UNIVERSITY OF KWAZULU-NATAL

# THE INVESTIGATION OF A PLANNED MAINTENANCE SYSTEM AT AN AUTOMOTIVE COMPONENT MANUFACTURER IN KWAZULU-NATAL

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A dissertation submitted in partial fulfillment of the requirements for the degree of Master of Business Administration

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College of Law and Management Studies

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## ABSTRACT

Equipment is placed in the manufacturing organisation because it is required to do a specific task, such as producing goods at the required output and quality standard. Therefore the motivation for maintaining equipment is to preserve it in a condition such that it continues to do what it was intended to and this process is known as maintenance management. An important maintenance management strategy is a planned maintenance system which is a subset of a maintenance management system. A planned maintenance system (PMS) of maintaining equipment is recognized as preserving equipment in a condition such that it continues to do what it was intended to. Simply put, if the equipment is maintained in a manner it was intended to, it will continue to produce products at the required rate and quality. This will result in the business achieving its business goals. The primary objective of this study is to investigate the challenges that impede the proper functioning of a planned maintenance system at an automotive component manufacturer. The research data was obtained by surveying production and engineering employees at the automotive component manufacturer in KwaZulu-Natal. A sample size of 35, from a population size of 38 was drawn from the production and engineering departments at the automotive component manufacturer. Quantitative data was obtained from questionnaires for analysis to meet the studies objectives. The key objectives were to explore the current state of the maintenance management system at the organization, to identify the shortcomings of the current maintenance management system at the organization, to identify what improvements are required for the current maintenance management system at the organization and to provide recommendations based on the shortcomings identified. The key findings were the current maintenance management system is reactive, the equipment is deteriorating and that the equipment is unreliable. The main recommendations were to improve the uptime of the equipment, implementation of tools to predict and prevent breakdowns and the implementation of a formal maintenance and scheduling system which ultimately will refine the maintenance management system.

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## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| CMMS | Computerised maintenance management system |
| KZN | KwaZulu-Natal |
| IoT | The Internet of Things |
| MTBF | Mean Time Between Failure |
| MTTR | Mean Time To Repair |
| DEA | Data Envelopment Analysis |
| SPC | Statistical Process Control |
| SPSS | Statistical Package for the Social Science |
| MMS | Maintenance Management System |
| PMS | Planned Maintenance System |

# CHAPTER ONE – INTRODUCTION

## 1.1 Introduction

In most manufacturing plants it is common to find a department that is responsible for maintaining the machines and equipment that is used to produce the goods that the organisation sells to make a profit (Campbell and Reyes-Picknell, 2015, p. 20). That department is commonly known as the maintenance department, and it usually utilises a maintenance management system to achieve its goals. Tinga (2013, p.165) describes maintenance of equipment as preserving it in a condition such that it continues to do what it was intended to so that it will continue to produce products at the required rate and quality. At the automotive component manufacturer in KwaZulu-Natal the main goal of the maintenance department is to increase the production time of the equipment which maximises the production output and therefore increases the profits for the organisation (Tinga, 2013, p.165).

The organisation discussed in this study is a manufacturer of automotive components used in the assembly of automotive engines and is based in Pinetown, Durban. The actual name of the automotive component manufacturer will not be disclosed due to confidentiality reasons. The manufacturing process is labour and asset intensive. The manufacturing of automotive components at the required productivity rate and quality standard is dependent on the stable functioning of the production equipment. The organisation under investigation has been struggling for the past 10 years to maintain a stable production output and meet its customers' requirements. Thus, for a period the organisation has not been achieving its business goals. The management team decided to make a positive change by implementing constraint management to identify the constraints in the business. Goldratt and Cox (2016, pp.7-9) use the theory of constraints to describe the limiting factor or constraint in an organisation. The constraint stands in the way of the organisation achieving a goal. Naturally, once the constraint is identified the next step is to methodically improve that constraint until it is no longer a constraint and then identify the next constraint. The root cause for the unstable production output at the organisation was excessive equipment failures due to the current inadequate planned maintenance management system.

## 1.2 Overview of a planned maintenance system

All manufacturing plants that make use of equipment to produce products cannot operate at full capacity if the equipment they are utilising are unreliable. Unreliable equipment results in reduced capacity or output of the plant that ultimately reduces the revenue and profitability of the organisation. Furthermore, unreliable equipment produce defective products due to the equipment being unstable or its condition progressively worsening (Ben-Daya, Kumar and Murthy, 2016, p.3).

Ben-Daya et al. (2016, p.3) defined maintenance as “Maintenance consists of actions to ensure that the desired performance of the equipment is achieved so that it may perform its required function”. Equipment is placed in the manufacturing organisation because it is required to do a specific task, such as producing goods at the required output and quality standard. Therefore the motivation for maintaining equipment is to preserve it in a condition such that it continues to do what it was intended to.

A planned maintenance system is described by Gupta (2014, p.140) as the scientific application of maintenance in a comprehensive manner, such that a maintenance policy is in place and has been well-thought-out; the policy is carried out in a planned approach; the activities are structured and controlled to comply with the prearranged plan and data from the activities are recorded and maintained to evaluate the results and give direction for policy changes. Despite the implementation of the above activities and actions, the goals of the organisation are not being met. This therefore indicate that the current maintenance management system needs to be investigated further to understand why the goals are not being met.

Coleman, Damodaran, Chandramouli and Deul (2017, p.2) state that maintenance management systems typically fall into four categories, each with its own pros and cons. See Figure 1.1.

1. Reactive - equipment is fixed after it breaks.
2. Planned - equipment is fixed before it breaks.
3. Proactive - improve performance by removing defects.
4. Predictive - use data from the equipment to determine when the machine will fail.

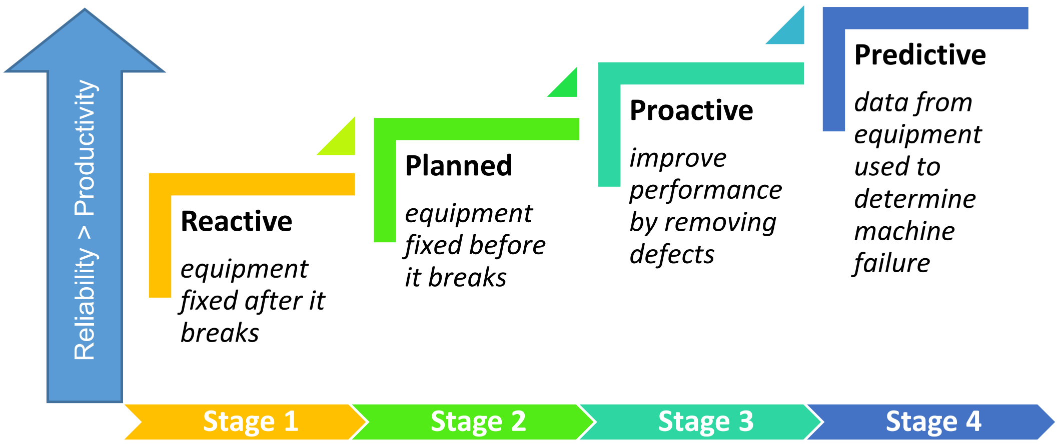



**Figure 1. 1 Maintenance Management Stages**

Adapted from Coleman, Damodaran, Chandramouli and Deul, 2017.

Figure 1.1. which outlines the maintenance management stages a manufacturing organisation progresses through to achieve operating excellence. The model shows organisations starting at the first stage which is reactive maintenance where they wait for equipment to fail before it is repaired. The second stage is planned maintenance where equipment is repaired before it breaks. The third stage is proactive maintenance where the equipment is improved to prevent breakdowns from initiating. The fourth stage is described as predictive maintenance where data from the equipment is used to determine when the machine will fail.

The analysis by Coleman et al. (2017, p.4) revealed that ineffective maintenance management systems negatively impacted a production plant's productivity by 5 to 10% and machine failures cost the manufacturing industry approximately $50 billion per annum. Some of the challenges faced by the organisations is the inability to determine the frequency a machine should be taken off production to be maintained; the gamble of replacing potentially good machine parts verses maximising the useful life of the machine part or using experience to determine when machine parts will fail and making the decision to replace them proactively (Coleman et al., 2017, p.2).

In order for an organisation to improve the current state of its maintenance management system, it is important to understand at what stage the maintenance management system is currently at in order for the organisation to take steps to progress to the next stage.

## 1.3 Motivation for the study

The motivation of the study was to identify and construct a planned maintenance strategy for an automotive component manufacturer that will result in the reduction of downtime and result in an increase in the uptime percentage. This will enable the business to achieve its business goals and sustain it.

All businesses are not the same, not only do they produce different products and provide different services, they operate in different spaces and business environments. This study will show that it is important to choose a maintenance strategy that will be the best fit for the organisation and give it the positive change it needs to increase profitability. The study could enable the organisations management team to understand the importance and benefits of the maintenance function and they would be able to include it into its strategic goals and build the business plan accordingly. The employees placed at different ranks of the organisation could also understand the importance and benefits of the maintenance function and could understand the reasons for carrying out maintenance activities. Those involved in the maintenance function in other manufacturing sectors could also gain insight into the organisation being studied and the steps needed to progress from the current maintenance level to the next.

## 1.4 Focus of the Study

The study was conducted within an organisation based in Pinetown, South Africa. The organisation produces engine components for customers in the automobile engine rebuild after-market. The focus of the study was confined to employees of the organisation.

The focus area of the study was the current maintenance management system and the recommendations to progress from a reactive maintenance management system to a planned maintenance system. The study will not focus on recommendations to move to more complex levels of a maintenance management system such as reliability centred maintenance.

## 1.5 Problem Statement

The organisation being studied has been unprofitable for a number of years. The management team used a basic problem solving technique called the “5 Why Analysis” to establish the root cause for the lack of profitability. Sakichi Toyoda, the founder of Toyota Industries Corporation developed the “5 why” root cause analysis technique (Ohno, 2017, p.89). His theory uses the concept that by asking “why” five times, the root cause of the problem becomes clear.

By analysing the financial records and the business key performance indicators from 2012 to 2017, the “5 Why Analysis” revealed that the organisation was not generating enough revenue to cover its fixed and variable overheads. The variable overheads also exceeded the budget year on year.

The next step was to analyse the above problems using the “5 why” technique to establish the root cause. The reason for not generating enough revenue was not a lack of sales but rather the inability of the production department to produce enough product. This was due to frequent equipment breakdowns or the lack of capacity due to equipment being on long term breakdowns resulting in a low uptime average of 50%. The root cause was the lack of a planned maintenance system which resulted in frequent breakdowns.

Variable overheads exceeded the budget set due to maintenance spend being over budget. Currently maintenance is reactive in nature and is therefore unplanned. As a result excessive overtime is worked to recover lost production. In addition, inflated prices are paid for spares and external resources to repair equipment due to the urgency. The root cause was a lack of a planned maintenance system which resulted in frequent breakdowns and the resultant high variable cost expenditure.

Therefore the business set out two major business goals for 2017 namely: to increase equipment uptime (reduced downtime) and sustain profitability in order for it to be successful. A higher uptime is achieved by reducing the downtime of the equipment. This will be done by implementing a planned maintenance system. Attri, Grover, Dev and Kumar (2013, pp.313-326) also stated that in order for manufacturing organisations to be successful they must have an effective and efficient maintenance system. Therefore this study will make recommendations following an investigation of a planned maintenance system at the organisation.

### 1.6 Aim of the Study

The primary objective of this study is to investigate the challenges that impede the proper functioning of a planned maintenance system at an automotive component manufacturer.

## 1.7 Research Objectives

The research objectives for this study are:

- To explore the current state of the maintenance management system at the organisation.
- To identify the shortcomings of the current maintenance management system at the organisation.
- To identify what improvements are required for the current maintenance management system at the organisation.
- To provide recommendations based on the shortcomings identified.

## 1.8 Research Questions

In order to address the above research objectives the following research questions are answered in this study:

- What is the current state of the maintenance management system at the organisation?
- What are the shortcomings of the current maintenance management system at the organisation?
- What improvements are required for the current maintenance management system at the organisation?
- What recommendations can be provided based on the shortcomings identified?

## 1.9 Research Design and Methodology

### 1.9.1 Research Methodology

A quantitative approach will be used for this study because it would allow for the collection of data from members of the population who are most conveniently, willing and able to provide information. In order to meet the research objectives of the research, a questionnaire will be used to answer the research questions and will aid in making recommendations on the shortcomings identified.

### 1.9.2 Sampling Strategy

The target population of this study will be randomly selected operations staff members from the maintenance, production and engineering departments on site in Pinetown who are directly or indirectly involved in the maintenance process. The target population is 38.

A sample size of 35 will be selected. This will be a random sampling strategy that will eliminate bias as every member of the target population will have an equal chance of being selected.

### 1.9.3 Data Collection Instruments

According to Quinlan, Babin, Carr, Griffin and Zikmund (2015, p.143) a questionnaire is a quantitative data tool and also constitutes as a primary data collection method. A questionnaire will be used for this study and will be used to gather responses to the research questions.

### 1.9.4 Data Analysis

The data obtained from the questionnaire will be analysed using SPSS 25 (IBM, 2018). The questionnaire questions or variables will be captured into the SPSS programme and descriptive statistics will be carried out.

### 1.9.5 Pilot Study

According to Quinlan et al. (2015, p.981) pilot studies are usually conducted with five to fifteen respondents. Five respondents will participate in this study. The researcher's pilot study will compromise of engineering, maintenance and production staff because they have similar characteristics to the target population. Once the pilot study has been completed, any issues discovered by the respondent will be rectified to prevent inadequacies in the research results.

## 1.10 Ethical Considerations

Ethical clearance for this dissertation has been granted and therefore research activities may begin.

The organisation discussed in this study is a manufacturer of automotive components used in the assembly of automotive engines and is based in Pinetown, Durban. Due to the highly competitive nature of the industry that the organisation operates within and the nature of its customers the actual name of the automotive component manufacturer will not be disclosed.

## 1.11 Chapter Organisation

The chapters of this research study is summarised below:

Chapter -1 Will outline the motivation for the study, the focus, the aim for the study, the research objectives and questions, the research design and methodology, the proposed time line for the study, and the limitations of the study.

Chapter-2 Will provide a literature overview of the maintenance function. This will cover the evolution of maintenance, reasons for equipment failure, the need for maintenance, maintenance methodologies and an overview of a planned maintenance system. The overview of a planned maintenance system will cover the definition, the role players in a planned maintenance system, reasons it fails, its strategic role in a manufacturing organisation and the role of technology. The chapter will also provide an overview of the organisation where the investigation will take place.

Chapter-3 Will provide a background and justification for the research methodology. It will give details on the processes and procedures that were followed in conducting the investigation.

Chapter-4 Will present the results and findings of the investigation. The chapter sections will comprise of demographics, descriptive statistics and a discussion of the findings and results.

Chapter-5 Will discuss the conclusion and recommendations for the investigation based on the research questions.

## 1.12 Proposed Time-table

The following time table is proposed:

| STEPS | DATES |
|---|---|
| Ethical Clearance | April 2017 |
| Research Proposal | March 2017 |
| Chapter 2 – Literature review | September 2018 |

| | |
|---|---|
| Chapter 3 – Research Methodology | September 2018 |
| Chapter 3 – Data Collection & Analysis | October 2018 |
| Chapter 4 – Presentation of results | October 2018 |
| Chapter 5 – Discussion | October 2018 |
| Chapter 6 – Recommendations and conclusions | October 2018 |
| Chapter 1 – Introduction | October 2018 |
| 1st draft – Supervisor advises | October 2018 |
| 2nd draft – Supervisor advises | November 2018 |
| Submit dissertation | November 2018 |

## 1.13 Limitations of the study

The investigation will concentrate only operations staff members from the maintenance, production and engineering departments on site in Pinetown who are directly or indirectly involved in the maintenance process. This is possibly at the expense of not considering the impact of other departments within the organisation and the impact of other organisation stakeholders.

The investigation will also not probe the cost of a weak or strong planned maintenance system to the organisation. It will also not investigate the cost of researching and implementing an improved planned maintenance system.

## 1.14 Summary

In this chapter the researcher gave an overview of the dissertation by explaining the motivation of the study, the problem statement, the aim, and the research objectives and questions. A brief outline of the following chapters are discussed and the proposed time line of the study is given. An overview of the planned maintenance function in the organisation was also given.

In chapter 2 a literature review of the theory relating to planned maintenance and the research objective will be conducted.

# CHAPTER TWO - AN OVERVIEW OF THE MAINTENANCE FUNCTION

## 2.1 Introduction

An overview of the dissertation was given in Chapter 1, the topic was discussed and the research objectives and questions were stated. Chapter 2 will give an overview of the Maintenance Function and will address the research objective which is to investigate the challenges that impede the proper functioning of a planned maintenance system at an automotive component manufacturer. The overview will also address the aim of the study which is to make recommendations following an investigation of a planned maintenance system at an automotive component manufacturer in Durban.

A manufacturing organisation's productivity is limited by its constraints or its bottlenecks. This concept is known as the theory of constraints written by Dr. Eliyahu M. Goldratt who explains that the performance of the business can be significantly improved if the constraint is eliminated or reduced (Techt, 2014, p.17). The reason for this is due to the constraint reducing the production output of the business thus decreasing its profit. As explained by Maletič, Maletič, Al-Najjar and Gomišček (2014, p.441) in most manufacturing organisations, poor performing equipment is seen as a constraint which impacts negatively on the profitability.

Therefore, equipment breakdowns or a reduction in performance can be seen as a constraint to the business as it results in reduced or zero production. Any loss or reduction of production results in a loss or reduced profit. Protzman, Whiton, Kerpchar, Lewandowski, Stenberg and Grounds (2016, p.21) explain that in order for a business to produce goods or services at the right price, quality and on time, production has to be carried out efficiently and accurately. Therefore there must be no unscheduled stoppages to production.

The organisation being investigated operates in an environment of intense competition together with rapidly advancing machine and equipment technology. Customers are demanding and require goods delivered on time, in the correct quantity, the correct quality and the right price. Production plans are increasing in complexity and have little or no room for delays or stoppages. Therefore the organisation is continuously seeking opportunities to maximise production machine utilization by reducing stoppages.

According to Tse, Mathew, Wong, Lam and Ko (2014, p.377) rapidly advancing machinery and equipment in the production departments, any form of machine downtime becomes expensive due to the capital expenditure required to rectify the equipment excluding the loss of production. To guarantee maximum machine uptime and reliability, systematic maintenance activities must be completed on a regular basis. Due to rigid production plans and the costs associated with downtime the maintenance activities must be planned and scheduled with the production planning department to reduce the time lost. Inadequate or poor maintenance of equipment and machines can lead to high repair costs and the costs associated with lost production output. Therefore, the maintenance department plays a vital role in an organisation that produces goods with equipment that requires maintenance (Aghezzaf, Khatab and Le Tam, 2016, p.190).

## 2.2 The Evolution of Maintenance

The past century has seen different generations of the maintenance discipline being practised. Ben-Daya et al. (2016, p.15) explains the changes are due to the vast variety of complex equipment introduced through the years. The introduction of more complicated equipment requires the maintenance methodologies to evolve with the changes. The organisation's maintenance strategy must respond to the changes and must consider the impact of the equipment failure on safety, the environment, product quality, plant availability and cost reduction (Do, Voisin, Levrat and Iung, 2015, p.22). Furthermore, the evolution will test the attitude and skills of the maintenance team and the methodologies they employ. Therefore maintenance engineers and managers are constantly seek new methods to improve their current maintenance program (Wang and Wang, 2017, p.2).

Ben-Daya et al. (2016, p.15) summarises the evolution through three generations. These generations are detailed in the next sub-sections:

### 2.2.1 The First Generation – up to World War Two

Up the World War Two the manufacturing industry was not very automated. Most products were hand made using simple tools. Due to this, machine downtime was not critical. Furthermore, equipment that featured in that period were extremely robust and rarely broke down. If they did break down, they were easily repaired due to the basic designs of the period.

### 2.2.2 The Second Generation – World War Two to the 1960's

During World War Two, the increased requirement for various goods and the subsequent rapid decrease in labour resulted in the need for the mechanisation of various industries. By the 1950's the dependence on the equipment grew as the years went by and therefore maximum machine uptime and minimum downtime was required. By the 1960's a method known as preventative maintenance came about. In its basic form it consisted of repairing machines at predetermined intervals. The more frequent repairs increased the cost of maintenance which led to maintenance planning and control.

### 2.2.3 The Third Generation – 1970's to the start of the 21st century

Machine downtime negatively affects the productivity of the plant, increases variable costs and reduces the service levels to the customers. During the 1970's this concern grew with the implementation of just-in-time production methods. Just in time meant a reduction of inventory and work in progress in the factory, this therefore increased the need for maximum machine uptime. A tiny breakdown had the risk of bringing a production line to a halt. Furthermore, it also impacted greatly on the quality of the goods being produced because frequent stoppages to production result in inconsistencies in the required specifications of the product.

Another factor that has become fundamental to the sustainability of the organisation and its stakeholders is its impact on the environment and the safety of its employees, consumers and other stakeholders. This means that the organisation must continuously review its assets and assess its impact on safety and the environment (Ratnayake and Chaudry, 2017, p.33).

In order to keep the equipment in an efficient working order they need to be maintained in order to extend its useable life span and to ensure a maximum return on investment. The cost to operate equipment in industry is increasing rapidly and forms a large component of the organisations operating budget. This cost therefore needs to be planned and managed effectively (Garza-Reyes, 2015, p.506).

