

An analysis of effective maintenance planning at a steel manufacturer

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PREFACE

First and foremost I thank God Almighty for having given me this life and thus the opportunity to learn and be able to do this dissertation. I also give my humble thanks to my wonderful family who stood by me throughout in the trying times and supported me to be able to study and finish this prestigious MBA qualification. I extend my thanks to the lecturers and staff of the North-West University for having given me and my fellow students this precious gift of education and, I also thank them for their unwavering support in specifically concluding this dissertation, more specifically so to my sponsor Mr. Theo Venter. Lastly I thank my employer, my colleagues and management for allowing me to do this study in their plant, using their people and their time.

To you all *“Ke a leboga”* – I say thank you with these holy words:

“Consider it pure joy, my brothers, whenever you face trials of many kinds, because you know that the testing of your faith develops perseverance. Perseverance must finish its work so that you may be mature and complete, not lacking anything.” (The Bible, James 1: 2-4)

ABSTRACT

Problem statement: Manufacturing and production plants operate machines and equipment that deteriorate with usage and time thus requiring maintenance actions to restore them back to their original operational conditions.

Approach: This study investigates the current standard of maintenance planning at a steel manufacturing facility in South Africa. The study begins with a thorough literature study to find good characteristics of planning which should be present at any facility that is optimally engaged in performing excellent maintenance planning effectively and efficiently. A number of key observations from the literature are made indicating that planning is a key component of maintenance and affects excellence in maintenance significantly. The literature recommends that planning should be set and based on key principles to allow for standardisation and efficiency. An empirical study in the form of a survey is then completed to benchmark the current maintenance-planning environment of the steel facility against the good characteristics of maintenance planning found in literature.

Results: The results from the empirical study show that the current maintenance environment at the steel manufacturer is not optimal. The following issues are uncovered from the study: no schedulers employed to relieve the planners' work overload, no guiding principles for planning and standardisation of work planning, no efficient shutdown planning and also no existent measures for tracking some of the key performance areas.

Conclusion: Key recommendations to be considered for implementation for improving the status of the maintenance environment at the works include: introducing the scheduler position, standardising planning methodologies according to specific principles and rigorously focusing on overall maintenance improvement using standardised methodologies.

Key words: Maintenance, Maintenance Planning, Planner, Planning, Reliability, Scheduler, World Class, Maintenance Transformation

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ABBREVIATIONS

Except where otherwise stated the following symbols and abbreviations have been used in this document.

Table 1: List of abbreviations used in this document

| SYMBOL | ABBREVIATION |
|---------------|--|
| AM | Autonomous Maintenance |
| ARP | Asset Reliability Process |
| CMS | Centralised Maintenance Services |
| CMMS | Computerised Maintenance Management System |
| CSSA | The Company's South African Subsidiary |
| DRI | Direct Reduced Iron |
| EAF | Electric Arc Furnace |
| KPI | Key Performance Indicators |
| M&B | Mindsets and Behaviour |
| MI | Management Infrastructure |
| MLT | Million Tons |
| MST | Maintenance Support Team |
| MTBF | Mean Time Between Failure |
| MTTF | Mean Time To Failure |
| MTTR | Mean Time To Repair |
| MW | Mega Watts |
| OE | Operational Excellence |
| OEE | Overall Equipment Efficiency |
| OMI | Operational Management Infrastructure |
| OS | Operating System |
| PAS | Process Automation and Systems |
| PM | Preventative Maintenance |
| RCA | Root Cause Analysis |
| TCO | Total Cost of Ownership |
| SHER | Safety, Health, Environment and Risk |
| SLA | Service Level Agreement |
| SWP | Safe Working Procedure |
| VDB | Vanderbijlpark |
| VER | Vereeniging |
| VM | Visual management |
| WCM | World class manufacturing |

CHAPTER 1: NATURE AND SCOPE OF THE STUDY

1.1 THE COMPANY IN THE GLOBAL CONTEXT

The company of interest in this study is one of the world's leading steel companies with operations in more than 60 countries. As the company's website mentions, the company has an industrial presence in more than 20 countries and is the leader in all the main steel markets – from automotive to construction and from household appliances to packaging. It employs approximately 250,000 people across the globe (Company, 2014). A diversified and highly efficient steel producer, the company has an annual production capacity of around 130 million tons.

The company has pursued a consistent, three dimensional business strategy over a number of years. This focuses on product diversity, geographic reach and vertical integration – both upstream in the production of iron ore and coal and downstream in steel distribution (Company, 2014). The aim of the strategy is to reduce exposure to risk and cyclicity. A diversified portfolio of products allows the company to meet a wide range of customer needs across all steel consuming industries, including the automotive, appliance, engineering, construction, energy and machinery industries. The Company sells its products in local markets and through a centralized marketing organisation to customers in approximately 174 countries (Company, 2014).

1.2 THE COMPANY'S SOUTH AFRICAN SUBSIDIARY (CSSA)

The company's South African subsidiary is the largest steel producer on the African continent, with a production capacity of 7.8 million tons of liquid steel per annum (Company, 2014). The company has a depth of technical and managerial expertise carefully nurtured since 1911, a reputation for reliability and a sharply defined business focus, which has forged the organisation into a modern, highly competitive supplier of steel products to the domestic and global markets.

