaizen and change point management.

The lack of support felt by support staff in dealing with situations beyond their control is another example of the disengagement between management and support staff. This is a critical problem that must be taken care of on an urgent basis for ensuring that staff is able to effectively accomplish their designated tasks.

5.2.2 Research Question 2: Establish the skill level of maintenance personnel.

The majority of the respondents indicated they are well trained and felt that they were receiving adequate training for accomplishing their tasks. The demographic information highlighted that a large number of respondents had years of experience less than five years. This revealed that the staff turnover is comparatively high and the possibility of loss of skills was high. The solution to this is, however, effective mentoring and training program. It is positive to observe that respondents largely felt that they were adequately skilled to accomplish their tasks.

The feedback received was enough to conclude that maintenance personnel have the required skills to implement the Preventative Maintenance system.

5.2.2.1 Recommendation

It terms of a recommendation to improve, the focus would be on the negative comments regarding cross-functional teams that were used and the motivation of personnel for doing their best. The lack of motivation correlates with the responses from question one and then again this is most likely a consequence of production support and organisational inefficiencies. A key element is TPM and TQM in the use of cross-functional teamwork to resolve problems. A world-class organisation as discussed in the theory in chapter two is an organisation that makes use of the benefits of a highly skilled cross functional teams to resolve issues. This assists in

reducing the barriers that an individual department may face and combine overall resources to improve the present state of maintenance. Motivation of employees is widely researched topic and no single formulae exists. Motivation to do the best possible enroutes from management's ability to recognise the key personal drivers in each employee and do their best to focus developing a sense of achievement though effective work.

5.2.3 Research Question 3: To understand if the necessary information technology is in place to facilitate the system.

There is no CMMS system in place and hence no employees are given training for using it. It was found that there are systems for managing spares and the tracking of maintenance expenditure. Historical data was not registered and hence PM were not found to be improving on the basis of the lack of such data. The history of equipment then retains solely with the experience of the personnel. If this is not recorded this is lost with staff turnover. The demographic information showed a high level of young members (less than 5 years' experience) and a decline in experienced staff. Equipment failure may be the result of loss of experienced members who knew how to maintain and adjust PM by experience. Since there were no records available, thus, this knowledge is lost. This results in repeated breakdowns. This enables equipment to remain functional during production runs and eliminate repeat breakdowns. The lack of tracking of historical data prevents maintenance personnel from understanding the critical limits of equipment and results in maintenance development.

5.2.3.1 Recommendation

The recommendations would be firstly for using the IT infrastructure to create a database to record the historical data of equipment. This automotive plant generates the information on breakdowns but it is most likely manual and even if it is electronic it is not in any system that can store and retrieve such information effectively. There are systems for expenditure tracking and spares management as indicated in the results and we can accurate assume that there is a system for recording production information. The investment in some third party software for integrating all these systems is a necessity. A database that can generate queries and reports with the quality and production trends can help in highlighting

important information on PM trends and save maintenance costs. This will inevitably result in greater production uptime. A system to track and record information also demands the maintenance staff to receive the necessary training for operating such system.

5.2.4 Research Question 4: Evaluate the current Preventative Maintenance system.

The results indicated that work orders are not used. If a similar system is used it is not recognised as such. The PM system is not updated nor is it used for effective training or improvements. Predictive Maintenance tools form a nominal part of the PM process. It is felt that operator training is not effective on new equipment. This may result in unnecessary machine downtime. Respondents felt skills are adequate and access to equipment available. The overall result is that the current system lacks the key fundamentals of a PM system. This correlates with findings in the other research objectives. The PM system lacks the ability of generating work orders, which can be tracked and recorded. It does not have the ability to offer improvements and limits the future failure of equipment.

5.2.4.1 Recommendations

The current system lacks administrative control improvements and maintenance of quality. This must be developed and requires the creation from management level administrative systems that enforce and integrated working system. Work orders are fundamental processes and must be generated. This can only be generated by creating the administrative resources are created. Currently the current system is operating in a very similar way as to the corrective maintenance approach. This is not sustainable or effective to a world class organisation leveraging the flexibility and emphasising the cost management.

New equipment being introduced must be followed with the correct training for operators and process for establishing which must be done with a cross functional team for ensuring that all aspects are covered. Maintenance personal must be allowed to offer input on the training evaluation. This can be a source of motivation for both maintenance and production personnel and can increase the motivation levels. This also relates to the findings in second research question.

5.2.5 Research Question 5: To understand if the planning and scheduling activities are in line with PM system.

The results gathered reveal that maintenance planners are not used. Even if the plans are generated, they are for activities relating to emergency and shutdown. The PM system for daily maintenance does work use work requests that are generated, logged and processed. The use of contractors was made and it can be reasoned based on the information gathered that the work is mainly for emergency and shutdown periods where planning takes place. Planning is a fundamental activity that requires daily work that assesses PM activities on a daily basis and adjust plans for the future. Reports should be generated on findings and proposals for improvements and cost reductions should be created.