Over the years, maintenance strategies and methodologies have expanded and numerous developments have emerged which include:

a) Decision support tools – Failure modes and effects analysis (FMEA).
b) Maintenance techniques – Condition based monitoring.
c) Design – designing for maintainability and reliability.
d) Organisational Behaviour – emphasis on team work and a flexible work force.

However the numerous methods available to maintenance engineers results in the onerous task of choosing the right method for their individual businesses. Coleman et al. (2017, p.17) confirms that choosing the correct method would increase machine performance, reduce costs and reduce downtime. Choosing the wrong method may result in further downtime and additional complexities.

#### 2.2.4 The Fourth Generation – Start of the 21st century to present day

Ben-Daya et al. (2016, p.16) described three generations and expectations of maintenance which ended before the start of the 21st century. Since then the maintenance function and environment has changed.

a) Equipment Availability – the expectations from the third generation has not changed in the fourth generation. The expectation is that maintenance will continue to deliver higher availability.
b) Equipment Reliability – currently there is a greater awareness of the importance of reliability between the machine operators and maintenance team. With the widespread implementation of world class manufacturing practices and performance management tools any form downtime is escalated immediately for rectification increasing the need for a more reliable operation.
c) Greater Safety – recent industrial and environmental disasters have increased the need for managers to implement tighter management controls and systems that will prevent safety, health, environmental and product quality disasters that can impact on any of the organisations stakeholders.
d) Product Quality – the barriers to entry in some markets are quite low and the need for organisations to differentiate themselves from competitors lies in product quality and service delivery. With the ever increasing quality standards of consumers and stringent product safety bodies it is imperative

to maintain and improve this standard. Maintenance of equipment is vital in providing a stable process that ensures product quality is consistent.

e) Longer Equipment Life – in the past, with increasing costs it was imperative that equipment lasted long to maximise the return on investment and profit margins. However, this may not be the case anymore for some industries. With increasing competition and customer expectations, the reduced product life-cycles have reduced the focus on longer equipment life. In some cases equipment becomes obsolete at the end of the product life-cycle. This does not imply that premature machine failure is acceptable. The decrease in product life-cycles will mean that equipment will need to be more versatile and adaptable to changes in product life-cycles which will increase the return on investment.

f) Cost Effectiveness – In the third generation the strategy for cost effectiveness focused on the effective management of maintenance costs which ultimately resulted in reducing the total costs for the organisation. This strategy is still true but the focus is now on creating a "lean organisation", which essentially means reducing headcount and reducing any form of excess or waste from the organisation.

g) Risk Management – Maintenance management now plays a critical role in creating a defence mechanism for "high consequence, low probability events". It requires the creation and management of a "risk-aware, reliability-focused organisational culture". This task relies more on people management and commitment than on analytical tools (Ben-Daya et al., 2016, p.16).

The fourth generation of maintenance management focuses on failure elimination as opposed to failure prediction and prevention. The activities around maintenance are proactive in nature as opposed to reactive maintenance. It also requires that the maintenance function expand into equipment selection and design as opposed to maintenance of equipment only. This necessitates the need for greater amounts of team work and the need for cross functional teams to achieve failure elimination.

Coleman et al. (2017, p.2) summarises the different stages of maintenance management in Figure 1.1 which outlines the maintenance stages which a manufacturing organisation progresses through to achieve operating excellence. The model shows organisations starting at the first stage which is reactive maintenance where they wait for equipment to fail before it is repaired. The second stage is planned maintenance where equipment is repaired before it breaks. The third stage is proactive maintenance where the equipment is improved to prevent breakdowns from initiating. The fourth stage is described as predictive maintenance where data from the equipment is used to determine when the machine will fail.

### 2.3 Reasons for Equipment Failure

According to Mohanty (2014, p.179) even a well maintained piece of equipment may fail and the reasons for failure are many. It is usually the duty of the maintenance or engineering department diagnostician to ascertain the root cause of the failure. Equipment failures can be split into two categories. These are discussed below:

#### 2.3.1 Failure due to poor maintenance practices

Failure due to poor maintenance practices are many however some are more common. Lack of machine lubrication in the equipment which causes the machine to run dry which increases the friction between components thus causing failure. Poor repairs cause failure due to bad workmanship or the equipment being partially repaired. One of the root causes for bad workmanship can be inadequate training of maintenance personnel. Poor response to breakdowns cause failures because the time to react maybe too long causing the equipment to deteriorate further resulting in complete failure. However, the most common failure reason is the absence of inadequate routine maintenance (Mohanty, 2014, pp 179-187).

#### 2.3.2 Failure due to external or other influences

Dhillon (2014, pp 41-44) discusses equipment failure due to external or other influences. Machine operator errors cause equipment failure due to incorrect use. The operator is also responsible for setting up the equipment to produce goods and the incorrect setup can result in machine failure and even poor quality goods. The quality of the materials in the construction of the equipment and its components must be adequate for its intended use. This is a vital specification in the machine design stage. Machine design plays a vital role in the longevity of the equipment where the designer’s choices will determine if the equipment is built to last. The use of incorrect input raw materials used in the production of goods can also influence the reliability of the equipment due to its abrasive nature. A wet, dusty or even a high heat environment that the equipment is placed in influences the maintenance procedures and ultimately the reliability of the equipment. Human influence on the failure of equipment is either positive or negative. Some of the negative influences that are difficult to predict, manage or prevent are equipment sabotage, operator concentration and general housekeeping of the equipment.

## 2.4 The Need for Maintenance

According to Ben-Daya et al. (2016, p.31) machinery and equipment that is used to produce goods and provide services are unreliable in nature and therefore require maintenance. They inherently will degrade over time with usage and will eventually stop functioning when it is unable to produce goods and services.

## 2.5 Maintenance Methodologies

Coleman et al. (2017, p.3) used the maintenance management stages shown in Figure 1.1 to depict the relationship between improved operational performance and an increasing asset management or maintenance management system. This model shows five levels of maintenance methodologies that an organisation will fall into. These levels are detailed in the next sub-sections:

### 2.5.1 Reactive Maintenance

Equipment is only repaired once it fails. As explained by Shin and Jun (2015, p.119) this activity is surrounded by panic and huge expense to repair the equipment.

### 2.5.2 Planned Maintenance

Maintenance activities are planned in advance. In this methodology Susto, Schirru, Pampuri, McLoone and Beghi (2015, p.812) explain that the failure of the equipment is predicted, the activities to repair it is planned and thereafter the maintenance is scheduled.

### 2.5.3 Proactive Maintenance

Bousdekis, Magoutas, Apostolou and Mentzas (2015, p.1225) explain proactive maintenance as equipment that is maintained prior to failure and it is improved upon to prevent failure or to extend the mean time between failures.

### 2.5.4 Predictive Maintenance

Mentzas, Hribernik, Thoben, Kiritsis and Mousavi (2018, p.233) describe predictive maintenance that uses a platform to gather information or data from the machines that are linked. The data is used to predict when a specific component will fail thereby notifying the maintenance team to conduct maintenance on the equipment before the failure occurs. This method is used to maximise the usage of all the components that make up the equipment thus saving time and money by preventing unnecessary replacement of components.

### 2.6 Planned Maintenance System Definition

Ben-Daya et al. (2016, p.3) describes maintenance of equipment as preserving it in a condition such that it continues to do what it was intended to. Simply put, if the equipment is maintained in a manner it was intended to, it will continue to produce products at the required rate and quality. This will result in the business achieving its business goals.

However, a planned maintenance system is described by Tse et al. (2014, p.67) as the scientific application of maintenance in a comprehensive manner, such that:

a) A maintenance policy is in place and has been well-thought-out,
b) The policy is carried out in a planned approach.
c) The activities are structured and controlled to comply with the prearranged plan.
d) Data from the activities are recorded and maintained to evaluate the results and give direction for policy changes.

### 2.7 The Management of a Planned Maintenance System

According to Gupta (2014, p.148) the management of an effective planned maintenance system lies in planning and control. This is the responsibility of the engineering manager or the maintenance manager. Essentially the manager of the system must ask when is maintenance required, which items require maintenance, are there legal requirements for maintenance, will the maintenance activity result in a loss of production or services, how often should the maintenance activities take place and lastly how will the maintenance activity be funded?

To answer these questions a planned inspection and maintenance process is required and must be applied with discipline. An effective maintenance team requires discipline and the planning system is what drives this (Gupta, 2014, p.145).

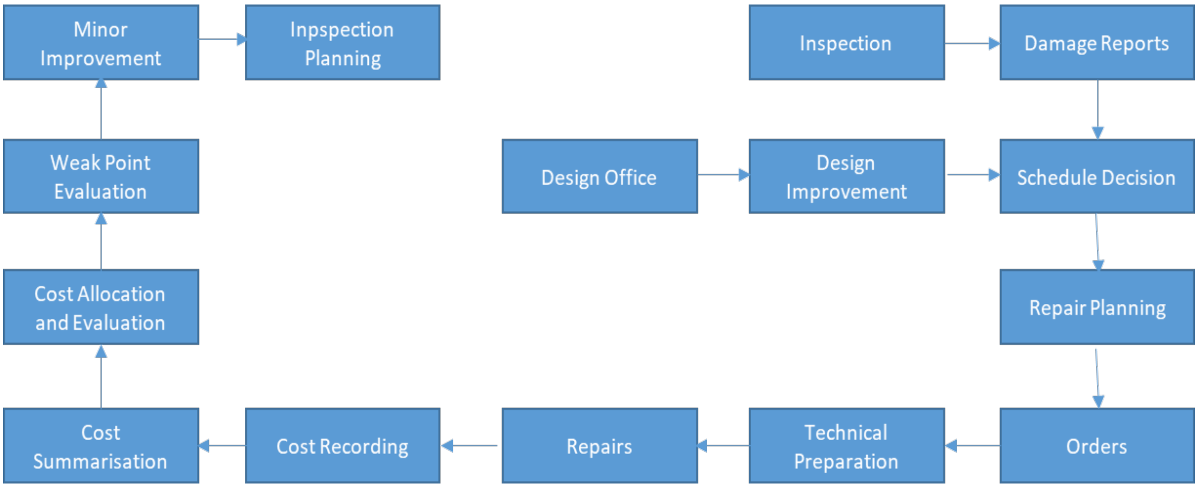



**Figure 2. 1 Planning and Control of Planned Maintenance**

Adapted from Gupta, A. 2014. Engineering Management, S. Chand Publishing.

Figure 2.1 shows a systematic approach to planning and control of a planned maintenance system. The starting point of a planning and control of a planned maintenance system is the inspection of the equipment and machinery in the plant. The inspection results in damage reports which state the facts on the wear and tear of the equipment. The detailed scheduling and planning process will then begin. Orders for spare parts and other resources are made followed by technical preparation for the repair activity. Once preparations and spares have arrived the scheduled time to repair arrives and the repair is completed. Now the feedback loop begins with cost information and allocation. The feedback reports give rise to minor improvements which decrease downtime. It is also important that the design office review the reports and other production feedback mechanisms to seek opportunities to improve productivity through a design-out maintenance approach (Gupta, 2014, p.146).

### 2.8 Benefits of a Planned Maintenance System

The implementation of a planned maintenance system will require time, money and effort from the various team members. In order for an organisation to justify the investment, the benefits must be worthwhile.

A planned maintenance system can be applied to almost any industry but the benefits will vary from one industry to another. Peters (2014, p.38) states that a planned maintenance system is not a cure for all maintenance issues that an organisation may face. This method will not make up for bad workmanship, lack of resources, or misuse of equipment. It also cannot miraculously transform outdated machinery into the latest, efficient and state of the art machinery. However, if the organisation implements it with careful planning and optimisation of resources, the following benefits can be yielded:

a) **Increased available time improves productivity**

   Regular maintenance of machinery results in fewer breakdowns and therefore increasing the available time to produce products. When maintenance is planned in conjunction with customer requirements, the time lost for maintenance impacts very little or none on the loss of production. A planned maintenance system is controlled. The time allocated is calculated and known. There are no surprises if the planning is correct. Because the maintenance is planned, the tools, spares and other resources are available. When the maintenance is unplanned the resources are not available immediately. This results in extended downtime reducing the available time to produce (Jain, Bhatti and Singh, 2015, p.503).

b) **Competitive advantage and reduced costs**

   Campbell and Reyes-Picknell (2015, p.386) confirmed that unexpected breakdowns cost more due to the unplanned stoppage during production. This could result in huge costs to source spare parts and technicians to repair equipment. Also, the unplanned stoppage to production results in costly delay in manufacturing the product and delivery to the customer. By implementing a planned maintenance system, a reduction in unplanned stoppages and breakdowns in the production department is expected and will maximise the availability of equipment for production and therefore improve the productivity of the organisation and thus gives it a competitive advantage over its competitors who do not have a planned maintenance system for its equipment. Planned maintenance activities results in better management and control over labour costs and increased demands on the labour. The maintenance data collected forms an integral component of the planned maintenance system. Besides assisting in the planning of future activities, the information gathered improves the control of budgets, control of spares, decision making and repair analysis.

**c) Improved morale**

Al-Turki, Ayar, Yilbas and Sahin (2014) explained that the progressive results of a planned maintenance system will be seen in an improvement in employee morale.

Do et al. (2015, p.22) also cautions that the maintenance costs can rise after a planned maintenance system is implemented due the backlog of repairs and the resources required to reverse the neglect of the equipment. The cost to return the equipment back to the original manufacturer's specifications can be significant.

### 2.9 Planned Maintenance System Responsibilities

It is widely debated over which department in a manufacturing environment is responsible for the maintenance of the equipment. Peters (2014, p.309) confirms that the maintenance department is responsible for the manner the equipment runs and therefore accountable for the maintenance. However, the operator of the equipment is still responsible for the equipment whilst he operates it. The best results are achieved when responsibility and accountability is assigned to a single department or an individual. This individual can either be an operator or artisan. Overlapping roles and responsibilities causes confusion and results in a lack of accountability.

#### 2.9.1 The Role of the Production Department

The production department is not absolved from the maintenance function. Karwowski, Trzcielinski, Di Nicolantonio and Rossi (2018, p.542) advises that the production operators must perform assigned and scheduled maintenance work called autonomous maintenance. For this function these chosen individuals will be trained and qualified beforehand. They will be guided using detailed work instructions. Autonomous maintenance is conducted by the operator of the machine opposed to members of the maintenance department. This method of maintenance empowers the machine operator to perform more preventative and continuous improvements activities on the equipment they operate daily. In the past, operators will run their machines until failure and then request the maintenance department to repair it. Autonomous maintenance requires the operator of the machine to conduct basic maintenance activities which they have been trained on previously and have been issued tools and resources to conduct such activities. Some of these activities include the safe cleaning, inspection, lubrication and adjusting of the machine or equipment. This level of responsibility given to the operator has the following benefits:

a) Creates accountability and a sense of ownership.
b) Improves problem solving skills. Due to a greater understanding of the machine, any changes to the machine functionality and quality of the product being produced the operator has a greater ability to solve the problem on their own.
c) The operator is able to assist the maintenance department during planned maintenance activities and during problem solving.

### 2.9.2 The Role of the Maintenance Department

According to Campbell and Reyes-Picknell (2015, p.29) the reason for having a maintenance department is to ensure that machines, buildings, services, and equipment are operating at the required level or productivity or efficiency and are available when required to be service to the production department. This role can be divided into four main groups:

a) Pure maintenance – work undertaken in order to keep or restore a facility to an acceptable standard.
b) Installation and alteration of plant, equipment and services.
c) Operation and supervision of particular utilities and specials services
d) Miscellaneous duties delegated to the maintenance department.

According to Ram (2018, p.32) the aim of the maintenance department is:

a) To ensure maximum plant availability and must be ready for start-up when required.
b) To ensure a reliable plant during its operation.
c) The plant must operate efficiently and at the required rate of productivity.
d) Downtime for maintenance must be planned and must not hinder the production plan.
e) Management and development of the maintenance budget and controlling the maintenance costs.

To achieve the above conditions:

a) An effective maintenance strategy for planning, controlling and directing the maintenance function is required.
b) The maintenance department must have adequate resources available in terms of tools and skills.
c) A continuously improving culture and a sense of urgency is required.
d) There must be a common goal relationship between production and maintenance functions.

## 2.10 Reasons for a Planned Maintenance System Failure

A planned maintenance system implementation has numerous benefits as discussed, however its implementation does come with its challenges and subsequently can result in the total failure of the system. There are several factors which Poduval and Pramod (2015, p.308) discuss:

a) Top Management Commitment – the success of planned maintenance program relies on the complete commitment and support of top management. The roll out of the program begins with management communicating the strategy and its benefits. The commitment comes in the form of allowing machine operators to train and spending money on the program. The program will fail if this commitment is not made.
b) Resistance to Change – the entire organisation needs to believe in this path that the business will take. In order to gain a competitive advantage change is required to differentiate the organisation.
c) Resource Commitment – a planned maintenance system requires valuable resources such as man hours, raw-materials, and time. These are required either for training or for making improvements. Short cuts should not be taken, the results of a planned maintenance system implementation are slow and patience is required.
d) Work Culture – a communication channel between management and shop floor employees is necessary in order to improve decision making and trust. Therefore a "boundary-less" organisation. It also means that the organisation must allow cross functional team to engage on various issues to foster new ideas and solutions and very importantly team work and buy-in.

e) Employee Resistance – it is common to encounter comments like “this is not my job”. With the alignment of the organisation goals and improvement in work culture this short-sighted comment will change to “I am glad to assist”.
f) Human Resources – The needs of the employees should not be forgotten. Throughout the implementation their concerns should be addressed as this could hinder the progress. With the implementation of lean manufacturing processes, it is common to embark on projects to reduce headcount. It is imperative that a balance is found that will not hinder the progress. In some cases additional skills will have to be recruited as they are not available internally.
g) Union Buy-in – Most manufacturing organisations have a unionised workforce that operate the equipment. When the program is being introduced it is imperative that management engage with the union officials on the benefits of the program. This step is critical as the shop floor employees participation in the program is a critical success factor.
h) Employee Recognition - it is important that management give recognition to those employees who show exemplary performance on the program. A suitable incentive scheme could be introduced.
i) Training – training form a critical step in the roll out of the program. This is done on a continuous basis and should be budgeted for accordingly. The training performed should be specific to the development of the skill sets required.
j) Pilot Study – a pilot study is required before an organisation wide roll out is carried out in order to identify any shortcomings. It also creates the necessary hype.
k) Cross Functional Teams – failure to involve cross functional teams from the organisation will stagnate problem solving. A team involving production and management with no involvement of the maintenance team will not add any value as an example.
l) Reliability Centered Maintenance – In most organisations, maintenance work focuses on the repair of the equipment in order to get production running again as quickly as possible. Maintenance should be focused on maximising the reliability of the equipment opposed to quick fixes.

m) Planned Maintenance Schedule – the time allocated for planned maintenance must be utilised for its intended purpose. Sufficient time must be given to the team to carry out the activities. Shortening the time will result in short cuts and defeat the purpose of planned maintenance.
n) Computerised Maintenance Management Systems (CMMS) – technology is required to gather the vast amount of data for analysis and creation of schedules. Attempting planned maintenance without this tool in a small organisation might be possible. However in a larger organisation with many complex machines this will be an onerous task to do manually.
o) Work Instructions – the absence of clear standardised work instructions which clearly outline the planned maintenance activities will result in inconsistent activities being carried out that will compromise the product quality and result in unplanned machine stoppages.
p) Tools of Trade – the production and maintenance personnel need to be issued with appropriate tools to perform the functions required of them. The use of mismatched tools can result in further machine downtime and even injury to the user. There are constantly new tools and technology being introduced that can facilitate faster and effective equipment repair and failure detection. This should be reviewed on an ongoing basis as part of a continuous improvement initiative.

Kedar, Borikar and Kedar (2016, p.162) state that a planned maintenance system fails due to a few barriers that prevent an organisation from reaching an increased level of reliability of their equipment.

a) Do maintenance and production members understand what machine failure is? The "old" definition of failure is the equipment has stopped working which is typical of a reactive maintenance mind-set in the organisation. The "new" definition of failure is when the equipment cannot meet its intended function at a specific rate of production. This is typical of a pro-active maintenance mind-set in the organisation.
b) Are the maintenance members aware when the equipment produces poor quality product or when the productivity is reduced? Maintenance members need to understand that the equipment is not meeting its intended function.

c) Do the maintenance members know the key performance indicators of the production plant? Do they understand the indicators? It is critical that the entire organisation goals are aligned so that no department will operate in a silo but rather work towards common goals.

If all members of the organisation understand if a functional failure has occurred, the necessary action can be taken immediately resulting in quicker results thereby achieving increased equipment reliability. It starts with aligning the goals of everyone in the organisation and regular review of the current asset performance so that corrections can be made with all team members. Eventually when a piece of equipment functionally fails all team members will understand the impact on profitability of the organisation.

## 2.11 The Strategic Role of the Maintenance Function in a Manufacturing Organisation

The plant productivity strategy will always have a pillar dedicated to maintenance. Campbell and Reyes-Picknell (2015, p.21) confirms that the maintenance function forms an essential building block of the overall plan that meets the customers expectation of a quality product, delivered on time at the correct quantity and the right price.

The production department uses equipment to meets its targets. It is often that maintenance activities are delayed or overlooked due to urgent customer orders. This is when the equipment deteriorates, product quality diminishes, and orders are delivered late. It is not long before the effects of not doing maintenance is seen on the bottom line. Very often there is a fight between the maintenance department and the production department for time to produce vs time to maintain the equipment. In most cases the production department will win the first round, however the fight is lost by production when the machine breakdowns unexpectedly. Then there is a rush to repair the machine, which is often not done to standard due to the pressure on the maintenance team to get the machine up and running. This method of maintenance is reactive in nature which is not world class.