1.2.1 CSSA Fast Facts

The following information has been summarised from the company's internal documents:

- Founded in 1911 at Vereeniging.
- Headquarters in Vanderbijlpark in South Africa's Gauteng province.
- Over 9 000 employees.
- Revenue in excess of R32 billion as per the end of year 2013/2014 financial statements and company reports.
- Annual electricity consumption of 600 MW.
- Annual water consumption of 22 000 Mlt.
- Global standing underpinned by being part of the world's largest steel producer.

1.3 VEREENIGING WORKS OF THE COMPANY

The following is a significantly summarised narrative of the history of the Vereeniging works and the CSSA group as reported in the company's South African 100 years celebrations book released in 2012.

The long steel products business of the company's South African subsidiary consists of the electric-arc furnace (EAF) based mill in Vereeniging and the integrated steel works in Newcastle. Vereeniging works is an electric-arc furnace based mill, which produces a wide range of specialty steel products, targeting primarily local niche markets. The works were established in 1911 as the first primary steel producer in South Africa. At that time, the works consisted of 2 EAF melt shops producing approximately 280 000 tons per year of continuously cast billets, and ingots for a bar and medium section rolling mill and 2 forge presses.

The works has grown steadily by means of capacity expansion and acquisitions. In 1993, a steel forge company was acquired and a modern 2700-ton press was incorporated into the existing forging business. The works embarked on an extensive re-engineering process in 1997, aimed at reducing costs and achieving excellent

standards in all areas of the business. At the same time, the production facilities were modernized and processes streamlined. A new continuous caster, capable of casting high quality round and square billets, as well as a new 55-ton electric arc furnace, were installed. This allowed the closure of one of the melt shops whilst production of liquid steel increased to the current level of approximately 370 000 tons per year.

The Vereeniging Works currently has approximately 610 permanent employees with a further ~500 contractors and temporary employees. Today, the Vereeniging business is organised into three divisions, namely profile products, forged products and seamless tubes. All three divisions dominate the local market with market share of the respective products in excess of 80%. Approximately 90% of the profile and forge products are sold in the domestic market. Because of the relatively small local market, seamless tubes are sold mainly into the export market. The unique capability of Vereeniging to service a quality conscious low-volume speciality steel market affords it a dominant position in the South African steel market, and the ability to sustain positive cash flows while financing its own capital requirements.

1.4 PROBLEM STATEMENT

Companies, like human beings, want to be excellent in everything they do. When it comes to excellent maintenance management, this requires companies to be essentially very good in their planning function (Worrall & Mert, 1980). In the last three decades, manufacturing industries have experienced an unprecedented degree of changes such as product specifications, process technologies, supplier attitudes and customer requirements (Ahuja, Khamba & Choudhary, 2006). These rapid changes have forced them to enhance and improve their performance by focusing on cost reduction, productivity level increases, higher quality products and prompt deliveries in order to satisfy customers (Balan, 2011).

As an employee of the company, the author has a first-hand experience of the maintenance pains and frustrations that are carried and experienced by the planners in the maintenance function. This research is done to either support or prove empirically

the hypothesis that the planning function plays a key role in any efforts towards improving a company's maintenance and can significantly improve the efficiencies of maintenance management. The main problem is the confusion and differences which exist between what *'planners currently do'* versus what *'planners are supposed to do'* in their daily roles and responsibilities.

The author has a strong opinion that the planners do very little 'planning' of maintenance tasks currently, but a lot more 'firefighting', 'managing and procuring spares' and other unnecessary organisational wastes that prohibit them from efficiently carrying out their planning duties. Therefore there is an opportunity for improvement that exists in job execution, role definition and responsibilities that can help improve the maintenance department's effectiveness and therefore the availability and reliability of the plant machinery and equipment. The online maintenance dictionary (Idcon, 2014) website defines availability as the "percentage of total hours (8760/year) or scheduled operating time a system is available for production". Improving maintenance availability is one of the key deliverables of improved maintenance planning.

One of the most important aspects in the design of a production system is the design of the maintenance subsystem, which has the responsibility of keeping the physical plant in an operating condition. The function of the maintenance system can be defined as the total process of planning, scheduling, organising and controlling the total maintenance operation to achieve optimum use of repair costs (Worrall & Mert, 1980). Improving asset utilisation by better maintenance is a key productivity strategy that can reduce the working capital and fixed capital needed to support an organisation by great utilisation, more careful acquisition, or disposal of parts of the current and fixed asset base (Chase, Jacobs & Aquilano, 2004:29). Improving maintenance is thus one of the few ways companies can ensure their competitive advantages based on cost efficiencies, which in turn make them more agile and flexible. In his book on leadership in the globalisation era, South African supply chain legend Barry Saxton (2006:110) defines agility as *"the ability to successfully manufacture and market a broad range of low-cost, high quality products and services with short lead times and varying volumes"*

that provides enhanced value to customers through customisation. Agility merges the four distinctive competencies of cost, quality, dependability and flexibility.” These are all main benefits of excellent maintenance management, which can be enabled by better planning efficiencies and effectiveness.