A Maintenance system depends on the schedules being drawn up and PM plans setup for ensuring the completion of task as well as tracking of activities. This is a key to management and ensures the work is done relating to equipment maintenance.

5.2.5.1 Recommendations

The findings points clearly to the presence of consistent planning function. Planning cannot be undertaken once for only situations relating to shut down and emergency. The reduction of downtime and the improvement of equipment availability requires a flexible PM system that can be audited and managed. This cannot occur without dedicated planners who control and assess the state of PM activities. The main recommendation would be to assess the state of the current PM functions and create a planning facilitator. This should not be hard to justify, as it should be in alignment with the requisites of the organisational key performance. The use of adhoc personnel to modify PM with no documented system and procedure leads to irregular information inconsistent reports and inaccurate PM. Staff turnover risk can be counter measured by training and job rotation which is something that should be allowed to cause system failure.

5.3 Limitations of the Study

The research was limited to the weld plant for the purposes of the study. This resulted in a small population size. Every department is different and hence the research cannot be regarded as a representation of all other manufacturing departments in the organisation. The research is quantitative in nature and lacks the depth of a qualitative study. Respondents are the staff from engineering and maintenance and the study lacks input from operators.

5.4 Recommendations for further study

The following are possibilities for further research or extensions of the study:

- The study was conducted based on a small population within one department. It can be extended to other departments and even industries.
- Research could explore motivational strategies within the field of maintenance planning.
- Further study can be done on the financial benefits of PM implementation
- The research can be extended to explore gender disparities in technical fields.

5.5 Summary

The research questions were discussed and recommendations were made in order to address the shortcomings that were revealed. The findings explain the situations of high machine downtime that prompted the study. The study revealed that despite the organisation being regarded as world class and having a PM system, it was found lacking major key components. The recommendations address the findings. The development of historical tracking and a planning function proved to be the priority. The role of management as key drivers for change is emphasised. Management support is noted as a requirement for the improvement of organisational functionality and addresses the issue of staff imbalances. The development of a system to manage PM information and

generate reports were in alignment to the key performance indicators and also emerged as a requirement. It can be concluded that addressing the PM shortfalls will ultimately result in production equipment being available for production, which directly made contribution to an organisations ability to become truly world class.

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Appendix A1

Informed Consent Letter 3C

UNIVERSITY OF KWAZULU-NATAL
GRADUATE SCHOOL OF BUSINESS AND LEADERSHIP

Dear Respondent,

MBA Research Project
Researcher: Ugandren Pillay (0726963004)
Supervisor: Dr Muhammad Hoque (031 2608690)
Research Office: Ms P Ximba 031-2603587

I, **Ugandren Pilay** an MBA student, at the Graduate School of Business and Leadership, of the University of KwaZulu Natal. You are invited to participate in a research project entitled Evaluation of Preventative Maintenance System at an Automotive Weld Plant. The aim of this study is to: Understand the current preventative maintenance system and make changes to improve.

Through your participation I hope to understand the various factors that contribute to overall maintenance system

Your participation in this project is voluntary. You may refuse to participate or withdraw from the project at any time with no negative consequence. There will be no monetary gain from participating in this survey/focus group. Confidentiality and anonymity of records identifying you as a participant will be maintained by the Graduate School of Business and Leadership, UKZN.

If you have any questions or concerns about completing the questionnaire or about participating in this study, you may contact me or my supervisor at the numbers listed above.

The survey should take you about **15** minutes to complete. I hope you will take the time to complete this survey.

Sincerely

Investigator's signature_____ Date_____

This page is to be retained by participant

UNIVERSITY OF KWAZULU-NATAL
GRADUATE SCHOOL OF BUSINESS AND LEADERSHIP

MBA Research Project
Researcher: Name (Telephone number)
Supervisor: Name (Office Telephone number)
Research Office: Ms P Ximba 031-2603587

CONSENT

I……(full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

SIGNATURE OF PARTICIPANT DATE

……

This page is to be retained by researcher

Appendix A2

NO	QUESTION	INPUT		
			Support	Management
A	Please Indicate Department	Maintenance		
		Production		
		Engineering		

A	General Information					
1	What is your age	21-30	31-40	41-50	51-60	61-65
2	What is your gender ?	Male		female		
3	What is your highest Academic Qualification ?					
4	Please indicate years of service at Weld Plant					

OB1	**Understanding the Resources required to implement the PM system**	Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
1	Do you feel maintenance is staffed to do its job?					
2	Does the overall structure of the maintenance organisation seem to be logical and helpful in accomplishing the work?					
3	Does the organisation help to remove barriers maintenance encounter in their jobs that they have no control over, which prevents them from doing a good job?					
4	Does management encourage maintenance to meet the needs of production?					
5	Does management encourage production to help maintenance in doing its job?					
6	Are cross-functional (production and maintenance) teams used to identify and resolve issues that affect both departments?					
7	Does management encourage maintenance and production operators to work together on issues?					
OB2	**Understanding the Skills required to implement the PM system**	Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
8	Have Maintenance personel received training to help them do their jobs?					
9	Are maintenance in your plant properly skilled to do their jobs?					
10	Are maintenance in your plant properly motivated to do the best possible job?					
11	Do maintenance follow safety policies and procedures?					
12	Does management follow-up and review housekeeping (with regard to man,method,machine) with maintenance?					