## 2.12 The Role of Technology in Planned Maintenance Management Systems

According to Karwowski et al. (2018, p.532) technology plays a vital role in maintenance management and this has evolved through the years. Originally this was manually managed in hand written note books, followed by spread sheets and then computer maintenance managements systems (CMMS). However, pending on the size of the organisation, its operating budget and its maturity level in terms of technology and maintenance some organisations have progressed much further than CMMS.

### 2.12.1 Computer Maintenance Management System (CMMS)

The task of managing the maintenance function in an organisation grows as the size and its complexity of equipment grows. As this task grows, it becomes increasingly apparent that the assistance of a computer based application is required to store, retrieve and analyse information.

According to Karwowski et al. (2018, p.532) CMMS assist organisations to reduce maintenance and its associated costs. Its gives the maintenance department increased information to improve decision making by collecting information and creating insight. It focuses on increasing the life cycle of equipment, a higher return on investments and improving maintenance workflows by ensuring planned maintenance activities are carried out. It also creates accountability with the maintenance department by tracking repeat breakdowns. There are increasing regulatory checks that need to be carried out on equipment and facilities. CMMS assists in scheduling these safety, health and environmental regulatory checks. An important resource in completing any maintenance task is the availability of spare parts. If the maintenance is predicted then the spares are only ordered when required or an agreed amount is kept in stock thus reducing inventory levels and working capital. Ultimately, CMMS is a productivity tool that reduces the man hours required to manage a system manually.

According to Lödding, Riedel, Thoben, von Cieminski and Kiritsis (2017, p.384) CMMS started in the 1960s with the use of punch cards which then improved by the use of printed documents. As computers became smaller and cheaper in the 1980s more organisations made use of computers with CMMS. Then in the 1990s these computers had the ability to share information between each other via the use of local area networks and the software evolved with more features. With the rapid rise of the internet in the 2000s, CMMS solutions became web based and the software was supported the software vendors. Currently, CMMS software is now moving towards the cloud which allows multiple users with a unique log in to access the same system. CMMS is now focused on speed of implementations, mobility and predictive maintenance reporting.

### 2.12.2 Industry 4.0

According to Grunow (2016, p.16) Industry 4.0 was coined by the German government when they began to prepare for the future of production, the fourth generation. The fourth generation comes at a time when there is a need for customer specific products, flexible production and the integration of the customer, the organisation and other business stakeholders. Industry 4.0 is dependent on the implementation of smart technology creating a smart factory. A smart factory uses the Internet of Things (IoT) which makes use of wireless networks, smart equipment, sensor technology, self-managing devices and actuating technology.

### 2.12.3 The Internet of Things (IoT)

The next generation of technology in the maintenance management field is the Internet of Things (IoT), which is essentially the linking of many devices and instruments in the working environment to the internet. According to Hussain (2017, p.2), IoT is regarded as the forth industrial revolution succeeding steam, mass production and the Internet. It is not uncommon to hear consumers control their lights and security systems at home with their smart phones from around the world. In the near future, maintenance technicians will be able generate or pick up error codes on their smart watch or tablet as the breakdown occurs on the shop floor. Sensors within the machine will measure the wear on critical components and place orders for the spare parts itself before the machine breaks down. This real time analysis is being used by the machine manufacturers to improve their designs by getting real time feedback from the equipment installed around the world. They are able map out behaviours and failure patterns which are used to design out failures as well as software upgrades. This information is also used by factory operations teams to make decisions. Due to the accurate real time feedback, metrics such as mean time between failure (MTBF) and mean time to repair (MTTR) are calculated immediately and displayed on dash boards. The IoT plays an important role in improving asset reliability by extracting costs and providing real time feedback to connected devices and the end user.

## 2.13 The Automotive Component Manufacturer

### 2.13.1 Overview of the Organisation

The organisation is a manufacturer of automotive components for the predominantly for the after-market engine rebuilder industry and for original equipment manufacturers. The plant is based in KwaZulu-Natal, South Africa. The manufacturing process is labour and asset intensive. The organisation has been struggling for the past 10 years to maintain a stable output and reduce its scrap rate and therefore did not achieve its business goals.

The management team decided to make a positive change by implementing constraint management to identify the constraints in the business. Techt (2014, p.29) use the theory of constraints to describe the limiting factor or constraint in an organisation. The constraint stands in the way of the organisation achieving a goal. Naturally, once the constraint is identified the next step is to methodically improve that constraint until it is no longer the constraint and then identify the next constraint. This method was applied and the root cause for the unstable production output and poor product quality at the organisation was excessive equipment failures. It was also found that the current maintenance system was not addressing the equipment failures.

### 2.13.2 The Current State of the Maintenance Management System.

The maintenance management system is operated by a maintenance supervisor supported by artisans, electricians and mill-rights that work on a three shift pattern.

The day to day activities of the department are predominantly attending to reactive maintenance repairs and if production planning allows, planned maintenance is carried out.

Downtime statistics are not recorded due to the absence of a planned maintenance clerk. However, there is a system to record the data but it is outdated and is only accessible by one user on a single computer. Due to the lack of downtime and maintenance statistics, information from the daily maintenance activities are not used in any management decision making processes.

## 2.14 Conclusion

Chapter two gave a literature review of a planned maintenance system and an overview of the automotive component manufacturer. According to Peters (2014, p.38) in machine reliability or maintenance management, information is critical for success. The information gathered from the maintenance management system must steer the organisation correctly. Therefore it is important for the maintenance management team and the organisation leadership review the current reality of how the maintenance is managed. If equipment is failing continuously and maintenance is reactive in nature then a new direction is needed to improve the reliability of the equipment. Chapter three will outline the research methods and processes followed.

# CHAPTER THREE - RESEARCH METHODOLOGY

## 3.1 Introduction

Chapter three will discuss the research methodology used to conduct this study, thereby satisfying the study objectives. The primary objective of this study is to investigate the challenges that impede the proper functioning of a planned maintenance system at an automotive component manufacturer. The research objectives of this study were as follows:

- To explore the current state of the maintenance management system at the organisation.
- To identify the shortcomings of the current maintenance management system at the organisation.
- To identify what improvements are required for the current maintenance management system at the organisation.
- To provide recommendations based on the shortcomings identified.

This chapter will discuss the research method and design, population, sample size, sampling method, construction of the instrument, data collection, data analysis, reliability and validity of the study, bias, ethical considerations, and summary.

## 3.2 Aim of the Study.

The primary objective of this study is to investigate the challenges that impede the proper functioning of a planned maintenance system at an automotive component manufacturer.

## 3.3 Research Method and Design

Creswell (2014, p.3) explains research design as the basic plan for answering the research objectives and questions. In addition, the correct research design and method will guide the researcher to obtain the necessary data to answer the research objective (Adams, Khan and Raeside, 2014, p.81). Research methods refers to the different methods utilised by researchers for their research. Saunders, Lewis and Thornhill (2015, pp.136-144) explained that research methods are categorised into two key research methods, namely the qualitative research method and the quantitative research method. They can be used in sequence or in parallel in a study that results in a combined or mixed research approach (Saunders et al., 2015, p.497). Quantitative research, in most cases, requires the use of questionnaires to collect useful numeric data (Saunders et al., 2015, p.360). Qualitative research involves collection of useful verbal information which gains insight into human behaviour and the latent assumptions that govern that behaviour (Taylor, Bogdan and DeVault, 2015, p.7). For this study, a quantitative research method is used to investigate the challenges that impede the proper functioning of a planned maintenance system at an automotive component manufacturer. The quantitative research method is empirical, precise and requires objectivity (Creswell, 2014, p.4). Hence, the quantitative research method was considered the most useful because it allowed the researcher to investigate, in a more scientific manner, the challenges that impede the proper functioning of a planned maintenance system at an automotive component manufacturer.

Saunders and Tosey (2013, P.59) use the research onion (Figure 3.1) to describe the different research methods. The research onion is made up of five different interdependent stages that were used for this study. The first layer which is research philosophy is made up of positivism, realism, interpretivism, and pragmatism (Saunders and Tosey, 2013, p.59). The next layer unpacks these philosophies into methodical choices namely, mono method quantitative or qualitative, multimethod quantitative or qualitative, mixed method simple and mixed method complex. The next layer unpacks the different strategies that can be used for quantitative and qualitative methods. For a quantitative research strategy, experiments and surveys can be used. For a qualitative research strategy, narrative inquiry, grounded theory, action research, ethnography, focus groups or case studies can be used (Saunders, Lewis, Thornhill and Bristow, 2015).

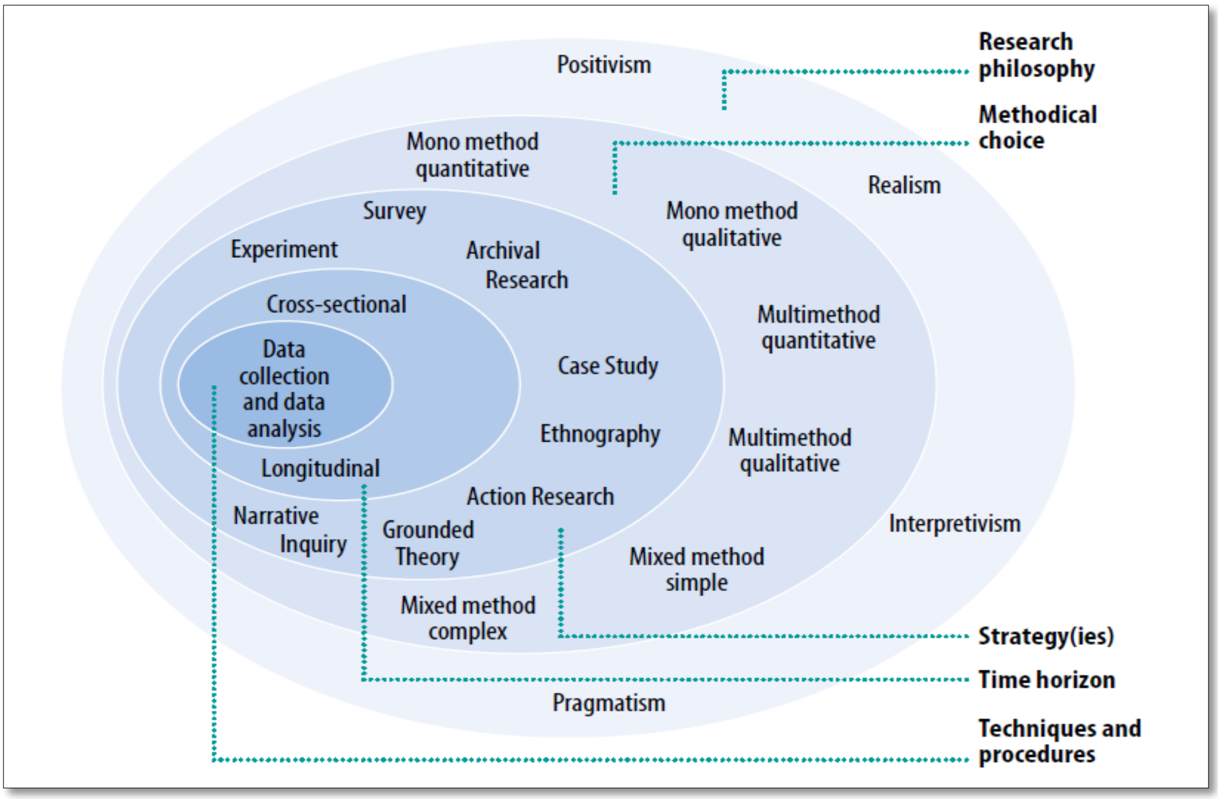



**Figure 3. 1 The research onion**

Adapted from Saunders, M. N., Lewis, P., Thornhill, A. & Bristow, A. 2015. Understanding research philosophy and approaches to theory development.

## 3.4Population and sample of the study

As explained by Weathington, Cunningham and Pittenger (2017, p.90) a population is described as the whole collection of elements that are of importance to the researcher and is the whole set of observations that under assessment. The authors also explain that the population of the study is the whole group of participants with shared features. The target population for this study consisted of all the employees at the automotive component manufacturer.

Adams et al. (2014, p.72) explains that a sample is an extract of the population and is made up of a portion of participants chosen from the population Adams et al. (2014, p.72). Similarly, Weathington et al. (2017, p.90) explained that a sample is a portion of a larger population of components. For this study, a sample of 35 staff members was collected at an automotive component manufacturing company in KwaZulu-Natal.

### 3.5 Sampling method

Sampling methods can either be probability or non-probability according to Adams et al. (2014, p.73). For probability sampling, given that the drawing of elements is random, there is a probability of drawing each element of the population and the probability could be the same for all the elements. However, the opposite applies for non-probability sampling because the drawing of each element is unlikely. With the aim addressing the research question, sample statistic is used to create inferences about the entire population that is being studied by testing the hypotheses. For probability sampling methods, Hair, Celsi, Money, Samouel and Page (2015, p.192) explain that surveys and research by experiment are normally utilised.

The first 35 research participants where randomly selected from the automotive component manufacturing company in KwaZulu-Natal to respond to the questionnaire. Due to all members of the staff having an equal opportunity to be selected, the random sampling strategy eliminated bias.

### 3.6 Construction of the Instrument

The research instrument chosen for this study was a questionnaire. A questionnaire is a research instrument that is used for collecting data from the participants of the study by requesting the participants to respond to a unique set of questions that are set out in a prearranged manner (De Vaus, 2014, p.140).

Questionnaires are versatile and can be used for quantitative and qualitative methods of study. It is also cost effective and allows for quick responses and retrieval of data (Hair, Celsi, Money, Samouel and Page, 2015, p.210). Furthermore, the intention of standardised questionnaires are for the participants to complete the same set of questions by themselves and to give predetermined responses, which will supports the need for content and validity of the research instrument and the study (Brace, 2018, p.5).

When designing the questionnaire, Sekaran and Bougie (2016, p.58) explain that there are three critical points, namely the look and layout of the questionnaire, the grouping, scaling and coding of the variables and lastly the construction of the questions. The authors advise that the construction of the instrument must be prepared with consideration given to the critical points mentioned (Sekaran and Bougie, 2016, p.58).

The construction of the questionnaire was given careful consideration and is shown in Appendix C. For this study, the questionnaire was used to collect data at the automotive component manufacturer in KwaZulu-Natal. The data obtained from the questionnaire was used to answer the research questions that addresses the research objectives. To answer the research questions, the required data was acquired from close-ended questions that gave consideration to the research objectives. The Likert scale (five point scale) was used, it allows the respondents to express by how much they disagree or agree with the question asked (Joshi, Kale, Chandel and Pal, 2015, p.397). The authors also explain that the respondents are given a choice of five pre-coded responses with a neutral response which implies the respondent neither disagrees nor agrees. The respondents were asked to rate each question in each section using a five-point Likert scale arranged as follows, 1-strongly disagree, 2-disagree, 3-neutral, 4-agree and 5-strongly agree. The responses are allocated scores from which the mean and standard deviation is calculated for each question (Brace, 2018, p.95).

Biographical questions were also included in the questionnaire, this included gender, age, education, position, functional area, and length of service. The questionnaire was divided into four sections, namely demographics, the current state of the maintenance management system at the organisation, the shortcomings of the current maintenance management system at the organisation and improvements required for the current maintenance management system at the organisation.

## 3.7 Data collection

When the design of the questionnaire, pilot tests and corrections are completed the data collection process may begin (Adams et al., 2014, p.72). In the case of this study the questionnaire forms part of the ethical clearance process. There is an onus on the researcher to be ethical in his/her approach in the data collection and management of the questionnaire. According to Hair et al. (2015, p.304) the purpose of the pilot study is to identify questions that are confusing to the respondents and questions that can lead to biased responses, it also tests the validity and reliability of the data collected. For this study, a sample of one research participant was used to pilot test the questionnaire before any data was collected. This process assisted the researcher by identifying questions that were confusing to the respondents and therefore some questions were rephrased to ensure the clarity. There was also no problems when the data was analysed. At the start of the data collection process, the researcher invited the research participants to a meeting at the automotive component manufacturer in KwaZulu-Natal and explained the purpose of the questionnaire and the process that will be followed. Printed copies of the questionnaire were then handed out to the research participants. The 35 research participants were then asked to complete the questionnaire and returned it to the researcher. The participants were given sufficient time to complete the questionnaire.

### 3.8 Data analysis

Data Analysis is the process of using statistical methods or other logical methods to describe, summarise and asses data (Hair et al., 2015, p.317). Adams et al. (2014, p.221) explained that computer software such as Statistical Package for the Social Science commonly known as SPSS 25 (IBM, 2018) can be used to analyse the data. For this study, the questions were captured into SPSS 25 (IBM, 2018) and the data was analysed by means of descriptive statistics. The mean was established to measure central tendency and the standard deviation to measure dispersion (Adams et al., 2014, p.169). The data analysis variables is shown on Fig 3.2 that was captured on SPSS 25 (IBM, 2018).

### 3.9 Reliability and validity of the study

Validity is defined as the degree to which a study is accurately calculated in a quantitative study. Furthermore, validity also refers to the strength of the conclusions (Adams et al., 2014, p.247).

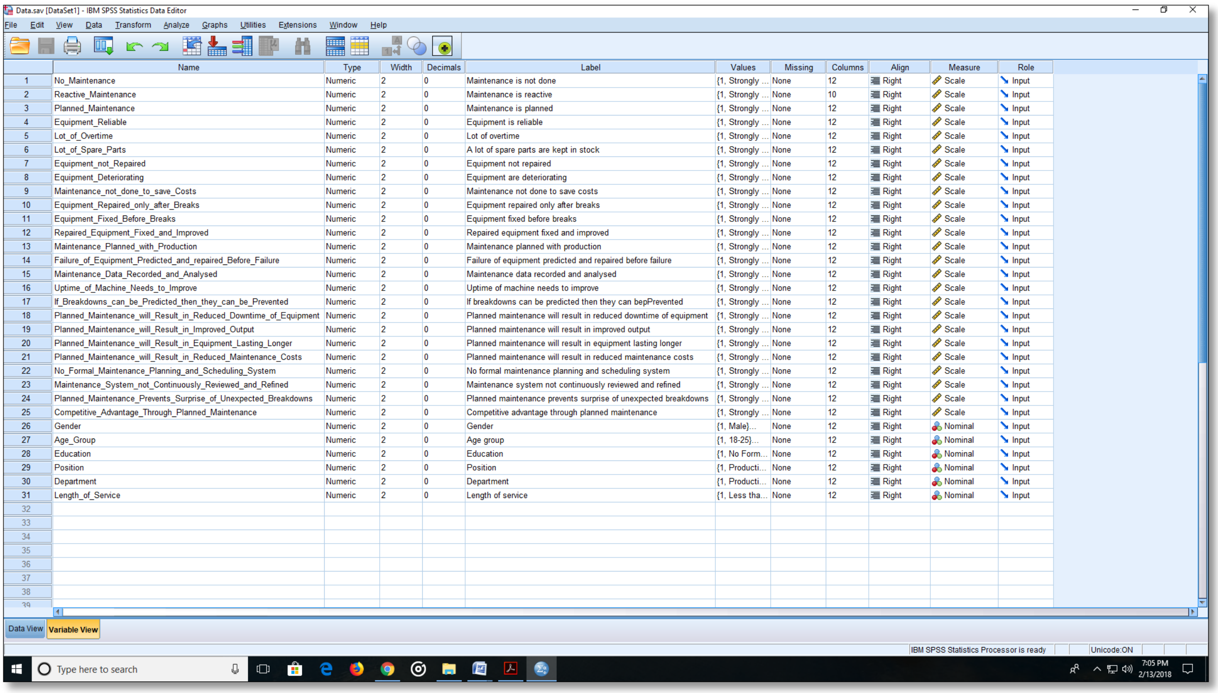
Reliability is defined as the degree to which a research instrument repeatedly has the same results if it is used in the same scenario repeatedly with the same subjects (Adams et al., 2014, p.245). For the purpose of this study Cronbach's alpha ($\alpha$) will be used to test the reliability or internal consistency of the Likert scale survey (Hair et al., 2015, p.255). A score greater than 0.7 is considered reliable (Taber, 2017, p.5). Cronbach alpha values substantially lower than 0.7 do not represent an acceptable reliability level (Taber, 2017, p.5). Table 3.1 shows the Cronbach's alpha value = 0.980 that was evaluated from the study. The result is greater than 0.7 and therefore the questionnaire was considered to have reliable internal consistency.

**Table 3. 1 Cronbach's alpha results**

| Cronbach's Alpha | N of items |
|---|---|
| 0.980 | 35 |

Adapted from IBM 2018. IBM SPSS Statistics for Windows. 25 ed.: IBM Corp. in Armonk, NY.