Planning is one of the most critical areas of any maintenance department and basically forms the foundation of everything else. The failure of planning systems will thus make all the other things that are being done to optimise and improve maintenance almost irrelevant.

Efficiency can be summarily defined as doing something at the lowest possible cost and therefore produce a good or provide a service by using the smallest input of resources (Chase & Jacobs, 2011:47). From the same text, the authors also explain effectiveness as doing the right things to create the most value for the company. McShane and Von Glinow (2010:9) agree with them but somehow simplify the definitions by summarily stating that “Efficiency is about *doing things right*, whereas effectiveness is about *doing the right things*”. Raturi and Evans (2005:143) mention that efficiency should however be seen as the measure of how well an organisation is performing relative to expectations. Thus maximizing efficiency and effectiveness is a key value addition and should be an important goal for maintenance planning to enable the maintenance service to reach the goals and expectations of all the organisation’s stakeholders.

According to Worrall and Mert (1980), maintenance can be classified into these five categories for planning purposes:

1. Routine and preventative maintenance.
2. Corrective maintenance which involves determining the cause of repeated breakdowns and eliminating the fault by modification of some part of the facility.
3. Scheduled overhaul which involves closure or shutdown of a plant and is organised so that the plant is shut down for the shortest possible time.
4. Emergency or breakdown maintenance, the process of returning equipment to service as soon as possible following a reported failure.

5. Scheduled overhaul, repair or building of equipment which does not fall under the above classifications.

The discussions in this research will be mainly concerned with categories 1, 3, and 5 and particularly with 1 and 3.

Kister (2006) mentions that if you consider all of the organisations and companies that have maintenance departments, only one third of them have the planner position in place, and typically only 10% of those planners are effectively being utilized. Kister (2006) also suggests that five factors are the main contributors to why planners are not optimised, which are:

1. Overlapping job responsibilities,
2. Overworked planner,
3. Unqualified planner,
4. Careless planner, and
5. Lack of communication.

It thus can be concluded that a necessary transition has to be made from the old processes of the ineffective reactivity of parts chaser, gopher, and clerk to that of an effective, proactive professional maintenance planner. This transition will allow maintenance supervisors to spend more time directing their labour resources and thus enabling maintenance crews to become more effective and efficient by having the right tools, equipment, materials, and instructions to perform the work assigned.

An investment must however be made to develop the planner properly, which can then lead to the benefits becoming realized and thus preventing imminent failure. The primary goal of an effective planner is the reduction of delays and waits during work execution. To make this possible, planners have to be allowed to focus on the future, which the author thinks, is not currently the case in the organisation which is why this research is necessary, among other reasons.

1.5 RESEARCH QUESTIONS

This section describes the key problem statement which will be discussed in terms of several research questions.

What are the characteristics of good maintenance planning?

This question will be answered from a literature study by reading articles and writings about the maintenance function in general to find out what current literature says are the key and most important characteristics of good maintenance. The author developed a questionnaire based on literature and benchmarking studies strategically positioned to derive knowledge with regards to these good characteristics from the maintenance personnel in the company.

How do the current roles and responsibilities of the company's maintenance planners compare to the benchmarked good characteristics, roles and responsibilities of the planner?

This question will be answered by comparing what the Vereeniging maintenance personnel say the planners do as part of their current roles and responsibilities to what the literature says planners are supposed to do in order to deliver a good maintenance planning function.

What activities or frameworks can be implemented in the future to improve on the planning function in the maintenance department of the company and what can be learned from these that which other organisations can use to improve their own maintenance performance?

This question will mostly be answered by analysing the gaps that exist between what the planners currently do and what they are supposed to do in order to highlight the activities and recommendations that must be implemented to close those gaps.

1.6 EXPECTED CONTRIBUTION OF THE STUDY

This study will highlight to the company, the characteristics of effective planning which the maintenance management needs to make sure become inherent in order to successfully improve the reliability and availability of plant and equipment. The study evaluates the extent to which the planners currently practice these traits of good planning and therefore suggest areas of possible improvement that can serve as learning points for managers in different organisations.

1.7 RESEARCH OBJECTIVES

The research objectives are divided into a general objective and specific objectives.

1.7.1 General objective

The general objective of this research is to compare the current planning characteristics of the company's Vereeniging plant to those that are widely considered proper as benchmarked in various literatures and to prove that the company is not performing according to these traits and therefore has an opportunity to improve by implementing some of the recommendations from the literature, industry and academia.

1.7.2 Specific objectives

The specific objectives of this research are:

1. To identify what qualities in planning are required to run a successful maintenance organisation.
2. To find out if the maintenance management and personnel of the company's Vereeniging works have these qualities.
3. To summarily suggest a framework of activities that can be applied by Vereeniging management and leadership in other companies to improve their maintenance performance and plant availability based on the good qualities and characteristics of their planning functions.