OB3	INFORMATION TECHNOLOGY	Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
13	Does your organisation use a Computerised System for Maintenance Activities (CMMS)? [Computerised Maintenance Management system]					
14	Is every piece of equipment tagged with an equipment or asset number?					
15	Does your organisation update its computerised maintenance system?					
16	Have maintenance been trained to use the CMMS?					
17	Does your organisation maintain accurate history records on equipment?					
18	Are maintenance stores computerised?					
19	Does your organisation track its total maintenance expenditures and costs?					
20	Are management decisions made from the CMMS reports?					
21	Is the time Maintenance personel spend on jobs tracked and recorded?					
OB4	**Preventative Maintenance Evaluation**	Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
22	Does your organisation use work orders for PM activities?					
23	Does maintenance periodically review PMs for accuracy, revision, increase/decrease, training needs, etc.?					
24	Does your organisation use Maintenance members dedicated solely to PM?					
25	Do operators help with minor PMs such as cleaning, lubricating, adjusting and inspecting?					
26	Does your organisation use Predictive Maintenance (PdM), i.e., vibration, oil analysis, infrared or thermal technology, ultrasonics, or optical or laser alignment?					
27	Does your organisation track PM and PdM costs?					
28	Does production allow maintenance to access the equipment for scheduled PMs?					
29	Does the organisation try to prevent breakdowns and failures from recurring?					
30	Is maintenance involved in equipment selection decisions?					
31	Are the people responsible for operating new equipment trained well?					
32	Are the people responsible for servicing and maintaining new equipment trained well?					
33	Does your organisation track how much it costs (Life Cycle Cost) to maintain equipment?					
OB5	**Planning and Scheduling evaluation of PM**	Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
34	Are priorities set for maintenance job tasks?					
35	Does your organisation use work orders for maintenance work activities?					
36	Is the system of how maintenance work orders are requested, planned and estimated effective?					
37	Does your organisation control overtime?					
38	Does your organisation record information from a work order into equipment history?					
39	Are maintenance people assigned to job tasks based on their specialized knowledge and abilities?					
40	Are non-emergency jobs well-planned before work begins?					
41	Does your organisation use maintenance planners to plan and prepare scheduled maintenance work such as major repairs and shutdowns?					
42	Does your organisation use contractors to handle excessive workloads and specialized skill applications?					
43	If you have planners, do they prepare a job plan before a job is scheduled to begin?					
44	Are shutdowns and major repairs planned in advance?					

Appendix A3

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

27 March 2013

Mr Ugandren Pillay 200269086
Graduate School of Business and Leadership
Westville Campus

Dear Mr Pillay

Protocol reference number: HSS/0130/013M
Project title: Evaluation of Preventative Maintenance Systems at an Automotive Weld Plant

EXPEDITED APPROVAL

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

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

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

Yours faithfully

[redacted]

Professor Steven Collings (Chair)

/pm

cc Supervisor: Mr Muhammad Hoque
cc Academic Leader: Dr E Munapo
cc School Admin.: Ms Wendy Clarke

Professor S Collings (Chair)
Humanities & Social Sc Research Ethics Committee
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban, 4000, South Africa
Telephone: +27 (0)31 260 3587/8350 **Facsimile:** +27 (0)31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za

Appendix A4

Turnitin Originality Report

Evaluation of a Preventative Maintenance System at an automotive weld plant by Ugandren Pillay

From Final Chapter (Dissertation)

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10

Appendix A5

Response ID	Time Taken to Complete (Seconds)	Response Status	Seq. Number	External Reference	Country Code	Region		What is your Age	What is your sex ?	What is your highest academic qualification?	Please indicate years of service at Weld Plant	What Department do you work for ? Maintenance
8601275	149	Complete	1	test_response	ZA	02					3	
8601523	386	Complete	1	test_response	ZA	02		2	1	Bsc Eng	7	
8601710	0	Incomplete	1	test_response	ZA	02						
10790987	0	Incomplete	1	test_response	ZA	02						
10791448	2308	Complete	1	test_response	ZA	02		4	1	LC National Diploma Eng	27	
10791717	0	Incomplete	1	test_response	ZA	02						