By using close-ended questions in the questionnaire that were aligned to the literature reviewed, content validity was attained (Babbie, 2015, p.155). Furthermore, the pilot study conducted before the main data collection ensured external validity and clarity of the questions for the data collection process (Hair et al., 2015, p.304). By using different questions to re-test the exact concept in various sections, the reliability of the data and the consistency of the respondents was achieved (Babbie, 2015, p.151).



| | Name | Type | Width | Decimals | Label | Values | Missing | Columns | Align | Measure | Role |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | No_Maintenance | Numeric | 2 | 0 | Maintenance is not done | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 2 | Reactive_Maintenance | Numeric | 2 | 0 | Maintenance is reactive | {1, Strongly ... | None | 10 | Right | Scale | Input |
| 3 | Planned_Maintenance | Numeric | 2 | 0 | Maintenance is planned | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 4 | Equipment_Reliable | Numeric | 2 | 0 | Equipment is reliable | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 5 | Lot_of_Overtime | Numeric | 2 | 0 | Lot of overtime | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 6 | Lot_of_Spare_Parts | Numeric | 2 | 0 | A lot of spare parts are kept in stock | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 7 | Equipment_not_Repaired | Numeric | 2 | 0 | Equipment not repaired | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 8 | Equipment_Deteriorating | Numeric | 2 | 0 | Equipment are deteriorating | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 9 | Maintenance_not_done_to_save_Costs | Numeric | 2 | 0 | Maintenance not done to save costs | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 10 | Equipment_Repaired_only_after_Breaks | Numeric | 2 | 0 | Equipment repaired only after breaks | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 11 | Equipment_Fixed_Before_Breaks | Numeric | 2 | 0 | Equipment fixed before breaks | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 12 | Repaired_Equipment_Fixed_and_Improved | Numeric | 2 | 0 | Repaired equipment fixed and improved | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 13 | Maintenance_Planned_with_Production | Numeric | 2 | 0 | Maintenance planned with production | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 14 | Failure_of_Equipment_Predicted_and_repaired_Before_Failure | Numeric | 2 | 0 | Failure of equipment predicted and repaired before failure | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 15 | Maintenance_Data_Recorded_and_Analysed | Numeric | 2 | 0 | Maintenance data recorded and analysed | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 16 | Uptime_of_Machine_Needs_to_Improve | Numeric | 2 | 0 | Uptime of machine needs to improve | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 17 | If_Breakdowns_can_be_Predicted_then_they_can_be_Prevented | Numeric | 2 | 0 | If breakdowns can be predicted then they can bepPrevented | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 18 | Planned_Maintenance_will_Result_in_Reduced_Downtime_of_Equipment | Numeric | 2 | 0 | Planned maintenance will result in reduced downtime of equipment | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 19 | Planned_Maintenance_will_Result_in_Improved_Output | Numeric | 2 | 0 | Planned maintenance will result in improved output | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 20 | Planned_Maintenance_will_Result_in_Equipment_Lasting_Longer | Numeric | 2 | 0 | Planned maintenance will result in equipment lasting longer | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 21 | Planned_Maintenance_will_Result_in_Reduced_Maintenance_Costs | Numeric | 2 | 0 | Planned maintenance will result in reduced maintenance costs | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 22 | No_Formal_Maintenance_Planning_and_Scheduling_System | Numeric | 2 | 0 | No formal maintenance planning and scheduling system | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 23 | Maintenance_System_not_Continuously_Reviewed_and_Refined | Numeric | 2 | 0 | Maintenance system not continuously reviewed and refined | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 24 | Planned_Maintenance_Prevents_Surprise_of_Unexpected_Breakdowns | Numeric | 2 | 0 | Planned maintenance prevents surprise of unexpected breakdowns | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 25 | Competitive_Advantage_Through_Planned_Maintenance | Numeric | 2 | 0 | Competitive advantage through planned maintenance | {1, Strongly ... | None | 12 | Right | Scale | Input |
| 26 | Gender | Numeric | 2 | 0 | Gender | {1, Male}... | None | 12 | Right | Nominal | Input |
| 27 | Age_Group | Numeric | 2 | 0 | Age group | {1, 18-25}... | None | 12 | Right | Nominal | Input |
| 28 | Education | Numeric | 2 | 0 | Education | {1, No Form... | None | 12 | Right | Nominal | Input |
| 29 | Position | Numeric | 2 | 0 | Position | {1, Producti... | None | 12 | Right | Nominal | Input |
| 30 | Department | Numeric | 2 | 0 | Department | {1, Producti... | None | 12 | Right | Nominal | Input |
| 31 | Length_of_Service | Numeric | 2 | 0 | Length of service | {1, Less tha... | None | 12 | Right | Nominal | Input |

**Figure 3. 2 Data analysis variables**

Adapted from IBM 2018. IBM SPSS Statistics for Windows. 25 ed.: IBM Corp. in Armonk, NY.

## 3.10 Bias

Hair et al. (2015, p.284) defines bias as any propensity that stops the fair consideration of a question. The authors further explain that bias can occur at any stage of the study and it usually occurs when a systematic fault is created during sampling, testing or forcing a particular result and avoiding others. Furthermore, research participant bias was minimised significantly by engaging the research participants at a convenient location and time (Adams et al., 2014, p.88).

## 3.11 Ethical considerations

According to Adams et al. (2014, p.21), ethical considerations in research are very important because ethics are the standard for our behaviour and it helps us to decipher right from wrong. The authors also explain that it refers to the appropriate behaviour of the researcher when considering human rights, and the rights of organisations and various other stakeholders when conducting research. A key requirement for research participants is the granting of their informed consent. There is an onus on the researcher to be honest and have integrity and to ensure the confidentiality of identity, safety and privacy of the participants (Adams et al., 2014, p.23).

For this study, at the start of the data collection process, the researcher invited the research participants to a meeting at the automotive component manufacturer in KwaZulu-Natal and explained the purpose of the questionnaire and the process that will be followed and then asked the research participants to consider taking part in the study. An informed consent form (Appendix 2) was discussed with the research participants, it outlined the aim and objective of the research and the voluntary participation of the research participants. It also guaranteed their privacy and confidentiality.

Throughout the research process, responsibility, integrity and respect for human rights were practiced and gave direction when decisions were taken. The researcher was responsible for the entire project and avoided any form of personal influence over the responses of the research participants and therefore ensured that the research participants were given the liberty and impartiality on their part.

### 3.12 Summary

This chapter discussed the research methodology and process used to conduct the study and to answer the research questions. A quantitative research method was employed to investigate the challenges that impede the proper functioning of a planned maintenance system at an automotive component manufacturer. Closed-ended questions were used in the questionnaire and the data was captured and analysed using the Statistical Package for the Social Science (SPSS). The next chapter is the presentation of the results. This chapter will cover the results and findings of this research.

# CHAPTER FOUR - PRESENTATION OF RESULTS

## 4.1 Introduction

This chapter covers the results and findings of this research. To facilitate the understanding of the quantitative information, the researcher summarised the results and findings using tables and figures. The primary objective of this study is to investigate the challenges that impede the proper functioning of a planned maintenance system at an automotive component manufacturer. The objectives of this research were as follows:

- To explore the current state of the maintenance management system at the organisation.
- To identify the shortcomings of the current maintenance management system at the organisation.
- To identify what improvements are required for the current maintenance management system at the organisation.
- To provide recommendations based on the shortcomings identified.

## 4.2 Demographics

The genders of the research subjects are summarised on Table 4.1 and Figure 4.1. As shown on Table 4.1, more than 82 percent of the research subjects are male while only about 17 percent are female.

**Table 4. 1 Gender of research subjects**

| Gender | Frequency | Percent |
|---|---|---|
| Male | 29 | 82.9 |
| Female | 6 | 17.1 |
| Total | 35 | 100 |

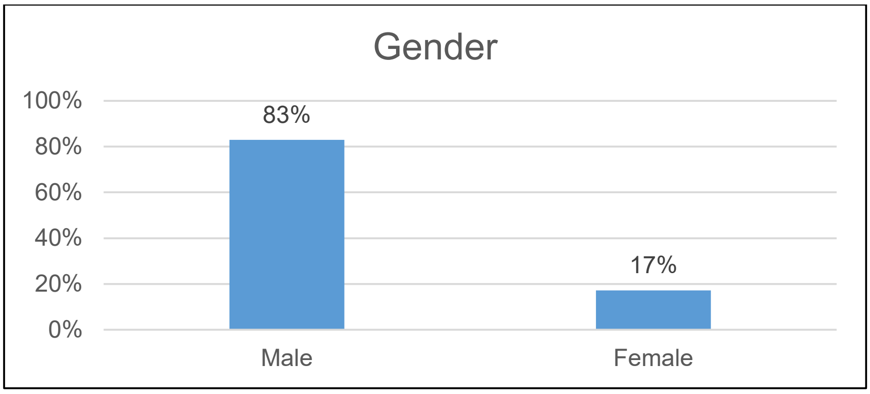



**Figure 4. 1 Gender of research subjects**

The age groups of the research participants are shown on Table 4.2 and Figure 4.2. As shown on Table 4.2 more than 34 percent of the research subjects are 46 to 55 years old while more than 31 percent are 36 to 45 years old. In addition, 20 percent of the research subjects are 26 to 35 years old. However, only more than eight percent of the research subjects are 18 to 25 years old while only more than five percent are 56 to 65 years old.

**Table 4. 2 Age group of the research subjects**

| Age Group | Frequency | Percent |
|---|---|---|
| 18 to 25 years | 3 | 8.6 |
| 26 to 35 years | 7 | 20.0 |
| 36 to 45 years | 11 | 31.4 |
| 46 to 55 years | 12 | 34.3 |
| 56 to 65 years | 2 | 5.7 |
| Total | 35 | 100 |

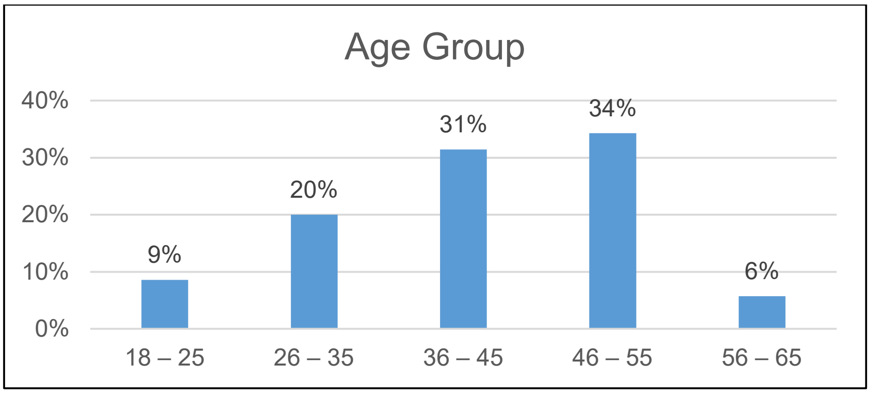



**Figure 4. 2 Age group of the research subjects**

The education of the research subjects are shown on Table 4.3 and Figure 4.3. As shown on Table 4.3, 60 percent of the research subjects have a matric level education while 20 percent have a diploma level education. However, 20 percent of the research subjects have no formal education.

**Table 4. 3 Education of the research subjects**

| Education | Frequency | Percent |
|---|---|---|
| No formal education | 7 | 20.0 |
| Matric | 21 | 60.0 |
| Diploma | 7 | 20.0 |
| Total | 35 | 100 |

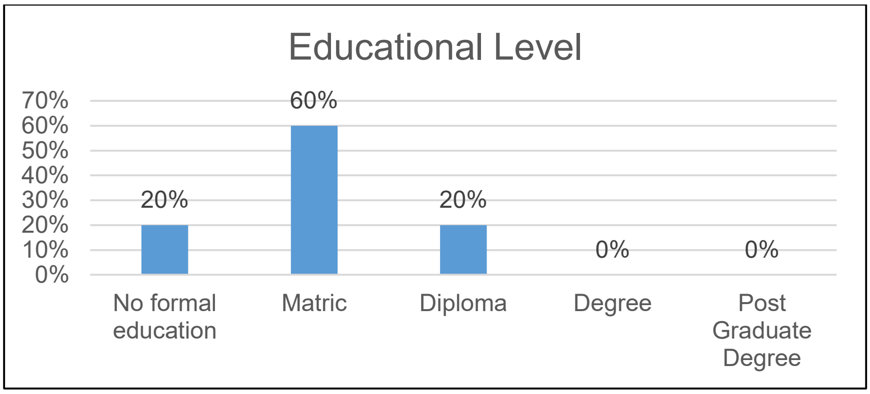



**Figure 4. 3 Education of the research subjects**

The positions of the research subjects are shown on Table 4.4 and Figure 4.4. As shown on Table 4.4, more than 34 percent of the research subjects are maintenance artisans while more than 28 percent are production operators. In addition, more than 14 percent of the research subjects are maintenance coordinators while only less than six percent are engineers, production supervisors, and machine setters. More so, less than three percent of the research subjects are value steam managers, and production zone leaders.

**Table 4. 4 Position of the research subjects**

| Position | Frequency | Percent |
|---|---|---|
| Production operator | 10 | 28.6 |
| Machine setter | 2 | 5.7 |
| Maintenance artisan | 12 | 34.3 |
| Maintenance coordinator | 5 | 14.3 |
| Engineer | 2 | 5.7 |
| Production zone leader | 1 | 2.9 |
| Production supervisor | 2 | 5.7 |
| Value steam manager | 1 | 2.9 |
| Total | 35 | 100 |

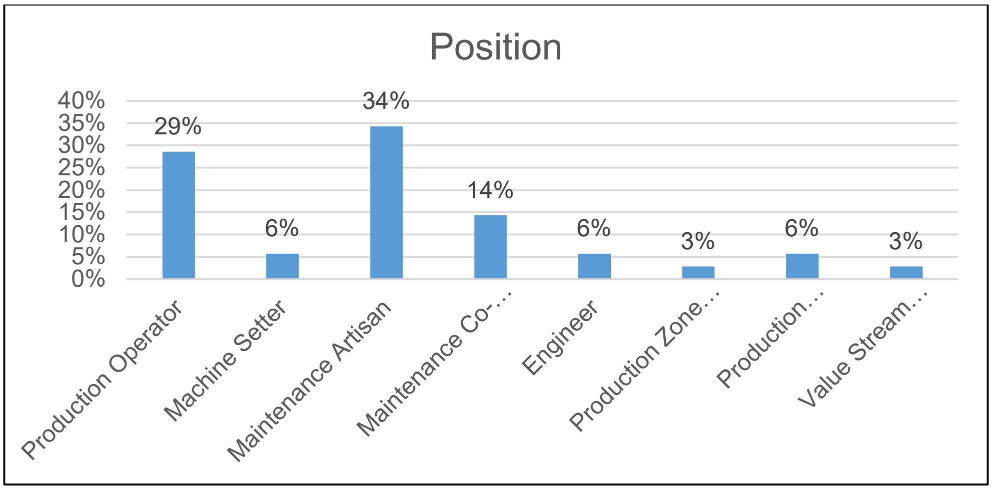



**Figure 4. 4 Position of the research subjects**

The departments of the research subjects are shown on Table 4.5 and Figure 4.5. As shown on Table 4.5, 45.7 percent of the research subjects are in the production or engineering departments. However, 8.6 percent of the research subjects are in the maintenance department.

**Table 4. 5 Department of research subjects**

| Department | Frequency | Percent |
|---|---|---|
| Production | 16 | 45.7 |
| Engineering | 16 | 45.7 |
| Maintenance | 3 | 8.6 |
| Total | 35 | 100 |

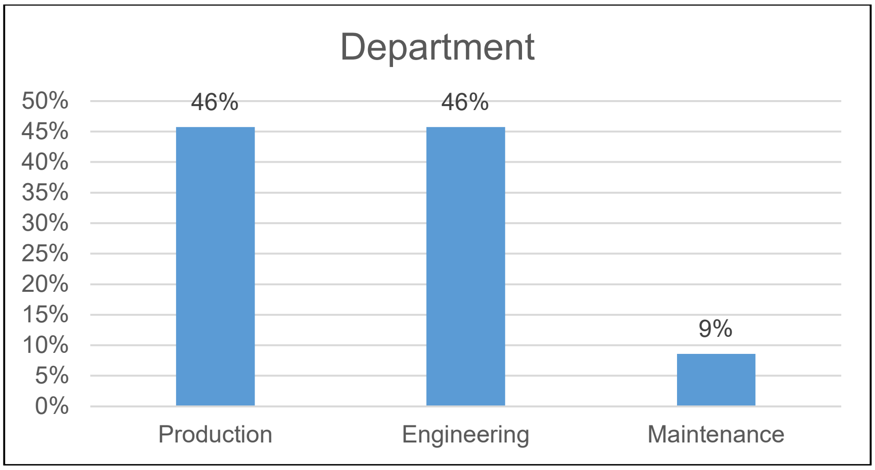



**Figure 4. 5 Department of the research subjects**

And lastly, the lengths of service of the research subjects are shown on Table 4.6 and Figure 4.6. As shown on Table 4.6, more than 37 percent of the research subjects have worked for less than 5 years while more than 37 percent have worked for more than 20 years. In addition, more than 17 percent of the research subjects have worked for five to ten years and more than five percent have worked for 16 to 20 years. However, less than three percent of the research subjects have worked for 11 to 15 years.

**Table 4. 6 Length of service of research subjects**

| Length of Service | Frequency | Percent |
|---|---|---|
| Less than 5 years | 13 | 37.1 |
| 5 to 10 years | 6 | 17.1 |
| 11 to 15 years | 1 | 2.9 |
| 16 to 20 years | 2 | 5.7 |
| More than 20 years | 13 | 37.1 |
| Total | 35 | 100 |

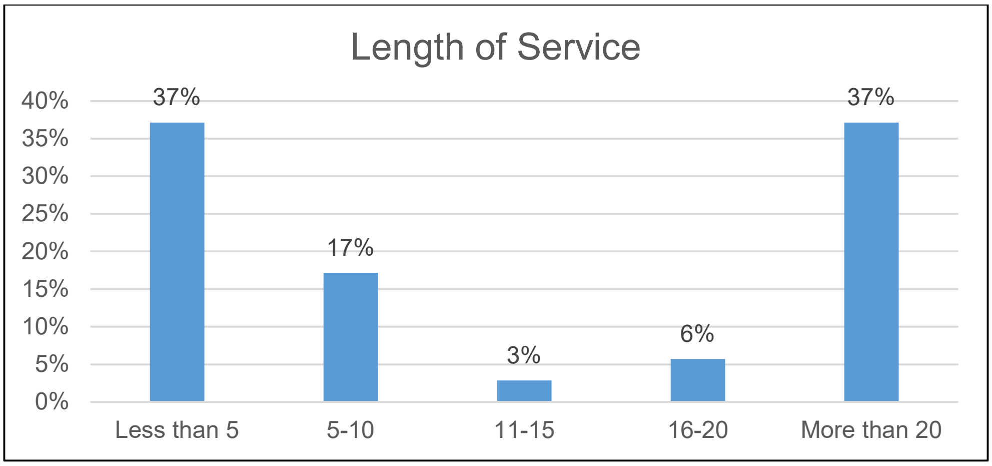



**Figure 4. 6 Length of service of the research subjects**

## 4.3 Descriptive Statistics

The research participants were asked to respond to statements in the questionnaire using the following five-point Likert scale shown on Table 4.7:

**Table 4. 7 Likert scale**

| | |
|---|---|
| Strongly Disagree | 1 |
| Disagree | 2 |
| Neutral | 3 |
| Agree | 4 |
| Strongly Agree | 5 |

Adapted from Joshi, A., Kale, S., Chandel, S. & Pal, D. 2015. Likert scale: Explored and explained. British Journal of Applied Science & Technology, 7, 396.

The 25 questions on the questionnaire were grouped into three sub-sections that are presented subsequently.

### 4.3.1 What is the current state of the maintenance management system at the organisation?

The means and standard deviations of the responses to the sub-questions or sub-variables under this main variable are shown on Table 4.8.

**Table 4. 8 Current state of the maintenance management system at the organisation**

| Variable | Mean | Standard Deviation |
|---|---|---|
| Maintenance is not done. Machines are not fixed. The fix is delayed. | 3.20 | 1.491 |
| Maintenance is reactive. Equipment is fixed after it breaks | 3.77 | 1.190 |
| Maintenance is planned. Equipment is fixed before it breaks. | 3.29 | 1.250 |
| Equipment is reliable. Equipment is fixed and improved. | 3.14 | 1.309 |
| A lot of overtime is worked to repair breakdowns. | 3.20 | 1.346 |
| A lot of spare parts are kept in stock in preparation for breakdowns. | 3.09 | 1.337 |
| Equipment are not repaired in order to save on the maintenance budget. | 3.40 | 1.288 |

On Table 4.8, a mean value that is close to one shows strong disagreement to the sub-question while a mean value that is close to two indicates disagreement to the sub-question. Conversely, a mean value that is close to four shows agreement to the sub-question while a mean value that is close to five shows strong agreement to the sub-question. However, a mean value that is close to three shows a neutral agreement to the sub-question. To interpret the results, the mean values are rounded to the nearest whole numbers.