1.8 RESEARCH DESIGN

1.8.1 Research approach

The research was conducted by means of questionnaires which were distributed to maintenance planners, maintenance schedulers, general maintenance personnel, maintenance management employees and plant managers. This approach was chosen as it would practically yield the most coverage of the people involved in the maintenance function of the organisation as well as those affected by it.

1.8.2 Research strategy

The research reviewed all related literature and case studies that have been concluded in the past ten years to test and develop theories about how planning affects the maintenance function in general.

1.8.3 Research method

The research was conducted according to the strategy outlined in the following paragraphs.

1.8.4 Literature study

In the literature study, a complete review regarding the research constructs was done. The sources consulted include:

1. Journals both academic and otherwise,
2. Magazines,
3. General South African legislation,
4. Textbooks,
5. Newspapers,
6. Company websites, procedures, and financial statements and reports as well as,
7. Any other relevant literature regarding maintenance planning, with a specific focus on the South African steel manufacturing industry.

1.8.5 Research setting

The empirical research was mainly conducted via questionnaires which were sent to the respondents via the internal company mail system or delivered by hand where necessary by the researcher. For clarification interviews, the researcher and the interviewee agreed on the best place to conduct the interview, and accordingly the researcher complied with interviewee's preferences. Since this research was conducted mainly on the company's premises, either the researcher's office or the respondents' offices was used to conduct one-on-one interviews at their place of employment.

1.8.6 Entrée and establishing researcher roles

The researcher made sure that all arrangements in terms of entry to any private property were arranged beforehand via a telephone conversation with the research respondents. Since the author is an employee of the company, he has access to all management levels and can communicate with all maintenance employees directly via internal company mail and telephones. Where necessary, the author also ensured that he followed and adhered to all internal company protocols and procedures in scheduling meetings and interactions within the company for interviews and knowledge gathering and sharing.

1.8.7 Sampling

A non-probability convenience sampling method was used to target the respondents for the survey. All maintenance employees working at the company's Vereeniging works were initially considered as target population. The works currently has approximately 151 positions available for maintenance, excluding vacancies. All personnel working for maintenance available at the time when the survey was completed were provided the opportunity to participate.

1.8.8 Data collection methods

Data was collected via a questionnaire answering template as well as from some unstructured interviews.

1.8.9 Recording of data

Each questionnaire was assessed individually, and the data from it was entered into spread sheets for analysis.

1.8.10 Data analysis

The data was analysed using statistical packages available at the Statistical Consultation Services of the North-West University at the Potchefstroom campus and Microsoft Excel spread sheet software.

1.8.11 Strategies employed to ensure quality data

Statistical tests were applied to test the validity and reliability of the questionnaire as well as the data integrity. Since the researcher is part of the research setting, questionnaires were collected without any names to ensure anonymity.

1.8.12 Ethical considerations

All ethical considerations relevant to the data with regards to confidentiality to the respondents will be guaranteed by the researcher.

1.9 CHAPTER DIVISION

The outline of the mini-dissertation is divided into the following chapters:

Chapter 1: Nature and scope of the study

This chapter provided a high-level introduction to the organisation where the research will be conducted, highlight the problem to be solved and introduce the process followed to conduct the research.

Chapter 2: Overview of the organisation

This chapter provides a detailed overview of the organisation in which the study was completed as well as the background and major causal factors to the study.

Chapter 3: Literature review on maintenance planning

This chapter gives a detailed view of a complete literature review on maintenance and specifically 'good' or 'world class' maintenance planning from different sources.

Chapter 4: Empirical study

This chapter discusses the process of developing the questionnaire; provide the responses of the survey, a summary of the analysis and results of the responses. The chapter concludes with a critical discussion on the results observed.

Chapter 5: Conclusions and recommendations

This chapter will contain the consolidated recommendations from both the literature study and other knowledge sources. The chapter concludes with a review of the achievements of the study objectives and makes recommendations for future research.

List of references

All references used in the mini-dissertation and study will be listed in this section.

Appendices

All the supporting information and questionnaires will be shown in the appendices.

1.10 CHAPTER 1 SUMMARY

The brief literature and company history provided in this introductory chapter illustrates good evidence that maintenance planning plays a very vital role in the excellence of plant maintenance. Although this might seem like common sense to those who spend their lives in maintenance jobs, there is very little literature that exists on the extent to

which planning transformational projects should be structured, standardised and implemented. The main aim of this study will thus be to investigate and highlight some common principles that could lead to excellence in the implementation of maintenance planning transformation projects in order to improve reliability and availability of plant equipment.

CHAPTER 2: OVERVIEW OF THE ORGANISATION

2.1 HISTORY OF THE VEREENIGING WORKS OF THE ORGANISATION

The history¹ of the organisation's Vereeniging plant is an electric-arc furnace based mini-mill, which produces a wide range of specialty steel products, targeting primarily local niche markets. The Vereeniging works of the company were established in 1911 as the first primary steel producer in South Africa. At that time, the works consisted of 2 Electric Arc Furnace (EAF) melt shops producing approximately 280 000 tons per year of continuously cast billets, and ingots for a bar and medium section rolling mill and two forge presses. The plant has grown steadily by means of capacity expansion and acquisitions.