The results on Table 4.8 show that these distributions have mean values that are close to four and three. The standard deviations of these distributions are above one and this shows that some respondents may be far away from the mean even though there is agreement among the respondents. According to the output presented on Figure 4.7, the majority (42%) of the research subjects disagreed that maintenance is not done such that the fix is delayed. Table 4.8 shows the results of this distribution. However, the standard deviation is above one (s = 1.491) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

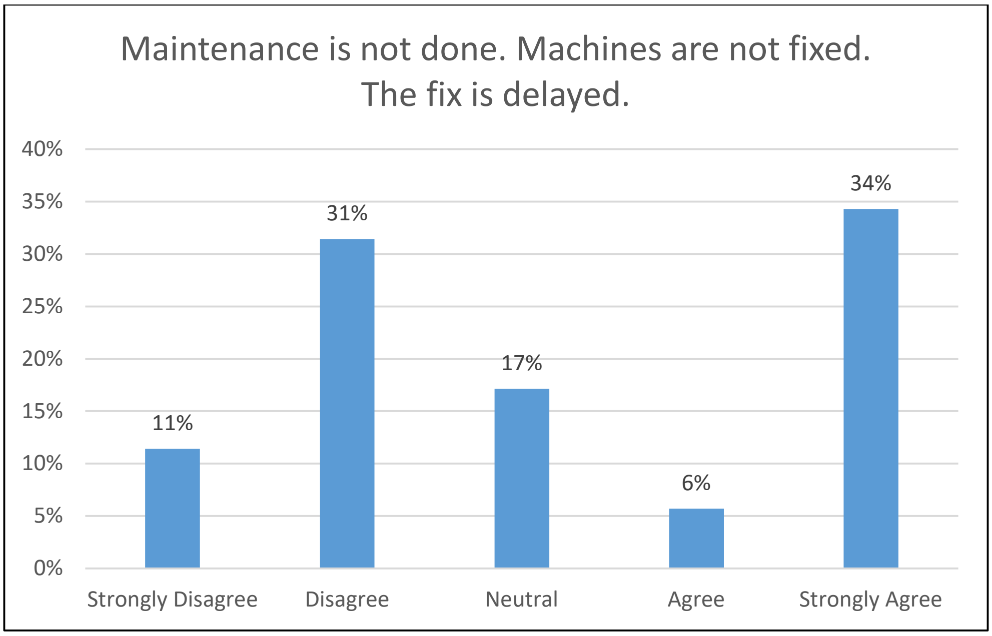



**Figure 4. 7 Maintenance is not done**

In addition, Figure 4.8 shows that the majority (60%) of the research subjects agreed that maintenance is reactive such that it is fixed after it breaks. Table 4.8 shows the results of this distribution. Similarly, the standard deviation is above one (s = 1.190) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

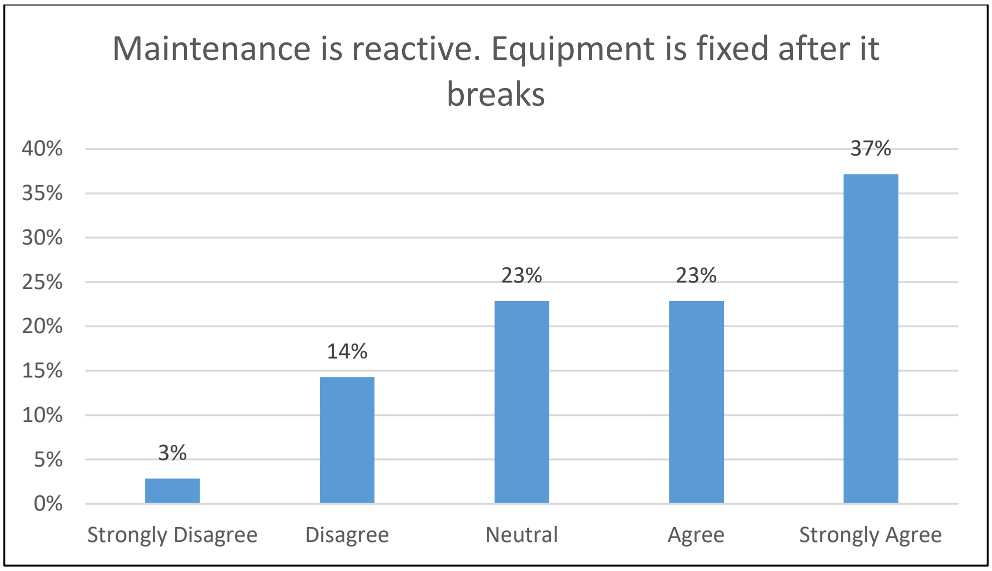



**Figure 4. 8 Maintenance is reactive**

Furthermore, Figure 4.9 shows that the majority (46%) of the research subjects agreed that maintenance is planned. Table 4.8 shows the results of this distribution. Again, the standard deviation is above one (s = 1.250) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

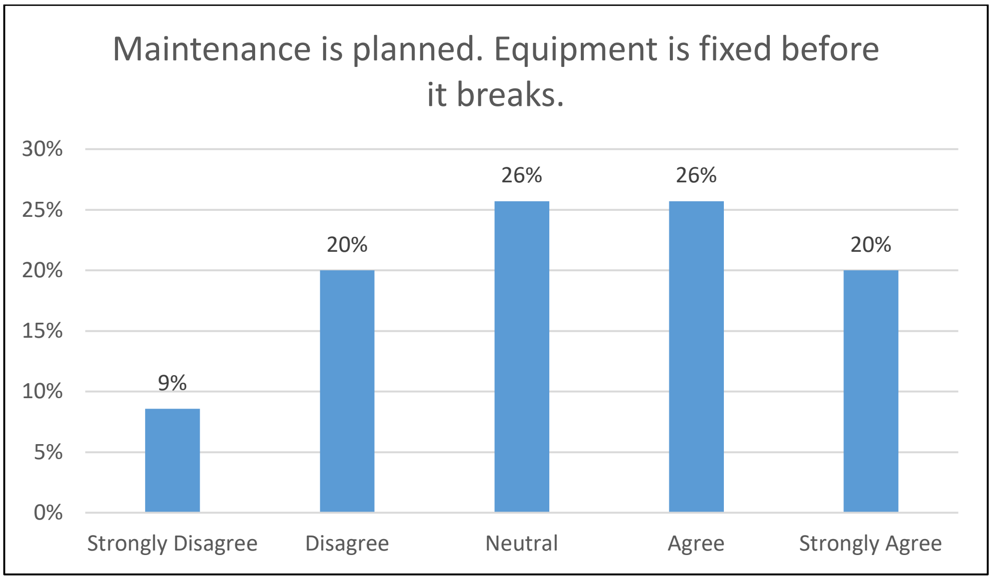



**Figure 4. 9 Maintenance is planned**

Then, Figure 4.10 shows that the majority (43%) of the research subjects disagreed that equipment is reliable and equipment is fixed and improved. Table 4.8 shows the results of this distribution. As indicated, the standard deviation is above one (s = 1.309) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

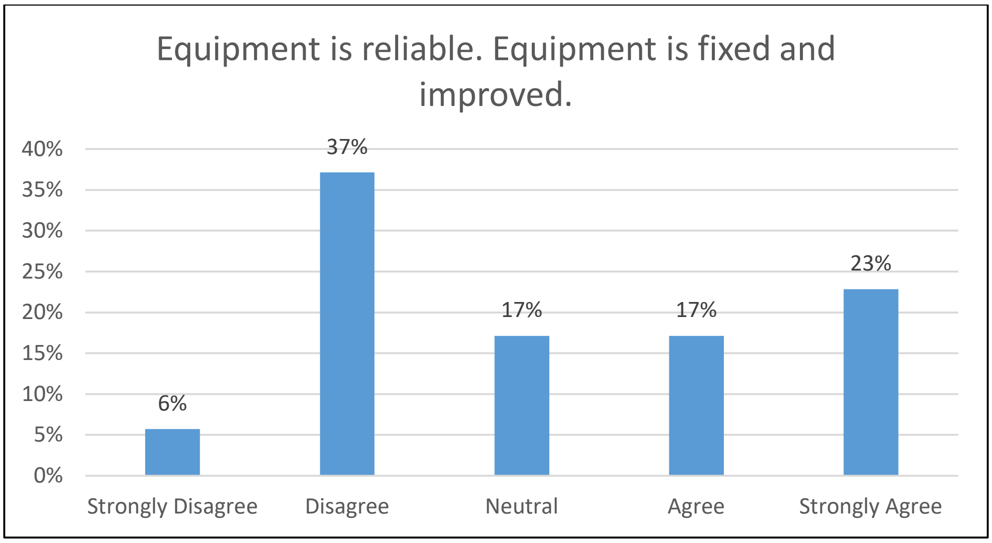



**Figure 4. 10 Equipment is reliable**

Next, Figure 4.11 shows that the majority (46%) of the research subjects disagreed that a lot of overtime is worked to repair breakdowns. Table 4.8 shows the results of this distribution. As shown, the standard deviation is above one (s = 1.346) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

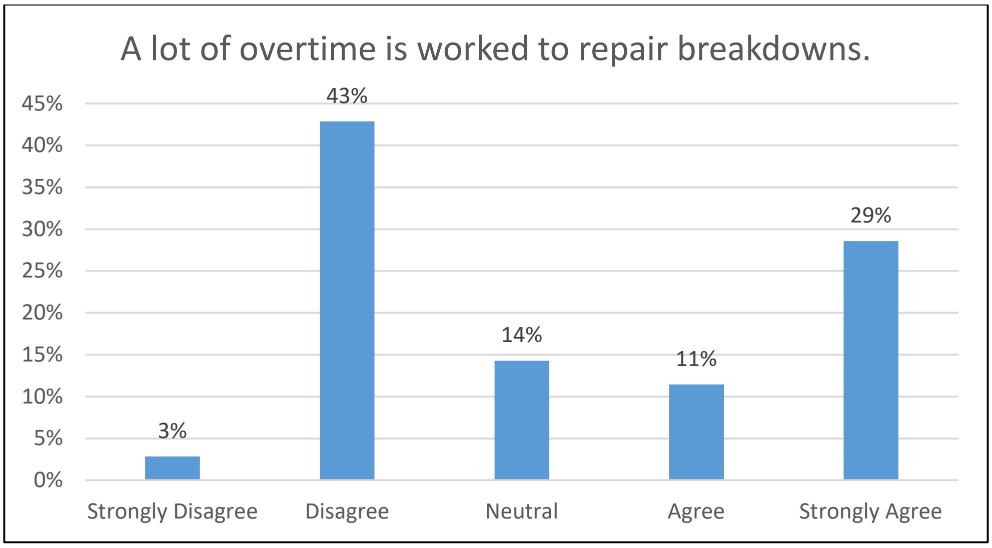



**Figure 4. 11 A lot of overtime is worked**

More to this, Figure 4.12 shows that the majority (37%) of the research subjects disagreed that a lot of spare parts are kept in stock in preparation for breakdowns. Table 4.8 shows the results of this distribution. As indicated, the standard deviation is above one (s = 1.337) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

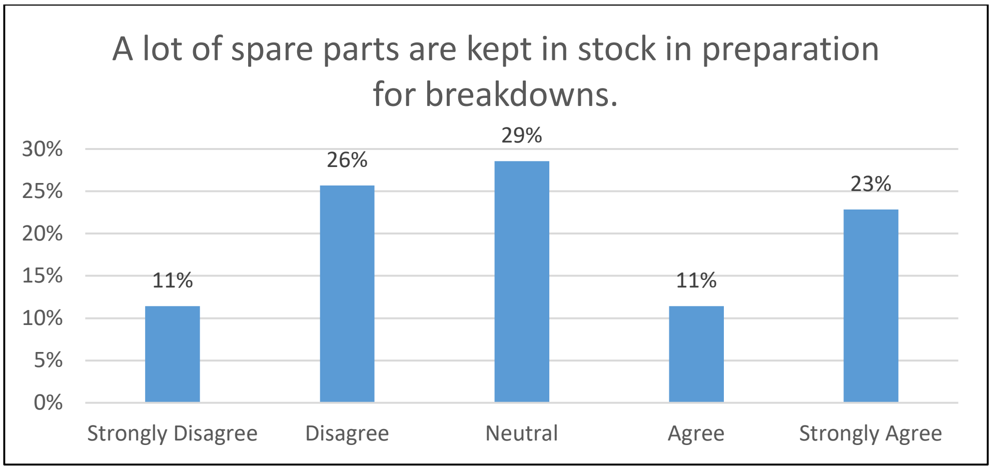



**Figure 4. 12 A lot of spare parts are kept in stock**

And lastly, Figure 4.13 shows that the majority (40%) of the research subjects agreed that the equipment is not repaired in order to save on the maintenance budget. Table 4.8 shows the results of this distribution. In this distribution, the standard deviation is above one (s = 1.288) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

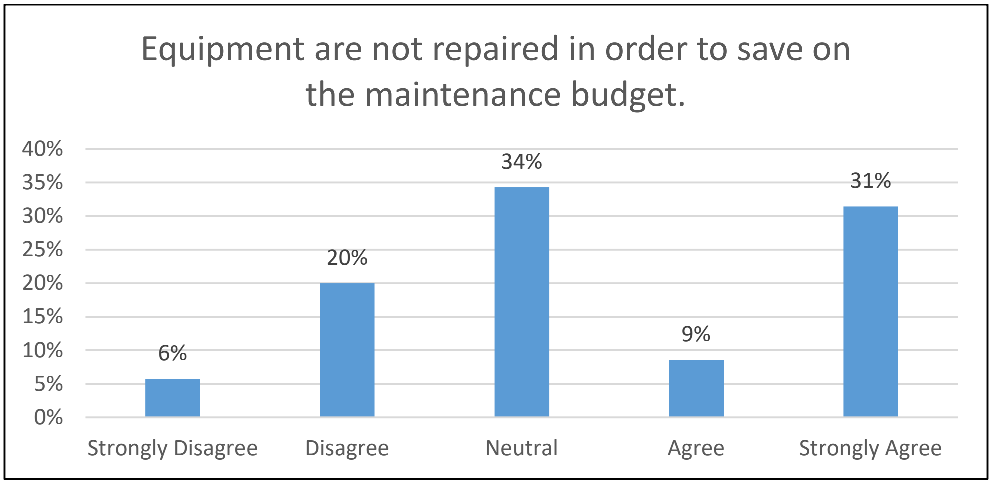



**Figure 4. 13 Equipment not repaired**

### 4.3.2 What are the shortcomings of the current maintenance management system at the organisation?

The means and standard deviations of the responses to the sub-questions or sub-variables under this main variable are shown on Table 4.9.

**Table 4. 9 Shortcomings of the current maintenance management system**

| Variable | Mean | Standard Deviation |
|---|---|---|
| Equipment are deteriorating | 4.11 | 1.022 |
| Maintenance is not done to save on maintenance costs. | 3.34 | 1.282 |
| Equipment is repaired only after it breaks. | 3.69 | 1.255 |
| Equipment is fixed before it breaks. | 3.14 | 1.332 |
| When equipment is repaired it is not only fixed it is improved as well | 3.37 | 1.352 |
| Maintenance of equipment is planned in conjunction with production. | 3.83 | 1.150 |
| Failure of equipment is predicted and repaired before it fails. | 2.86 | 1.458 |
| Data from maintenance and breakdowns are recorded and analysed | 3.83 | 1.098 |

On Table 4.9, a mean value that is close to one shows strong disagreement to the sub-question while a mean value that is close to two indicates disagreement to the sub-question. Conversely, a mean value that is close to four shows agreement to the sub-question while a mean value that is close to five shows strong agreement to the sub-question. However, a mean value that is close to three shows a neutral agreement to the sub-question. To interpret the results, the mean values are rounded to the nearest whole numbers.

According to the output presented on Figure 4.14, the majority (72%) of the research subjects agreed that the equipment is deteriorating. Table 4.9 shows the results of this distribution. However, the standard deviation is above one (s = 1.022) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

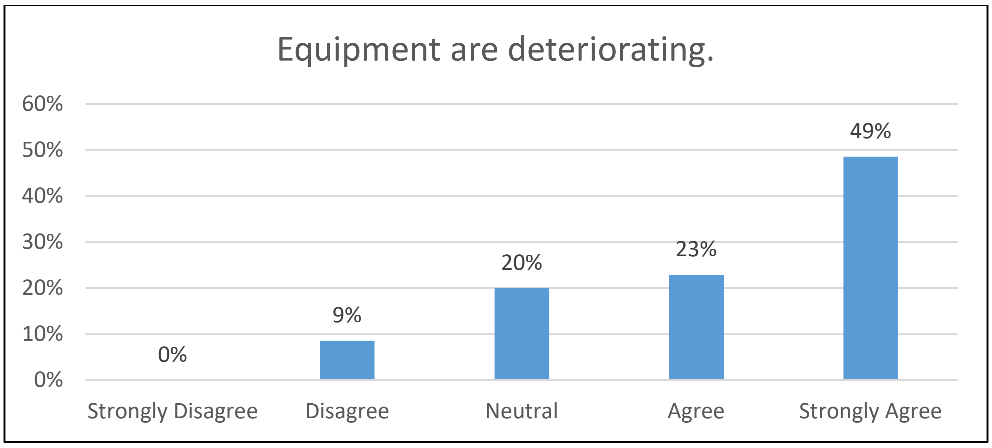



**Figure 4. 14 Equipment are deteriorating**

Then, Figure 4.15 shows that the majority (49%) of the research subjects agreed that maintenance is not done to save on maintenance costs. Table 4.9 shows the results of this distribution. Similarly, the standard deviation is above one (s = 1.282) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

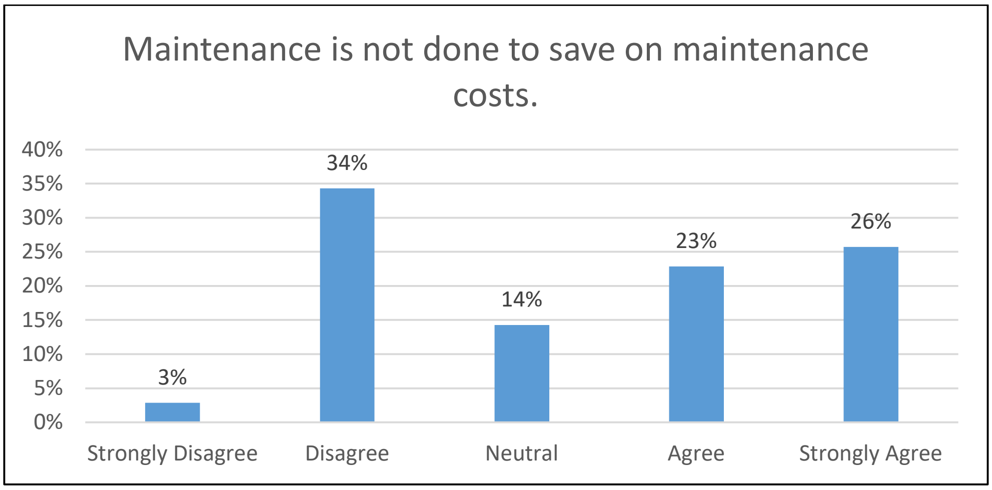



**Figure 4. 15 Maintenance is not done to save cost**

Next, Figure 4.16 shows that the majority (63%) of the research subjects agreed that equipment is repaired only after it breaks. Table 4.9 shows the results of this distribution. Again, the standard deviation is above one (s = 1.255) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

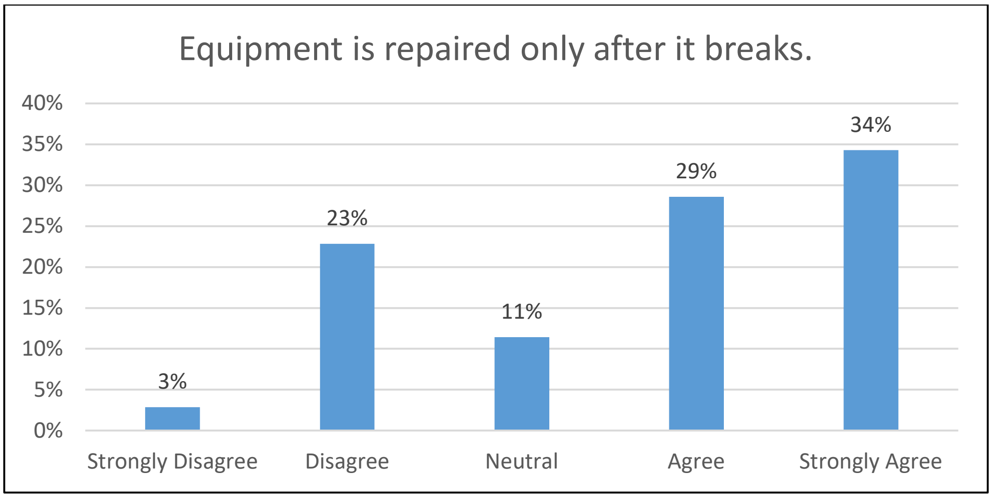



**Figure 4. 16 Equipment repaired only after breaks**

In addition, Figure 4.17 shows that the majority (43%) of the research subjects agreed that the equipment is fixed before breaks. Table 4.9 shows the results of this distribution. As indicated, the standard deviation is above one (s = 1.332) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

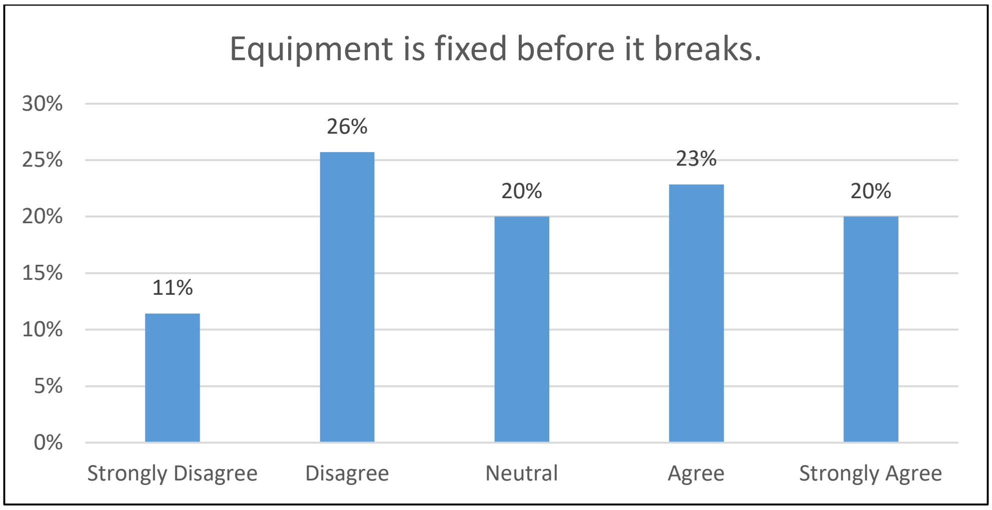



**Figure 4. 17 Equipment fixed before breaks**

Furthermore, Figure 4.18 shows that the majority (54%) of the research subjects agreed that the repaired equipment is fixed and improved. Table 4.9 shows the results of this distribution. As shown, the standard deviation is above one (s = 1.352) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