The plant embarked on an extensive re-engineering process in 1997, aimed at reducing costs and achieving world-class standards in all areas of the business. To date, this process has resulted in hundreds of millions in yearly savings. At the same time, the production facilities were modernized and processes streamlined.

Today, the Vereeniging works business is organised into three divisions, namely profile products, forged products and seamless tubes. All three divisions dominate the local market with market share of the respective products in excess of 80%. Approximately 90% of the profile and forge products are sold in the domestic market. As a result of the relatively small local market, seamless tubes are sold mainly into the export market.

Below is a high-level timeline of the Vereeniging works of the organisation:

- 1911: The Company was founded.
- 1911: 1991: Diversified in steel, copper and aluminium.
- 1992: Acquired the steel forge 2700 ton press.
- 1995: Acquired a seamless mill.

¹ The well-researched and detailed history, as documented by the 100 year celebration book, served as theoretical base for this section of the study (Company 2012).

- 1997: Acquired the light section mill.
- 2006: Group renamed as a part of a global steel company.

The steel produced at the company's Vereeniging works is supplied into the following industry sectors:

- Agricultural - fencing, vineyards, hoes and more.
- Building - structural profiles and window sections.
- Merchants - general engineering grades.
- Mining industry - borer tubes, hollow drill and drill bits.
- Weapon industry - gun barrels, breech blocks and projectiles.
- Forging - drum winder shafts, sugar mill shafts and turbine shafts for electricity generation.
- Ring rolling - tires for trains.
- Bolts and nuts (cold forging grades).
- Motor industry for spring steels and re-forging grades.

2.2 THE ORGANISATION'S MAINTENANCE PROGRAMS AND INITIATIVES

This section of the study discusses the blueprint document for the South African subsidiary's maintenance management developed by the Asset Reliability Program (ARP) team of which the author has been a part of for the last three years. The blueprint is the document upon which the philosophy and approach to maintenance management and transformation across all of the company's plants is based.

2.2.1 The company's South African subsidiary (CSSA) maintenance problem description

The following concerns are currently prevalent within the maintenance environment of the South African subsidiary:

- Plant maintenance availability in most plants is below both internal (within the group) and external benchmarks.
- Over-expenditure on maintenance budgets is common.

- Maintenance, production and quality governance is not aligned and cooperation is not ideal.
- Skills shortages, vacancies and age profiles are problematic.
- Sharing of best practices and experience across units are not in place.
- A common approach to spares management and reconditioning is lacking.
- Root cause analysis (RCA) is not done efficiently, leading to recurring events.
- Basic conditions of equipment are not up to benchmark standards.
- The ratio of reactive/breakdown maintenance to proactive/preventative maintenance is not acceptable.

2.2.2 Scope and policy statement for the ARP transformation

2.2.2.1 Scope

The geographical scope of the asset management involves all plants within CSSA and all departments involved in maintenance of production equipment. The ARP portion of asset management will exclude process automation and systems, engineering, infrastructure as well as electrical and energy distribution.

2.2.2.2 Asset management policy

The statement of the asset management policy is shown below in Figure 1. This is applicable to the South African subsidiary level.

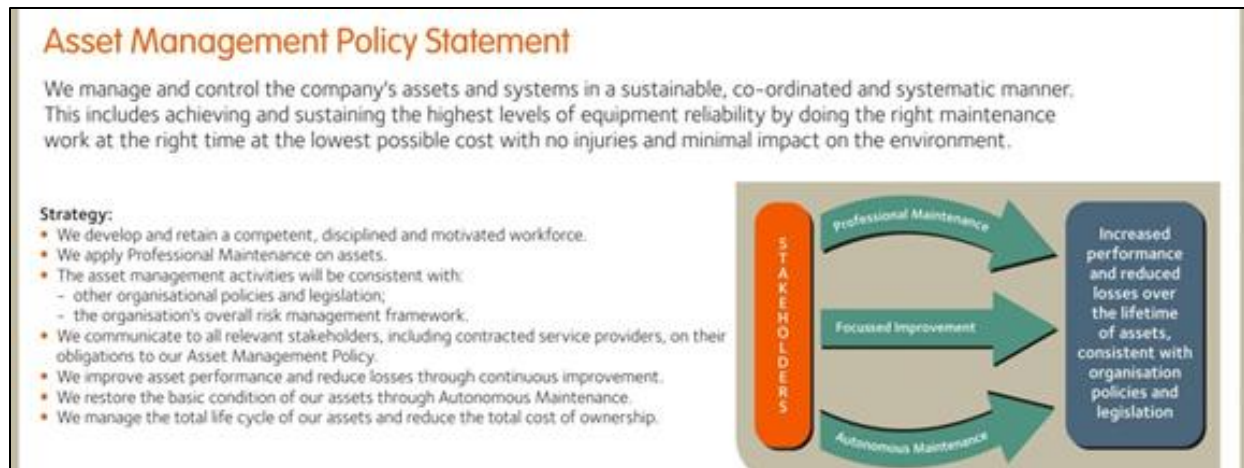


Figure 1: The asset management policy at the CSSA level

2.2.3 Principles and beliefs

The following are the main principles and beliefs that govern the ARP:

- Three dimensions of operational excellence - Excellent equipment and process reliability can only be achieved through the installation of a strong asset management with attention to the three dimensions of operational excellence, namely: Operating System (OS), Management Infrastructure (MI) and Mindset and Behaviours (M and B) as shown by Figure 10 in Appendix A.
- Losses caused by lack of reliability - Frequent unplanned production stops caused by equipment unreliability constitute a major disruptive factor in production, of which the hidden costs are grossly underestimated. These losses appear as loss of volume, quality, costs, failure reoccurrence, manpower and manpower effectiveness, project progress, motivation and more.
- Workforce morale - Increased process stability through good maintenance leads to a boost in morale across the whole organisation.
- Teamwork ensures success – Achievement of success within asset management starts with the close and coordinated cooperation of production and maintenance personnel.
- Maintenance and continuous improvement – An effective maintenance organisation is an important contributor to the continuous improvement of process quality and efficiency, safety and the environment.

- Plant versus central maintenance - Asset maintenance must be managed through an optimal split of responsibilities between plant and central maintenance. The principles guiding this collaboration should be:
 - Plant maintenance focuses only on production equipment with support equipment, infrastructure and support services being provided or managed by centralised maintenance services (CMS).
- Management routines - As demand for improvement is high everywhere, correct priority setting and resource allocation are essential. The decision-maker will also have to take into account the cost, the importance of the equipment and other factors, such as the number of resources to prioritise the work (Moore & Starr, 2006).
- Cost reduction - A maintenance organisation able to move away from breakdown maintenance and fire fighting will be more cost-effective.

2.2.4 Objectives and targets

The main goal of the CSSA Asset Management is to create higher equipment and process reliability. Characteristics of the new maintenance management should be:

- A well-described organisation suited to the CSSA environment and situation,
- A focus on all managerial aspects including a clear description of roles and responsibilities,
- Increased quality of maintenance execution and shutdown efficiency through a focus on planning and scheduling,
- Increased attention on people management and skills development
- The creation of a strong central maintenance organisation providing a number of support services such as scaffolding, mobile cranes, and others.

2.2.5 Asset Reliability Process (ARP)

2.2.5.1 ARP Model

The main processes of asset management are captured in the Asset Reliability Process which is shown in Figure 2. The process defines steps in performing world-class asset

management. The elements of the ARP process with a brief description of each step of each are shown below:

- P1 – Develop maintenance and automation strategy: Describes the steps for creating or maintaining a maintenance strategy, a maintenance budget, a maintenance organisational structure and workforce competencies.
- P2 – Develop asset reliability plan and capabilities: Describes the steps for creating an Asset Breakdown Structure, performing risk analysis, performing failure investigations, selecting a maintenance strategy for equipment and creating or reviewing maintenance plans.
- P3 – Establish asset reliability targets: Describes the steps for performing benchmarking (internal and external), performing criticality and sensitivity analysis and setting targets.
- P4 – Analysis of performance and cost: Describes the steps for managing plant performance including tracking and reporting as well as analysing Total Cost of Ownership (TCO).
- P5 – Project management: Describes the steps for project management with regard to maintenance related activities.
- P6 – Work identification: Describes the steps to take when analysing how work should be done, how abnormalities should be addressed as well as describing the process of gate-keeping.
- P7 – Planning: Describes steps for developing works order packages and instructions, identifying lockout needs, creating and maintaining a library of standard work orders as well as creating and maintaining a bill of materials. Shutdown planning is also covered in this sub-process.
- P8 – Scheduling: Describes steps for developing and managing a site-wide shutdown plan including resource balancing, reviewing backlogs and prioritisation of work, creating and maintaining a resource and attendance register.
- P9 – Execution: Describes the elements of maintenance execution such as lubrication, calibration, refurbishment and more.

- P10 – Follow-up. This sub-process describes the elements of closed loop control, follow-up, shutdown post mortems and so on.
- P11 – Materials and consumables: Describes the steps for creating a materials strategy, creating a common taxonomy, optimising spare parts between plants/sites and managing inventory.
- P12 – Centralised maintenance services: Describes the steps to take when managing sub-contracting, managing central services, managing the Maintenance Support Team (MST) and managing repairable sets.
- Enabling technologies – This element defines technologies that will enhance abilities to execute the ARP sub-processes in the most effective and efficient way with the added benefit of sustainability. Examples of enabling technologies are SAP enhancement packages and MS Projects.