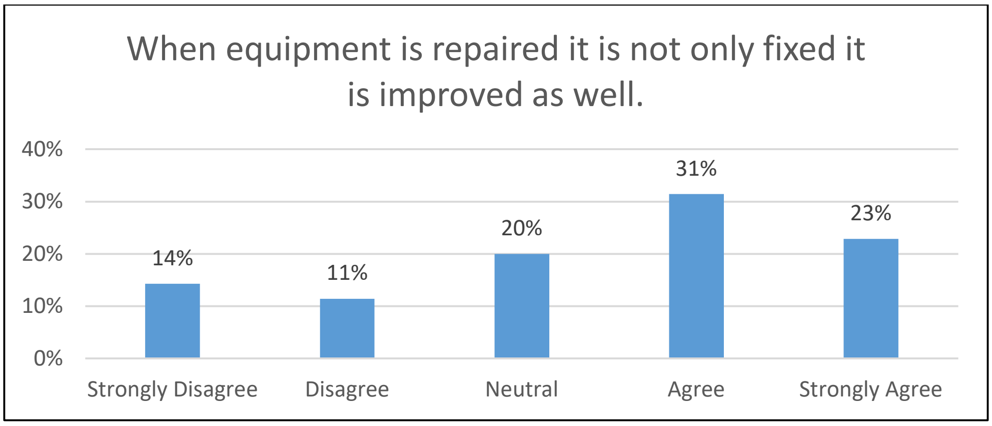



**Figure 4. 18 Repaired equipment fixed and improved**

More to this, Figure 4.19 shows that the majority (65%) of the research subjects agreed that maintenance is planned with production. Figure 4.19 shows the results of this distribution. As indicated, the standard deviation is above one (s = 1.150) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

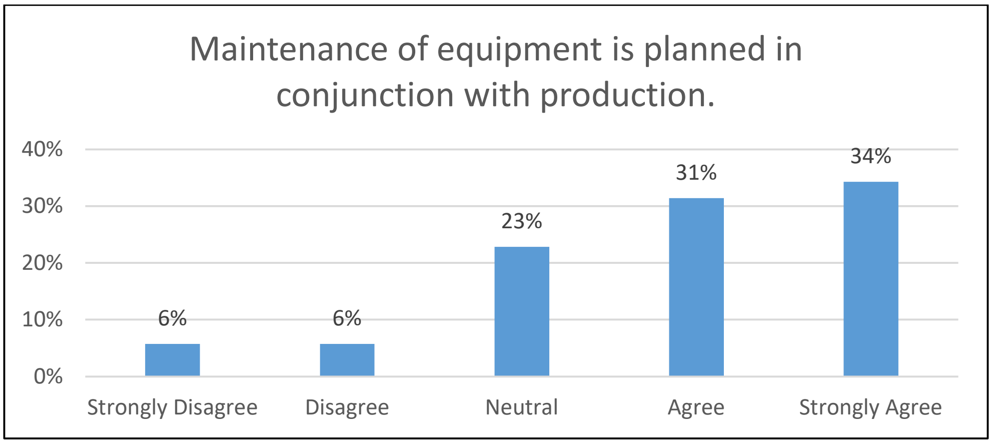



**Figure 4. 19 Maintenance planned with production**

Moreover, Figure 4.20 shows that the majority (51%) of the research subjects disagreed that the failure of equipment is predicted and repaired before failure. Table 4.9 shows the results of this distribution. In this distribution, the standard deviation is almost one (s = 1.458) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

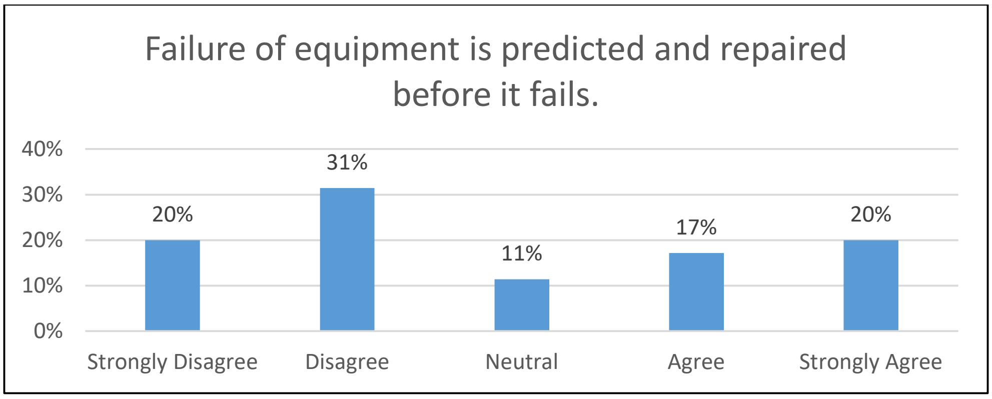



**Figure 4. 20 Failure of equipment predicted and repaired before failure**

And lastly, Figure 4.21 shows that the majority (72%) of the research subjects agreed that maintenance data is recorded and analysed. Table 4.9 shows the results of this distribution. In this distribution, the standard deviation is more than one (s = 1.098) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

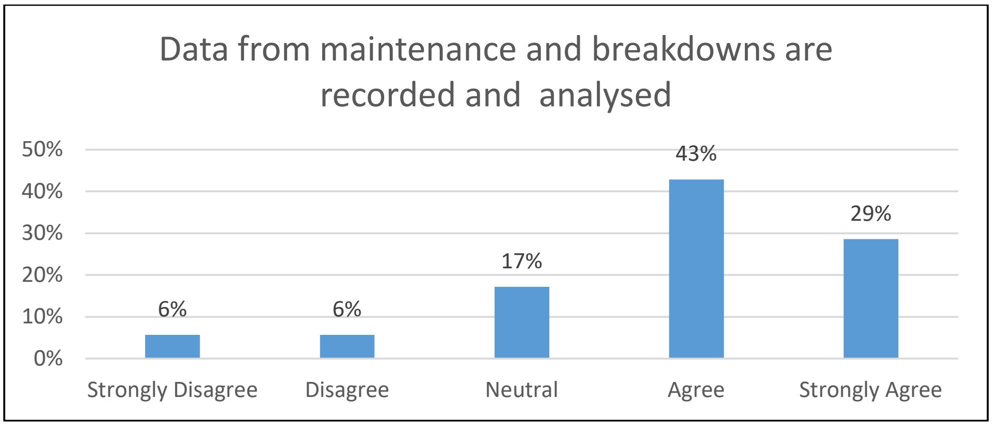



**Figure 4. 21 Maintenance data recorded and analysed**

### 4.3.3 What improvements are required for the current maintenance management system at the organisation?

The means and standard deviations of the responses to the sub-questions or sub-variables under this main variable are shown on Table 4.10

**Table 4. 10 Improvements that are required for the current maintenance management system at the organisation**

| Variable | Mean | Standard Deviation |
|---|---|---|
| Uptime of machines needs to improve | 4.34 | 0.802 |
| If breakdowns can be predicted before they happen then the breakdown can be prevented. | 4.60 | 0.604 |
| Planned maintenance will result in reduced downtime of equipment. | 4.54 | 0.657 |
| Planned maintenance will result in improved output (pieces) of the plant. | 4.54 | 0.611 |
| Planned maintenance will result in the equipment lasting longer. | 4.54 | 0.611 |
| Planned maintenance will result in reduced maintenance costs. | 4.20 | 1.023 |
| There is no formal maintenance planning and scheduling system | 3.26 | 1.379 |
| The planned maintenance system is not continuously reviewed and refined. | 3.80 | 1.106 |
| Planned maintenance prevents the surprise of unexpected breakdowns. | 4.51 | 0.612 |
| A competitive advantage can be achieved by implementing a planned maintenance system. | 4.43 | 0.698 |

On Table 4.10, a mean value that is close to one shows strong disagreement to the sub-question while a mean value that is close to two indicates disagreement to the sub-question. Conversely, a mean value that is close to four shows agreement to the sub-question while a mean value that is close to five shows strong agreement to the sub-question. However, a mean value that is close to three shows a neutral agreement to the sub-question. To interpret the results, the mean values are rounded to the nearest whole numbers.

The results on Table 4.10 show that all of these distributions have a mean value of more than three and almost all but three of the standard deviations of these distributions are less than one and this shows that most respondents are close to the mean and there is agreement among the respondents. According to the output presented on Figure 4.22, the majority (95%) of the research subjects agreed that the uptime of machine needs to be improved. Table 4.10 shows the results of this distribution. However, the standard deviation is less than one (s = 0.802) and this shows that most of the respondents are very close to the mean and the strong agreement is generally high among the respondents.

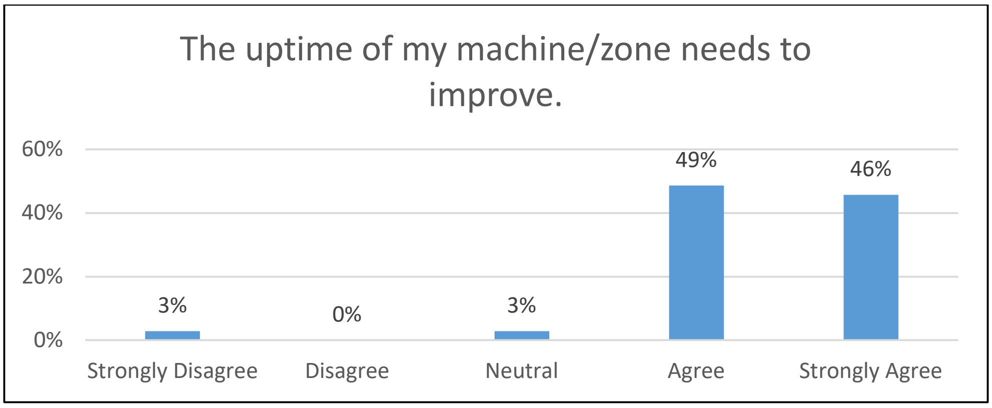



**Figure 4. 22 Uptime of machine needs to improve**

Then, Figure 4.23 shows that the majority (95%) of the research subjects agreed that if breakdowns can be predicted then they can be prevented. Table 4.10 shows the results of this distribution. Similarly, the standard deviation is less than one (s = 0.604) and the strong agreement is generally high among the respondents.

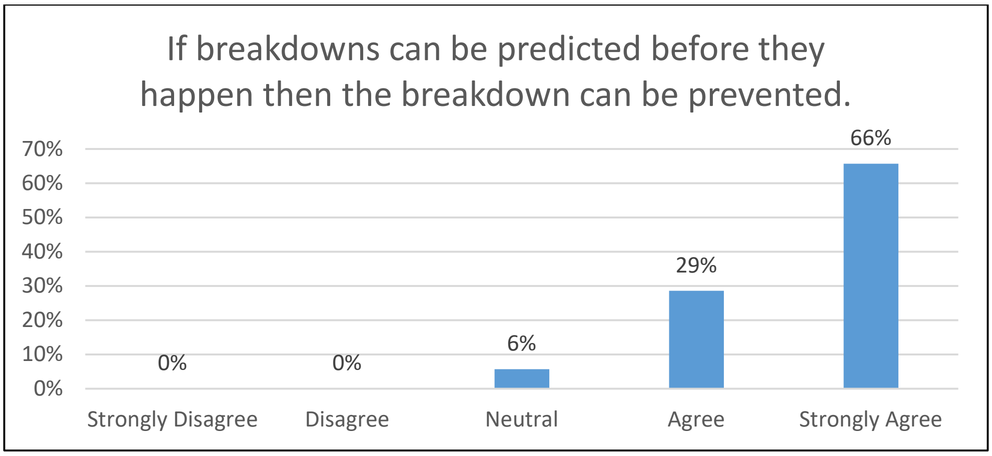



**Figure 4. 23 If breakdowns can be predicted then they can be prevented**

Next, Figure 4.24 shows that the majority (92%) of the research subjects agreed that planned maintenance will result in reduced downtime of equipment. Table 4.10 shows the results of this distribution. Again, the standard deviation is less than one (s = 0.657) and the strong agreement is generally high among the respondents.

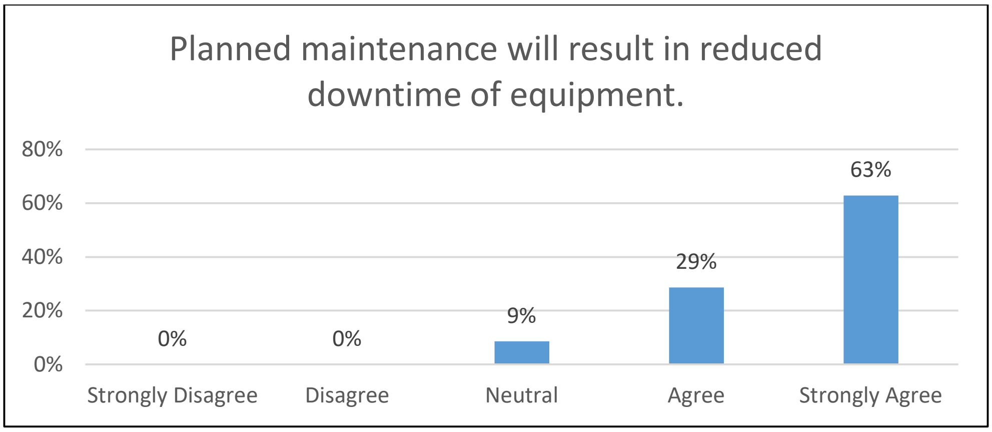



**Figure 4. 24 Planned maintenance will result in reduced downtime of equipment**

In addition, Figure 4.25 shows that the majority (94%) of the research subjects agreed that planned maintenance will result in improved output. Table 4.10 shows the results of this distribution. More so, the standard deviation is less than one (s = 0.611) and the strong agreement is generally high among the respondents.

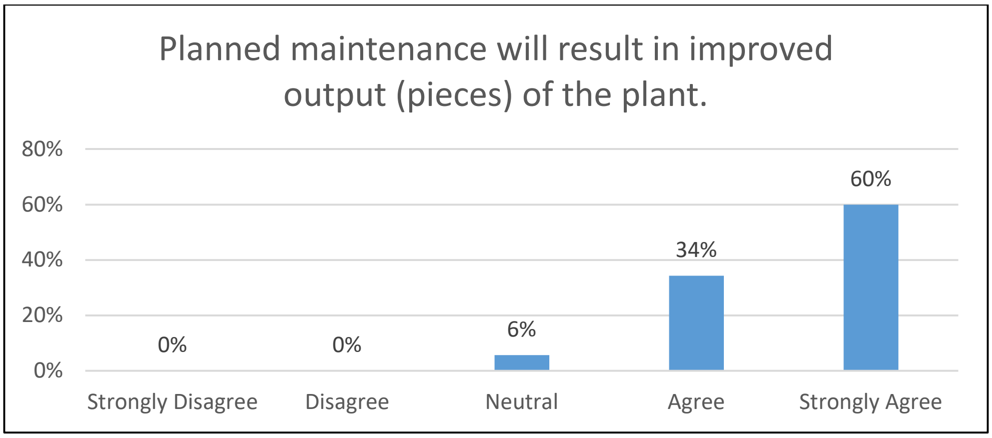



**Figure 4. 25 Planned maintenance will result in improved output**

Furthermore, Figure 4.26 shows that the majority (94%) of the research subjects agreed that planned maintenance will result in lasting equipment. Table 4.10 shows the results of this distribution. As indicated, the standard deviation is less than one (s = 0.611) and the strong agreement is generally high among the respondents.

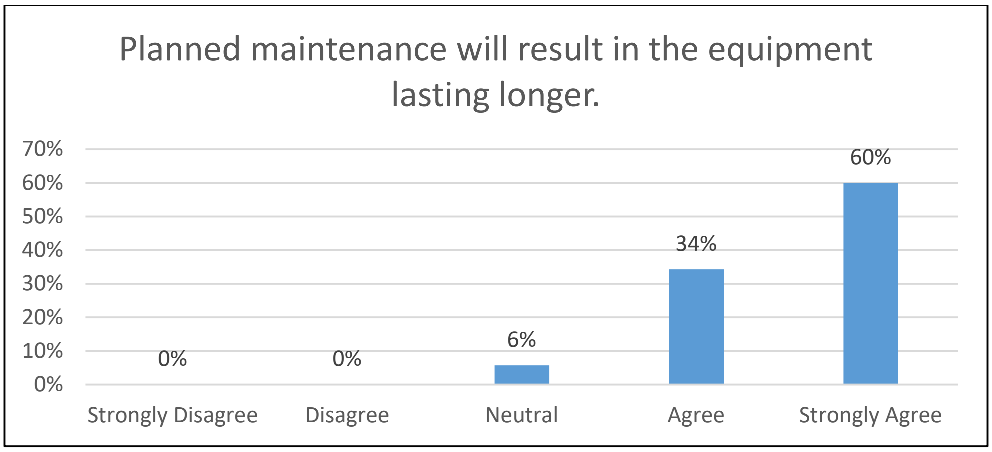



**Figure 4. 26 Planned maintenance will result in equipment lasting**

More to this, Figure 4.27 shows that the majority (74%) of the research subjects agreed that planned maintenance will result in reduced maintenance cost. Table 4.10 shows the results of this distribution. As shown, the standard deviation is above one (s = 1.023) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

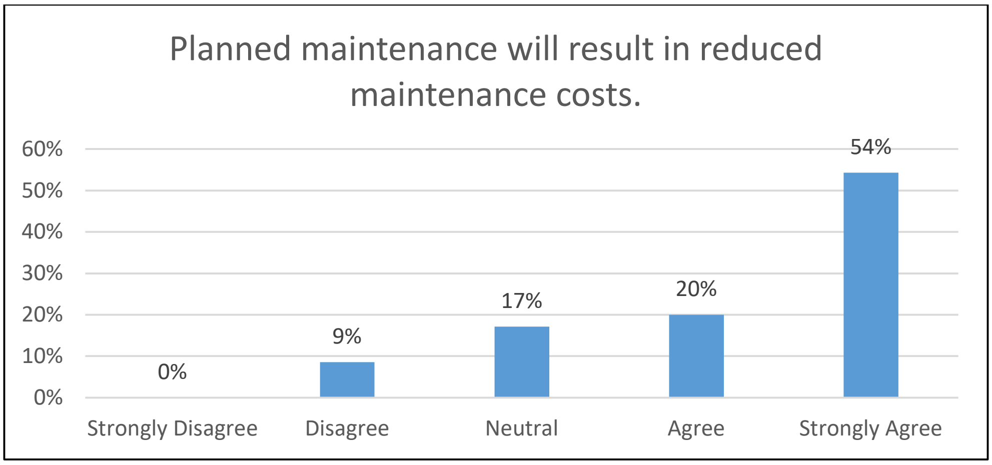



**Figure 4. 27 Planned maintenance will result in reduced maintenance cost**

Moreover, Figure 4.28 shows that the majority (40%) of the research subjects agreed that there is no formal maintenance planning and scheduling system. Table 4.10 shows the results of this distribution. In this distribution, the standard deviation is also above one (s = 1.379) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

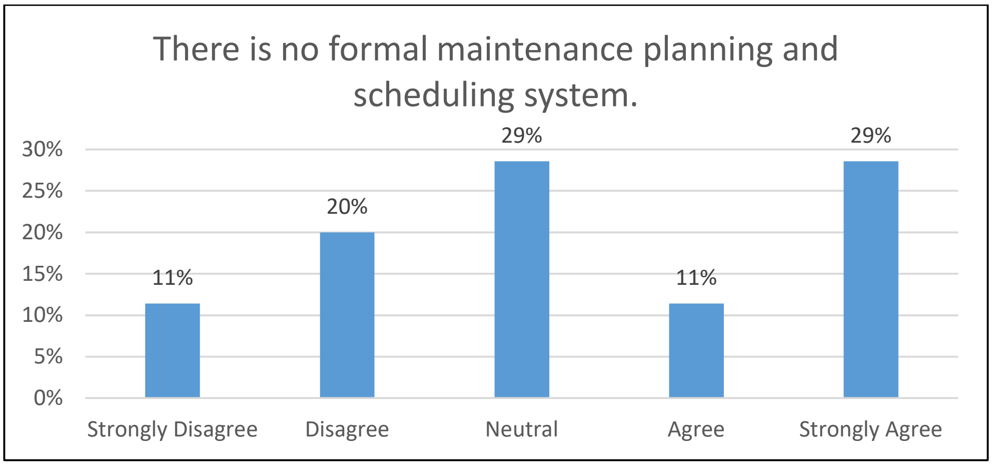



**Figure 4. 28 No formal maintenance planning and scheduling system**

In addition, Figure 4.29 shows that the majority (63%) of the research subjects agreed that the maintenance system is not continuously reviewed and refined. Table 4.10 shows the results of this distribution. In this distribution, the standard deviation is more than one (s = 1.106) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

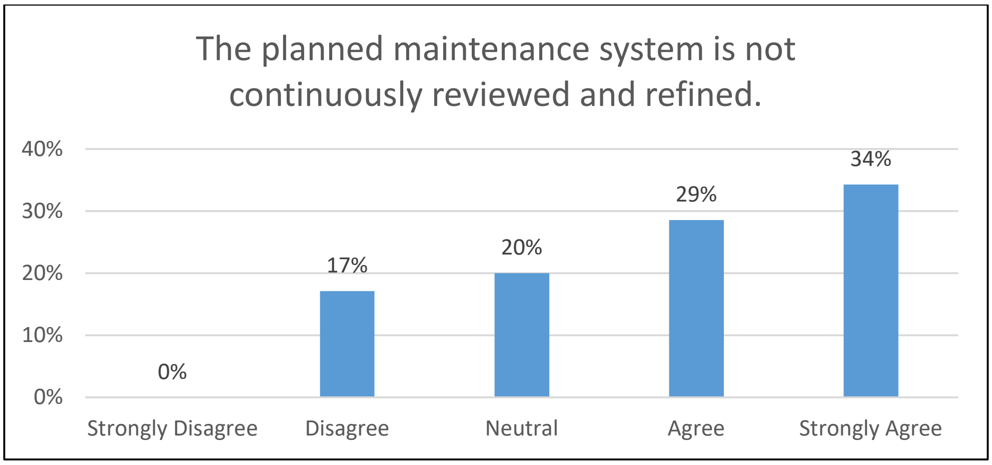



**Figure 4. 29 Maintenance system not continuously reviewed and refined**

Furthermore, Figure 4.30 shows that the majority (94%) of the research subjects agreed that planned maintenance system prevents surprise or unexpected breakdowns. Table 4.10 shows the results of this distribution. Similarly, the standard deviation is less than one (s = 0.698) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

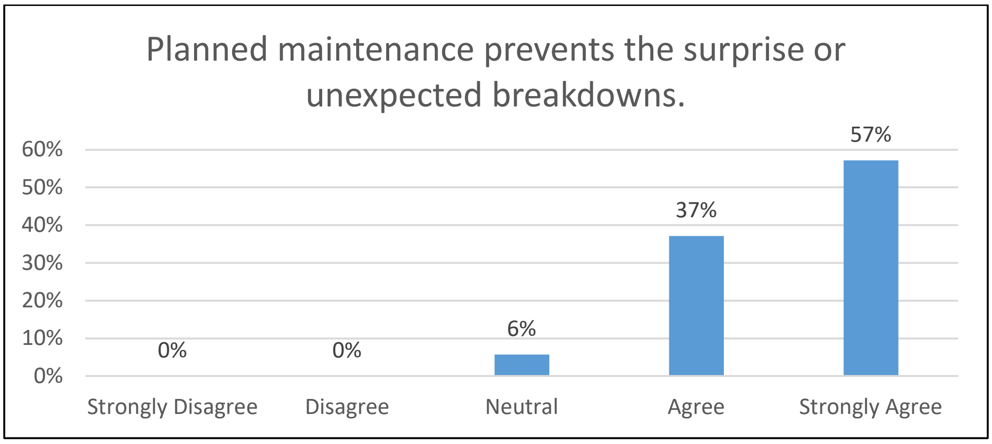



**Figure 4. 30 Planned maintenance system prevents surprise or unexpected breakdown**

And lastly, Figure 4.31 shows that the majority (88%) of the research subjects agreed that competitive advantage can be gained through planned maintenance. Table 4.10 shows the results of this distribution. As indicated, the standard deviation is less than one (s = 0.698) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

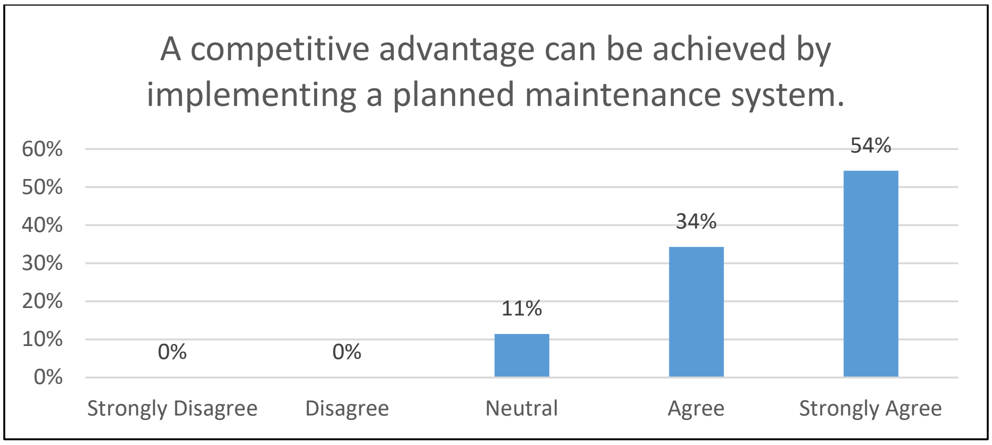



**Figure 4. 31 Competitive advantage through planned maintenance**

## 4.4Cronbach's Alpha

**Table 4. 11 Cronbach's alpha results**

| Cronbach's Alpha | N of items |
|---|---|
| 0.980 | 35 |

Adapted from IBM 2018. IBM SPSS Statistics for Windows. 25 ed.: IBM Corp. in Armonk, NY

Table 4.11 shows the Cronbach Alpha = 0.980 and a total of 35 items were tested. The result is greater 0.7 and therefore the questionnaire was concluded to have a reliable internal consistency.

## 4.5Conclusion

This chapter covered the results and findings of this study and the research objectives would be addressed accordingly. To facilitate the understanding of the quantitative information, the researcher summarised the results and findings using tables and figures. Based on the findings and with reference to the maintenance management stages in Figure 1.1, the current state of the maintenance management system is reactive to planned in nature. This is because the equipment is fixed after it breaks and the maintenance of equipment is planned with production. The equipment is also described as unreliable and a lot of overtime is worked to repair the equipment. In addition, there are several shortcomings of the current maintenance management system. This is because the equipment is deteriorating and maintenance is not done to save on maintenance costs, and the equipment is repaired only after it breaks. Furthermore, the study recommended a number of measures that could ameliorate the level of maintenance at the company. The uptime of the machine needs to be improved and breakdowns should be predicted and avoided. The study revealed that a planned maintenance system would result in improved output, reduced downtime of equipment and reduced maintenance costs. The company should institute a formal maintenance and scheduling system comprising of continuous review and refining of the maintenance system that could result in a competitive advantage for the company. The next chapter discusses the quantitative data gathered from the results generated by descriptive statistics. The findings for each research question will be discussed in association with the research objective.

# CHAPTER FIVE – DISCUSSION

## 5.1 Introduction

This chapter discusses the quantitative data gathered from the results generated by descriptive statistics. The findings for each research question will be discussed in association with the research objective.

The primary objective of this study is to investigate the challenges that impede the proper functioning of a planned maintenance system at an automotive component manufacturer. The objectives of this research were as follows:

- To explore the current state of the maintenance management system at the organisation.
- To identify the shortcomings of the current maintenance management system at the organisation.
- To identify what improvements are required for the current maintenance management system at the organisation.
- To provide recommendations based on the shortcomings identified.

## 5.2 Discussion of the Results

The discussion of results will link the results for each question to the respective research objective. A detailed explanation of each finding will be given.

### 5.2.1 Objective 1 - To explore the current state of the maintenance management system at the organisation

The discussion on the quantitative data are broken up into seven separate questions and then summarised in a discussion that links the research questions to the research objective.

a) Question one asked the candidates if maintenance is not done where the machines are not fixed and the fix is delayed. According to the output presented on Figure 4.7, the majority (42%) of the research subjects disagreed that maintenance is not done such that the fix is delayed. Table 4.8 shows the results of this distribution. However, the standard deviation is above 1 ($s = 1.491$) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.
b) Question two asked the candidates if maintenance is reactive so that equipment is fixed after it breaks. Figure 4.8 shows that the majority (60%) of the research subjects agreed that maintenance is reactive such that it is fixed after it breaks. Table 4.8 shows the results of this distribution. Similarly, the standard deviation is above 1 ($s = 1.190$) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.
c) Question three asked the candidates if maintenance is planned so that equipment is fixed before it breaks. Figure 4.9 shows that the majority (46%) of the research subjects agreed that maintenance is planned. Table 4.8 shows the results of this distribution. Again, the standard deviation is above 1 ($s = 1.250$) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.
d) Question four asked the candidates if equipment is reliable such that equipment is fixed and improved. Figure 4.10 shows that the majority (43%) of the research subjects disagreed that equipment is reliable and equipment is fixed and improved. Table 4.8 shows the results of this distribution. As indicated, the standard deviation is above 1 ($s = 1.309$) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

e) Question five asked the candidates if a lot of overtime is worked to repair breakdowns. Figure 4.11 shows that the majority (46%) of the research subjects disagreed that a lot of overtime is worked to repair breakdowns. Table 4.8 shows the results of this distribution. As shown, the standard deviation is above 1 (s = 1.346) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

f) Question six asked the candidates if a lot of spare parts are kept in stock in preparation for breakdowns. Figure 4.12 shows that the majority (37%) of the research subjects disagreed that a lot of spare parts are kept in stock in preparation for breakdowns. Table 4.8 shows the results of this distribution. As indicated, the standard deviation is above 1 (s = 1.337) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents

g) Question seven asked the candidates if equipment are not repaired in order to save cost on the maintenance budget. Figure 4.13 shows that the majority (40%) of the research subjects agreed that the equipment is not repaired in order to save on the maintenance budget. Table 4.8 shows the results of this distribution. In this distribution, the standard deviation is above 1 (s = 1.288) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

#### 5.2.1.1 Discussion of the results for objective one

Objective one required research data to explore the current state of the maintenance management system at the organisation. The first four questions provided data that showed that the respondents understood the different maintenance concepts and its relationship to the current state of maintenance at the organisation. This understanding is necessary to answer the questionnaire. As discussed by Coleman et al. (2017, p.3) in the literature review there are four types of maintenance methodologies, reactive, planned, proactive and predictive maintenance. Majority (60%) of the research subjects agreed that maintenance is reactive at the organisation where equipment is fixed after it breaks compared to 46% of the research subjects that agreed maintenance is planned. This view is further supported by the majority 43% of the respondents who disagreed that equipment is reliable. Data analysis for question five and six showed that a lot of overtime is worked to repair breakdowns and a lot of spares are kept in stock in preparation for breakdowns, both indicating high costs associated with a reactive maintenance system which is supported by Campbell and Reyes-Picknell (2015, p.386) in the literature review. The data therefore shows that the current state of the maintenance management system is at a reactive maintenance state.

### 5.2.2 Objective 2 - To identify the shortcomings of the current maintenance management system at the organisation

The discussion on the quantitative data are broken up into eight separate questions and then summarised in a discussion that links the research questions to the research objective.

a) Question one asked the candidates if equipment are deteriorating in the plant. Figure 4.14 shows that the majority (72%) of the research subjects agreed that the equipment is deteriorating. Table 4.9 shows the results of this distribution. However, the standard deviation is above 1 (s = 1.022) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.
b) Question two asked the candidates if maintenance is not done in order to save on maintenance costs. Figure 4.15 shows that the majority (49%) of the research subjects agreed that maintenance is not done to save on maintenance costs. Table 4.9 shows the results of this distribution. Similarly, the standard deviation is above 1 (s = 1.282) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.
c) Question three asked the candidates if equipment is repaired only after it breaks. Figure 4.16 shows that the majority (63%) of the research subjects agreed that equipment is repaired only after it breaks. Table 4.9 shows the results of this distribution. Again, the standard deviation is above 1 (s = 1.255) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

d) Question four asked the candidates if equipment is fixed before it breaks. Figure 4.17 shows that the majority (43%) of the research subjects agreed that the equipment is fixed before breaks. Table 4.9 shows the results of this distribution. As indicated, the standard deviation is above 1 (s = 1.332) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

e) Question five asked the candidates if equipment is repaired it is not only fixed it is improved as well. Figure 4.18 shows that the majority (54%) of the research subjects agreed that the repaired equipment is fixed and improved. Table 4.9 shows the results of this distribution. As shown, the standard deviation is above 1 (s = 1.352) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

f) Question six asked the candidates if maintenance of equipment is planned in conjunction with production. Figure 4.19 shows that the majority (65%) of the research subjects agreed that maintenance is planned with production. Figure 4.19 shows the results of this distribution. As indicated, the standard deviation is above 1 (s = 1.150) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

g) Question seven asked the candidates if the failure of equipment is predicted and repaired before it fails. Figure 4.20 shows that the majority (51%) of the research subjects disagreed that the failure of equipment is predicted and repaired before failure. Table 4.9 shows the results of this distribution. In this distribution, the standard deviation is almost 1 (s = 1.458) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

h) Question eight asked the candidates if the data from maintenance and breakdowns are recorded and analysed. Figure 4.21 shows that the majority (72%) of the research subjects agreed that maintenance data is recorded and analysed. Table 4.9 shows the results of this distribution. In this distribution, the standard deviation is more than 1 (s = 1.098) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

#### 5.2.2.1 Discussion of the results for objective two

Objective two required research data to identify the shortcomings of the current maintenance management system at the organisation. Question one provided data that showed that the research subjects strongly agreed (72%) that the equipment in the organisation is deteriorating, which is very substantial. The data analysis for question three, four and seven showed that 63% of the research subjects believed that equipment is repaired only after it breaks compared to 43% that believed equipment is fixed before it breaks and 51% disagreed that the failure of equipment is predicted and repaired before it breaks. Thus reconfirming the current reactive maintenance management state. The data analysis for question two shows that 49% of the research subjects agree that maintenance is not done to save on costs which is supported by Coleman et al. (2017, p.3). The data analysis for question five, six and eight showed that 54% of the subjects agreed that equipment is improved after it is fixed, 65% agreed that maintenance is planned in conjunction with production and 72% agreed that data from maintenance and breakdowns are analysed. This data shows a strength of the current maintenance management system rather than a shortcoming (Campbell and Reyes-Picknell, 2015, p.386). The data gathered from questions one to eight for objective two indicate mixed results, some shortcomings and some strengths as outlined in the literature review.

### 5.2.3 Objective 3 - To identify what improvements are required for the current maintenance management system at the organisation

The discussion on the quantitative data are broken up into ten separate questions and then summarised in a discussion that links the research questions to the research objective.

a) Question one asked the candidates if the uptime of machines needs to improve. Figure 4.22 shows that the majority (95%) of the research subjects agreed that the uptime of machine needs to be improved. Table 4.10 shows the results of this distribution. However, the standard deviation is less than 1 (s = 0.802) and this shows that most of the respondents are very close to the mean and the strong agreement is generally high among the respondents.

b) Question two asked the candidates if breakdowns can be predicted before they happen then the breakdown can be prevented. Figure 4.23 shows that the majority (95%) of the research subjects agreed that if breakdowns can be predicted then they can be prevented. Table 4.10 shows the results of this distribution. Similarly, the standard deviation is less than 1 (s = 0.604) and the strong agreement is generally high among the respondents.

c) Question three asked the candidates if planned maintenance will result in reduced downtime of equipment. Figure 4.24 shows that the majority (92%) of the research subjects agreed that planned maintenance will result in reduced downtime of equipment. Table 4.10 shows the results of this distribution. Again, the standard deviation is less than 1 (s = 0.657) and the strong agreement is generally high among the respondents.

d) Question four asked the candidates if planned maintenance will result in improved output (pieces) of the plant. Figure 4.25 shows that the majority (94%) of the research subjects agreed that planned maintenance will result in improved output. Table 4.10 shows the results of this distribution. More so, the standard deviation is less than 1 (s = 0.611) and the strong agreement is generally high among the respondents.

e) Question five asked the candidates if planned maintenance will result in the equipment lasting longer. Figure 4.26 shows that the majority (94%) of the research subjects agreed that planned maintenance will result in lasting equipment. Table 4.10 shows the results of this distribution. As indicated, the standard deviation is less than 1 (s = 0.611) and the strong agreement is generally high among the respondents.

f) Question six asked the candidates if planned maintenance will result in reduced maintenance costs. Figure 4.27 shows that the majority (74%) of the research subjects agreed that planned maintenance will result in reduced maintenance cost. Table 4.10 shows the results of this distribution. As shown, the standard deviation is above 1 (s = 1.023) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

g) Question seven asked the candidates if there is no formal maintenance planning and scheduling system. Figure 4.28 shows that the majority (40%) of the research subjects agreed that there is no formal maintenance planning and scheduling system. Table 4.10 shows the results of this distribution. In this distribution, the standard deviation is also above 1 (s = 1.379) and this shows that some respondents are far away from the mean and agreement is generally not high among the respondents.

h) Question eight asked the candidates if the planned maintenance system is not continuously reviewed and refined. Figure 4.29 shows that the majority (63%) of the research subjects agreed that the planned maintenance system is not continuously reviewed and refined. Table 4.10 shows the results of this distribution. In this distribution, the standard deviation is more than 1 (s = 1.106) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

i) Question nine asked the candidates if planned maintenance prevents the surprise of unexpected breakdowns. Figure 4.30 shows that the majority (94%) of the research subjects agreed that planned maintenance system prevents surprise or unexpected breakdowns. Table 4.10 shows the results of this distribution. Similarly, the standard deviation is less than 1 (s = 0.698) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

j) Question ten asked the candidates if a competitive advantage can be achieved by implementing a planned maintenance system. Figure 4.31 shows that the majority (88%) of the research subjects agreed that a competitive advantage can be gained through a planned maintenance system. Table 4.10 shows the results of this distribution. As indicated, the standard deviation is less than 1 (s = 0.698) and this shows that the majority of the respondents are very close to the mean and agreement is generally high among the respondents.

#### 5.2.3.1 Discussion of the results for objective three

Objective three sought to identify what improvements were required for the current maintenance management system at the organisation. The data for questions one to ten showed that the majority of participants (s = 0.810) agreed with all the questions. The majority of respondents (s = 0.810) agreed that the implementation of a planned maintenance system will improve uptime, reduce downtime, improve productivity, equipment longevity, reduce maintenance costs, improve planning and scheduling, prevent surprise breakdowns and give the organisation a competitive advantage. All results support the literature reviewed in chapter two which states that a planned maintenance system will increase machine availability, reduce operating costs, increases competitive advantage and improve morale (Campbell and Reyes-Picknell, 2015, p.386). The analysis for objective three showed a strong need for an improvement to the current maintenance management system.

## 5.3 Summary

This chapter discussed the quantitative data gathered from the results generated by descriptive statistics. The findings for each research question was discussed in association with the research objective and the associated literature reviewed in chapter 2. The findings revealed that the current maintenance management system is reactive in nature and the implementation of a planned maintenance system will improve uptime, reduce downtime, improve productivity, increase equipment longevity, reduce maintenance costs, improve planning and scheduling, prevent surprise breakdowns and give the organisation a competitive advantage.

# CHAPTER SIX - CONCLUSION AND RECOMMENDATIONS

## 6.1 Introduction

This chapter covers the conclusions and recommendations taking into consideration the research questions posed at the beginning of this study. The primary objective of this study is to investigate the challenges that impede the proper functioning of a planned maintenance system at an automotive component manufacturer. The objectives of this research were as follows:

- To explore the current state of the maintenance management system at the organisation.
- To identify the shortcomings of the current maintenance management system at the organisation.
- To identify what improvements are required for the current maintenance management system at the organisation.
- To provide recommendations based on the shortcomings identified.

The appending sections presents the findings relating to the research objectives, the limitations of the study, recommendations to the organisation and areas for further research.

## 6.2 Conclusion

The key findings in relation to each objective are presented below:

- The current state of the maintenance management system is reactive to planned in nature;
- Maintenance is planned with production;
- If the failure of equipment can be predicted then the breakdown can be prevented;
- The equipment are unreliable;
- Not enough spare parts are kept in stock in preparation for breakdowns;
- The data from maintenance and breakdowns are recorded and analysed; and

- The organisations equipment is deteriorating

In the appending sub-sections, each conclusion is discussed separately.

### 6.2.1 The current state of the maintenance management system is reactive to planned in nature

According to the results in Chapter 4, the current state of the maintenance management system is reactive to planned in nature. The research participants agreed that maintenance is reactive where equipment is fixed after it breaks and maintenance is planned with production. The equipment is also described as unreliable and a lot of overtime is worked to repair the equipment. Furthermore, the participants agreed that the equipment is not repaired in ordered to save on the maintenance costs. This response on the part of the research participants supports the researcher’s conclusion that the current state of the maintenance management system is reactive to planned in nature. Mangu, Koronka and Csiminga (2017, p.177) emphasised the importance of company performance in a very competitive and dynamic environment. The authors explained that role of management in steering the company through the whole system of production taking into consideration the technical capital that the company possesses and the importance of maintenance management (Mangu et al., 2017, p.177). Therefore, management should continue the improvement of the current maintenance management system.

### 6.2.2 Maintenance is planned with production

Next, the results in Chapter 4 showed that maintenance within the organisation is planned with production. Emil, Militaru, Zagan and Chitu (2015, p.221) emphasise the importance of performance indicators during the maintenance of an industrial plant. According to the authors, maintenance management should be an integral part of the organisational system in order to enhance the overall production of the company (Emil et al., 2015, p.221). In another study, Mahlangu and Kruger (2015, p.167) studied the impact of maintenance management system on production output and profitability at an industrial plant. According to the findings, maintenance management systems impacts positively on production output and profitability (Mahlangu and Kruger, 2015, p.167). Similarly, Mangu et al. (2017, p.170) explained that the top management of companies are increasingly employing maintenance management of technology at certain operating parameters, streamlining this process, and integrating this into a unitary management system even though with some challenges (Mangu et al., 2017, p.170). Therefore, management should plan maintenance with production so that the company's maintenance management system impacts positively on production output and profitability.

### 6.2.3 If the failure of equipment can be predicted then the breakdown can be prevented

In addition, the results in Chapter 4 revealed that if the failure of the equipment is predicted then the breakdown can be prevented. Assaf, Hadidi, Hassanain and Rezq (2015, p.1957) explained how the performance of equipment could be evaluated using the DEA (Data Envelopment Analysis) model. According to the authors, performance evaluation of the production units and equipment of an industrial plant would result in smooth and uninterrupted operation (Assaf et al., 2015, p.1957). In addition, Khodabakhshian (2013, p.147) emphasised the importance of preventive maintenance systems at an industrial plant. The author suggested that the use of different maintenance strategies depending on the condition and the building of signal processing procedures for extracting information relevant to targeted failure modes (Khodabakhshian, 2013, p.147). Similarly, Constantinescu, Constantin, Dumitru and Gheorghe (2016, p.47) explained the use of the smart system for predicting and preventing failures that focuses on the operational efficiency of the maintenance programme. According to the authors, a smart system would enable failure of equipment to be predicted and repaired before failure (Constantinescu et al., 2016, p.47). The organisation can therefore plan a specific shutdown date with production and order the spare parts. The time to taken for a planned shutdown of the equipment versus an unplanned stoppage due to a breakdown is much smaller and less expensive (Constantinescu et al., 2016, p.47). In another study, Ardakan, Hamadani, Sima and Reihaneh (2016, p.9) even proposed the use of statistical process control (SPC) and maintenance management programs because maintenance management programmes will help to reduce the type II error that often causes the SPC to function out of control at a cost to the company (Ardakan et al., 2016, p.9).

### 6.2.4 The equipment are unreliable

Furthermore, the results of the study revealed that the company's equipment is unreliable. Hafidi, El Barkany and Mahmoudi (2017, p.2856) emphasised the importance of reliable equipment in an industrial plant. According to the authors, production is optimal when the tools are in good working order and the maintenance and production functions of the company ought to be integrated in view of efficient operation of the means of production (Hafidi et al., 2017, p.2856).

### 6.2.5 Not enough spare parts are kept in stock

The results of the study also revealed that there is not enough spare parts kept in stock in preparation for breakdowns. The importance of spare parts kept in stock is supported by Hu, Boylan, Chen and Labib (2017, p.1) who explains that the effective management of spare parts stock holding will reduce the costly impact of downtime caused by the breakdown of equipment as the spares required to rectify the breakdown will be available when needed. This result is supported by Fourie and Umeh (2017, p.176) who explained that lean thinking has limited applications in the non-manufacturing or maintenance environments (Fourie and Umeh, 2017, p.176). However, the authors suggested the mapping of current supply chain processes in the maintenance function in order to reduce waste and also the use of performance indicators to facilitate continuous review and assessment of processes (Fourie and Umeh, 2017). Furthermore, Cahyo, El-Akruti, Dwight and Zhang (2015, p.123) explained that the utilisation of assets is more about how an asset is efficiently and effectively deployed and used. According to the authors, asset utilisation is essentially generally controlled by the asset design and most especially by the asset's reliability and maintenance considerations (Cahyo et al., 2015, p.123).

### 6.2.6 The data from maintenance and breakdowns are recorded and analysed

The results also show that the company's maintenance data is recorded and analysed. As explained by Assaf et al. (2015, p.1958) data envelopment analysis (DEA) can be used to calculate the efficiency of multiple maintenance cells and to evaluate the performance of maintenance plans in a manufacturing plant like the automotive component manufacturer. According to the author, DEA could help the managers to identify the flaws and the successes of the maintenance cells and also the most efficient cell (Assaf et al., 2015, p.1958). In addition, Ding and Kamaruddin

(2015, 1263) suggested the use of optimisation analysis and a computerised processing system to facilitate a user-friendly and effective maintenance system. Similarly, Azahar and Mydin (2014, p.51) explained the importance of computerised maintenance management system in facilities management. More so Poór, Kuchtová and Šimon (2014, p.1276) stated that all organisations make use of support services such as computer programmes that can enable workers to give better performance and contribute to overall success of business organization. Furthermore, Pliego Marugán, García Márquez and Pinar Pérez (2016, p.1) suggested the use of advanced statistical analysis in order to reduce the computational cost when optimising maintenance management at an industrial plant. Lastly, Slaichová and Marsíková (2013, p.60) found that a computerised maintenance management information system is important in improving overall equipment efficiency metrics and the efficient control of its production system. Therefore, maintenance data can be recorded and analysed in view of improving efficiency and output.

### 6.2.7 The organisations equipment is deteriorating

The data showed that the organisation's equipment is deteriorating. As explained by Pérez Ramírez, Bouwer Utne and Haskins (2013, p.329) equipment are assets that have a useful life and undergo aging through their use. The authors proposed that aging management could be used to extend the useful life of plant assets (Pérez Ramírez et al., 2013, p.329). In addition, Khoury, Deloux, Grall and Bérenguer (2013, p.12) acknowledged the gradual deterioration of equipment and that maintenance actions should be planned at imposed times called maintenance opportunities that are available on a limited visibility horizon. Thus, the deterioration of equipment can be age managed in view of enhancing the organisation's production output.

## 6.3 Evaluation of the study

The previous sub-sections confirm that all the research questions that were posed at the beginning of this research have been answered, and therefore, the research objectives of this study have been addressed by the researcher.

## 6.4 Implication of this research

This research study contributes to the field of maintenance management in the automotive component manufacturing industry. The research validated the literature reviewed and it gave a deep understanding of the current state of the maintenance management system. The practical understanding gained can be used by the organisation to redefine its strategy on maintenance management.

## 6.5 Limitations of the study

The investigation concentrated only on the operations staff members from the maintenance, production and engineering departments on site in Pinetown who are directly or indirectly involved in the maintenance process. This is possibly at the expense of not considering the impact of other departments within the organisation and the impact of other organisation stakeholders.

The investigation also did not probe the cost of a weak or strong planned maintenance system to the organisation. It also did not investigate the cost of researching and implementing an improved planned maintenance system.

## 6.6 Recommendations to solve the research problem

The study has revealed both positive and negative findings of the planned maintenance system at the automotive component manufacturer in KwaZulu-Natal. The positive findings are maintenance is planned with production and the data from maintenance and breakdowns are recorded and analysed. Both these findings are attributes required to enhance the planned maintenance system and will work in conjunction with the recommendations discussed.

Based on the findings of this study, the following recommendations on enhancing the planned maintenance system at an automotive component manufacturer in South Africa have been suggested:

- The uptime of the machine needs to be improved;
- Breakdowns should be predicted and avoided; and
- Institute a formal maintenance and scheduling system comprising of continuous review and refining of the maintenance system.

### 6.6.1 The uptime of the machine needs to be improved

A planned maintenance system will result in increased output, reduce the downtime of equipment and reduce maintenance costs. Moreover, aging management (AM) could be used to extend the useful life of plant assets (Pérez Ramírez et al., 2013, p.330). As explained by Pliego Marugán et al. (2016, p.1) exogenous conditions such as maintenance budget, human and material resources and weather conditions will determine the downtimes, together with the time required to carry out any maintenance task. Therefore, by reducing these exogenous conditions, the uptime of the maintenance machinery can be improved.

### 6.6.2 Breakdowns should be predicted and avoided

As explained by Constantinescu et al. (2016, p.47) the company can use a smart system for the prediction and prevention of breakdowns. A computerised maintenance management information system is important in improving overall equipment efficiency metrics and the efficient control of its production system (Slaichová and Marsíková, 2013, p.60).

### 6.6.3 Institute a formal maintenance and scheduling system comprising of continuous review and refinement of the maintenance management system

The company should institute a formal maintenance and scheduling system comprising of continuous review and refinement of the maintenance management system that could result in a competitive advantage for the company. To achieve this, the company should integrate the maintenance and production function Hafidi et al. (2017, p.2856). Further, the company can use DEA to calculate the efficiency of multiple maintenance units and to evaluate the success of maintenance plans (Assaf et al., 2015, p.1958). In addition, the company can apply optimisation analysis and a computerised processing system to facilitate a user-friendly and effective maintenance system (Assaf et al., 2015, p.1958).

## 6.7 Recommendations for Future Studies

The following direction could be exploited for future research

### 6.7.1 Industry 4.0

To investigate the impact of Industry 4.0 on the planned maintenance system at the organisation. According to Grunow (2016, p.16) Industry 4.0 was coined by the German government when they began to prepare for the future of production, the fourth generation. The fourth generation comes at a time when there is a need for customer specific products, flexible production and the integration of the customer, the organisation and other business stakeholders. Industry 4.0 is dependent on the implementation of smart technology creating a smart factory. A smart factory uses the Internet of Things (IoT) which makes use of wireless networks, smart equipment, sensor technology, self-managing devices and actuating technology. Li, Wang and He (2016, p.2) explains how self-aware machines are able to predict its own failure and it automatically schedules planned maintenance activities or in some cases heal itself. This concept should be studied to understand its impact on the organisation and its various stakeholders.

### 6.7.2 Additive Manufacturing

To investigate the impact of Additive Manufacturing on the planned maintenance system at the organisation. Knofius, Van der Heijden and Zijm (2018, p.3) explains how the advancement of manufacturing technologies has led to additive manufacturing also known as three dimensional printing which is a machine that can produce parts on demand without the need for specialised tooling. With this technology a maintenance technician can arrive at a breakdown and establish the spare parts required. The technician then goes to the three dimensional printer and produce the parts needed. Rauch, Unterhofer and Dallasega (2018, p.126) also explains that additive manufacturing allows the maintenance technician to produce spare parts when required and as close as possible to its place of use thus reducing downtime and the cost of holding an inventory of spare parts. This concept should be studied further to understand the opportunity to integrate this technology into the organisation that will result in a competitive advantage.

## 6.8 Summary

The primary objective of this study is to investigate the challenges that impede the proper functioning of a planned maintenance system at an automotive component manufacturer. This chapter concludes the study by linking the research objectives and the findings. Objective one required research data to explore the current state of the maintenance management system at the organisation. The data showed that the respondents understood the different maintenance concepts and its relationship to the current state of maintenance at the organisation and they agreed that maintenance is reactive at the organisation where equipment is fixed after it breaks, is unreliable, a lot of overtime is worked to repair breakdowns and a lot of spares are kept in stock in preparation for breakdowns. The data therefore shows that the current state of the maintenance management system is at a reactive maintenance state and therefore the research question was answered.

Objective two required research data to identify the shortcomings of the current maintenance management system at the organisation. The data showed that the research subjects agreed that the equipment in the organisation is deteriorating, the equipment is repaired only after it breaks and that the failure of equipment is not predicted and repaired before it breaks. This reconfirmed the current reactive maintenance management state. The data also showed that maintenance is not done to save on costs. There was also some data which showed some strengths in the current maintenance management system such as the equipment is improved after it is fixed, maintenance is planned in conjunction with production and that data from maintenance and breakdowns are analysed. These strengths are required for the implementation of the recommendations. The data therefore did answer the research question by identifying the shortcomings as well as the strengths of the current maintenance management system.

Objective three sought to identify what improvements were required for the current maintenance management system at the organisation. The data showed that the implementation of a planned maintenance system will improve uptime, reduce downtime, improve productivity, equipment longevity, reduce maintenance costs, improve planning and scheduling, prevent surprise breakdowns and give the organisation a competitive advantage. All results support the literature reviewed in chapter two which states that a planned maintenance system will increase machine availability, reduce operating costs, increases competitive advantage and improve morale. The analysis for objective three showed a strong need for an improvement to the current maintenance management system.

The study was limited to the operations staff members from the maintenance, production and engineering departments and the impact of the other organisation stakeholders was not measured. The key recommendations to the organisation include improving the uptime of the machines, the use of tools to predict breakdowns and avoid them and to institute a formal maintenance and scheduling system comprising of continuous review and refinement of the maintenance system. Recommendations for future studies include the impact of Industry 4.0 and the impact of Additive Manufacturing on the planned maintenance system at the organisation. The recommendations given based on the research findings of each objective is perceived that if implemented will result in improved availability of equipment and thus increased productivity and profitability of the organisation.

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## APPENDIX 1: GATEKEEPER'S LETTER

FEDERAL-MOGUL
MOTORPARTS

20 September 2016

Dear Mr Ageshan Reddy (s/n # 200272640) (ID # 8110155154080)

**RE: PERMISSION TO CONDUCT RESEARCH**

Permission is hereby granted to you to conduct research at Federal Mogul Motorparts in Pinetown towards your MBA qualification.

We note the title of your research is:

*"A maintenance management system for an automotive component manufacturing plant."*

It is noted that you will be conducting your research by means of a questionnaire with employees on the Pinetown site.

Yours Sincerely,

[redacted]

Mr Gerhard Pretorius
Plant Manager
Federal Mogul Pinetown

Federal-Mogul of South Africa (Pty) Limited
(Reg. No. 1995/007557/07) · P.O. Box 26047 · Isipingo Beach · 4115 - Kwazulu Natal
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Directors: JM Stevens, NK Mothilal, MM Hendricks*, TB Langdon, B Pynnonen**, ES Slack, MA Bagguley***
(* Germany), (**USA), (***England)

## APPENDIX 2: INFORMED CONSENT

**UNIVERSITY OF KWAZULU-NATAL**
**GRADUATE SCHOOL OF BUSINESS AND LEADERSHIP**

Dear Respondent,

**MBA Research Project**
**Researcher**: Mr Ageshan Reddy (0712955633)
**Supervisor**: Dr. BZ Chummun (Office Telephone number)
**Research Office**: Ms P Ximba 031-2603587

I, Mr Ageshan Reddy 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, The Investigation of a Planned Maintenance System at an Automotive Component Manufacturer in KZN. The primary objective of the study is to investigate the challenges of a planned maintenance system at an automotive component manufacturer in KZN.

The results of the focus group are intended to contribute to giving the researcher guidance in recommending a Maintenance Management 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 15-20 minutes to complete. I hope you will take the time to complete this survey.

Sincerely,
Mr Ageshan Reddy

Investigator's signature : [redacted] Date : 16 July 2017

This page is to be retained by participant

**UNIVERSITY OF KWAZULU-NATAL**
**GRADUATE SCHOOL OF BUSINESS AND LEADERSHIP**

**MBA Research Project**
**Researcher**: Mr Ageshan Reddy (0712955633)
**Supervisor**: Dr. BZ Chummun (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 3: QUESTIONNAIRE

**Survey Structure**

| Section | Category | Questions type and response |
|---|---|---|
| A | Demographics | Multiple Choice |
| B – RQ1 | What is the current state of the maintenance management system at the organisation? | Closed type questions – Likert type scale |
| C – RQ2 | What are the shortcomings of the current maintenance management system at the organisation? | Closed type questions – Likert type scale |
| D – RQ3 | What improvements are required for the current maintenance management system at the organisation? | Closed type questions – Likert type scale |

Please provide the following information by marking an X in the appropriate box. Sections A, B, C and D must be completed.

**Section A – Demographics**

Please select the appropriate category that applies to you:

| | | Select |
|---|---|---|
| Gender | Male | |
| | Female | |
| Age Group | 18 – 25 | |
| | 26 – 35 | |
| | 36 – 45 | |
| | 46 – 55 | |
| | 56 – 65 | |
| Educational Level | No formal education | |
| | Matric | |
| | Diploma | |
| | Degree | |
| | Post Graduate Degree | |
| Position | Production Operator | |
| | Machine Setter | |
| | Maintenance Artisan | |
| | Maintenance Co-ordinator | |
| | Engineer | |
| | Production Zone Leader | |
| | Production Supervisor | |
| | Value Stream Manager | |
| Department | Production | |
| | Engineering | |
| | Maintenance | |
| Length of Service | Less than 5 | |
| | 5-10 | |
| | 11-15 | |
| | 16-20 | |
| | More than 20 | |

**Section B - What is the current state of the maintenance management system at the organisation?**

Please select your level of agreement or disagreement.

| **Statements** | **Strongly Disagree** | **Disagree** | **Neutral** | **Agree** | **Strongly Agree** |
|---|---|---|---|---|---|
| Maintenance is not done. Machines are not fixed. The fix is delayed. | 1 | 2 | 3 | 4 | 5 |
| Maintenance is reactive. Equipment is fixed after it breaks | 1 | 2 | 3 | 4 | 5 |
| Maintenance is planned. Equipment is fixed before it breaks. | 1 | 2 | 3 | 4 | 5 |
| Equipment is reliable. Equipment is fixed and improved. | 1 | 2 | 3 | 4 | 5 |
| A lot of overtime is worked to repair breakdowns. | 1 | 2 | 3 | 4 | 5 |
| A lot of spare parts are kept in stock in preparation for breakdowns. | 1 | 2 | 3 | 4 | 5 |
| Equipment are not repaired in order to save on the maintenance budget. | 1 | 2 | 3 | 4 | 5 |

**Section C - What are the shortcomings of the current maintenance management system at the organisation?**

Please select your level of agreement or disagreement.

| **Statements** | **Strongly Disagree** | **Disagree** | **Neutral** | **Agree** | **Strongly Agree** |
|---|---|---|---|---|---|
| Equipment are deteriorating. | 1 | 2 | 3 | 4 | 5 |
| Maintenance is not done to save on maintenance costs. | 1 | 2 | 3 | 4 | 5 |
| Equipment is repaired only after it breaks. | 1 | 2 | 3 | 4 | 5 |
| Equipment is fixed before it breaks. | 1 | 2 | 3 | 4 | 5 |
| When equipment is repaired it is not only fixed it is improved as well. | 1 | 2 | 3 | 4 | 5 |
| Maintenance of equipment is planned in conjunction with production. | 1 | 2 | 3 | 4 | 5 |
| Failure of equipment is predicted and repaired before it fails. | 1 | 2 | 3 | 4 | 5 |
| Data from maintenance and breakdowns are recorded and analysed | 1 | 2 | 3 | 4 | 5 |

**Section D - What improvements are required for the current maintenance management system at the organisation?**

| Statements | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| The uptime of my machine/zone needs to improve. | 1 | 2 | 3 | 4 | 5 |
| If breakdowns can be predicted before they happen then the breakdown can be prevented. | 1 | 2 | 3 | 4 | 5 |
| Planned maintenance will result in reduced downtime of equipment. | 1 | 2 | 3 | 4 | 5 |
| Planned maintenance will result in improved output (pieces) of the plant. | 1 | 2 | 3 | 4 | 5 |
| Planned maintenance will result in the equipment lasting longer. | 1 | 2 | 3 | 4 | 5 |
| Planned maintenance will result in reduced maintenance costs. | 1 | 2 | 3 | 4 | 5 |
| There is no formal maintenance planning and scheduling system. | 1 | 2 | 3 | 4 | 5 |
| The planned maintenance system is not continuously reviewed and refined. | 1 | 2 | 3 | 4 | 5 |
| Planned maintenance prevents the surprise of unexpected breakdowns. | 1 | 2 | 3 | 4 | 5 |
| A competitive advantage can be achieved by implementing a planned maintenance system. | 1 | 2 | 3 | 4 | 5 |

## APPENDIX 4: PROOF EDITING

LLiWO
Consulting Services
Blazing New Trails

42 Sabie Mansions
Sunnyside
Pretoria

20 November 2018

RE: Proof of Editing for Ageshan Reddy

This confirms that a mini-thesis entitled "**THE INVESTIGATION OF A PLANNED MAINTENANCE SYSTEM AT AN AUTOMOTIVE COMPONENT MANUFACTURER IN KZN**" meant for submission to the University of KwaZulu-Natal has been received and edited by our team.

Should any additional information be required in this regard, please do not hesitate to contact us either through phones calls or emails.

Yours faithfully

[redacted]

Ndhlovu Emmanuel (Research consultant and Editor)
+27731458524
BA Hons (English), BA Hons (Dev studies), MA (Dev studies), PhD candidate (UNISA).

# APPENDIX 5: ETHICAL CLEARANCE

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

27 July 2017

Mr Ageshan Reddy (200272640)
Graduate School of Business & Leadership
Westville Campus

Dear Mr Reddy,

**Protocol reference number: HSS/1193/017M**
**Project title:** The investigation of a planned maintenance system at an automotive component manufacturer in KwaZulu-Natal

**Full Approval – Expedited Application**

In response to your application received on 24 July 2017, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and FULL APPROVAL for the protocol has been granted.

**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 discipline/department for a period of 5 years.**

**The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.**

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

Yours faithfully

[redacted]

**Dr Shamila Naidoo (Deputy Chair)**

/ms

Cc Supervisor: Dr BZ Chummun
Cc Academic Leader Research: Dr Muhammad Hoqe
Cc School Administrator: Ms Zarina Bullyraj

**Humanities & Social Sciences Research Ethics Committee**
Dr Shenuka Singh (Chair)
**Westville Campus, Govan Mbeki Building**
**Postal Address:** Private Bag X54001, Durban 4000
**Telephone:** +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** [illegible] / [illegible] / [illegible]
**Website:** www.ukzn.ac.za

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## APPENDIX 6: TURNITIN REPORT

THE INVESTIGATION OF A PLANNED MAINTENANCE SYSTEM AT AN AUTOMOTIVE COMPONENT MANUFACTURER IN KWAZULU-NATAL

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