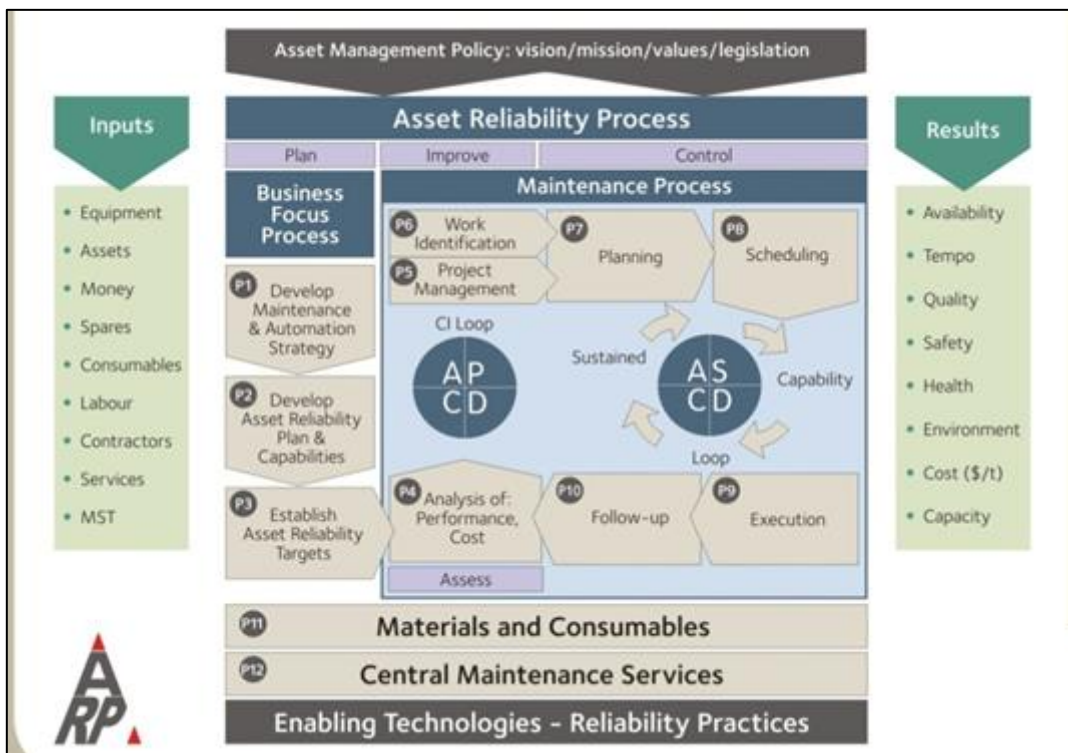


Figure 2: A graphical representation of the ARP

2.2.6 Scheduled maintenance

Scheduled maintenance, also called “preventive maintenance” or “planned maintenance” is a collection of activities aiming to keep all equipment in the optimal

state to run stable, reliable, qualitative and cost-effective production processes. An important indicator to measure the performance of scheduled maintenance is the concept of “Mean Time to Failure” (MTTF). A second indicator of effective planning and scheduling on maintenance is “Planning Degree”.

2.2.7 Breakdown maintenance

Breakdown corrective maintenance aims to set up an adequate response to unforeseen and urgent equipment malfunctions. An important indicator to measure the performance of breakdown maintenance is the concept of “Mean Time to Repair” (MTTR) as well as the ratio of Preventive Maintenance: Breakdown Maintenance.

2.2.8 Central maintenance services (CMS)

Central Maintenance is the department responsible for a large number of site-wide services. Part of these responsibilities is the support of all production plants regarding maintenance. Some important indicators to measure the performance of CMS could include “response time” or “adherence to SLA”, “hired labour spend” and “overtime”.

2.2.9 Organisational design

Maintenance management and execution mainly involves three different parties that being, plant maintenance teams, central maintenance services and a number of external service providers. The organisation of maintenance in each of these parties consists of a number of functional units, each with specific focus areas as illustrated in Figure 3 below:

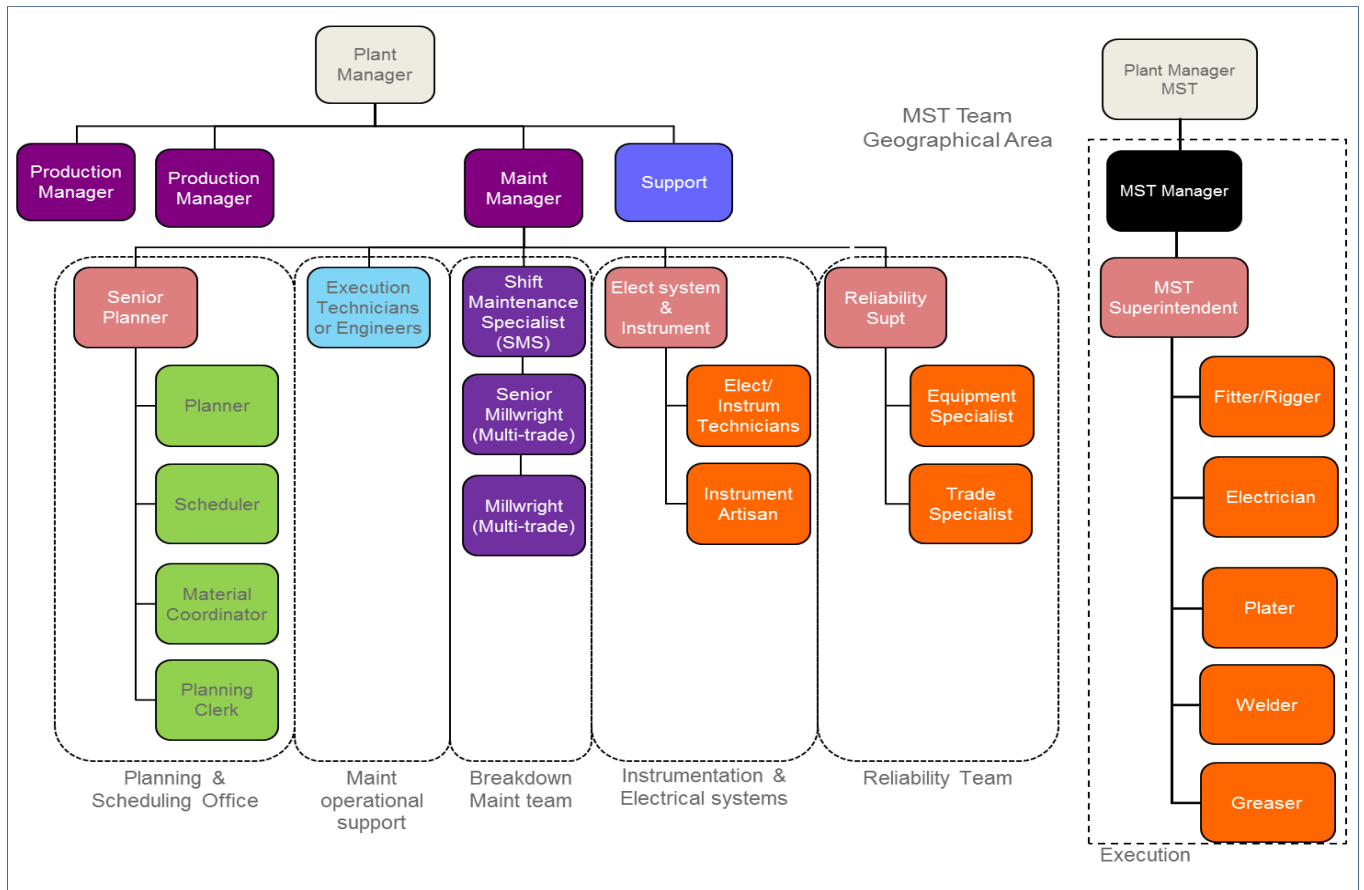


Figure 3: The functional units in the maintenance organisation

2.2.10 Meetings

The objective of the maintenance review meetings and interactions is to govern the content and structure of all recurrent maintenance meetings and reviews. Some of the core maintenance interactions are listed below with a brief summary of each meeting:

- Daily/Weekly planning review - This meeting brings around the table all the senior planners, planners and schedulers of the plants under the control of a maintenance manager on a daily/weekly basis.
- Shutdown planning (also called D-minus) meetings - This meeting brings together all parties involved in the planning and preparation of plant shutdowns.
- Shutdown post-mortem - This meeting brings together most parties involved in the planning, preparation and execution of plant shutdowns.

2.2.11 Performance tracking and reports

The objective of the maintenance performance tracking and reporting is to govern the tracking of and reporting on all maintenance related indicators which includes but is not limited to KPIs, leading indicators, lagging indicators, individual performance indicators, control items and check items.

2.2.12 Visual management

Visual Management (VM) is used as a tool for performance tracking and reporting.

VM allows:

- Two-way information flow between management and shop floor on performance, improvement project status, concerns, problem areas, and more.
- VM also allows for management involvement with and visibility at shop floor, which is very critical for transformation successes. The positive effects ascribed to increasing the scope of involvement include: improved strategy execution, higher quality strategic decisions, better understanding of deliberate strategy, enhanced organisational learning, stronger organisational commitment, higher job satisfaction, more adaptive core competencies, the development of competitive advantage and improved organisational performance (Burgelman, 1994:24).

2.3 SUMMARY

This chapter highlighted the fact that the company chosen for the study has a long and proud history of steel manufacturing which has lasted for more than a century already. One can safely infer from this that the company is not new to the theory and problems of maintenance planning and improvement.

The history illustrated that the plant has been in existence since 1911 and gradually grew with acquisitions and mergers until recently. It is also evident that a challenge of aged machinery and equipment that has been operational for long and extended periods over the years currently exists. Maintenance therefore forms an important and crucial role in the survival and competitiveness of the Vereeniging works.

The history and background of the company illustrates that it is currently busy implementing a thoroughly structured program called the ARP. The ARP also takes maintenance planning very seriously and even includes it as a separate process in its overall program. It can thus also be postulated that maintenance planning is indeed an essential component of any maintenance improvement initiative, thus this study will help in going a long way to help organisations in structuring their maintenance planning transformation initiatives correctly for optimal impact.

CHAPTER 3: LITERATURE REVIEW ON MAINTENANCE PLANNING

3.1 INTRODUCTION

According to Welman, Kruger and Mitchell (2005:39) a literature study is a method that enables a researcher to refer to current and previous research on the same topic that may suggest ways of eliminating inconsistencies between their findings and those of other studies. These are some of the reasons why a literature study is important:

- A review of related literature can provide the researcher with important facts and background information about the subject study.
- The study also enables the researcher to avoid duplicating previous research.
- Findings and conclusions of past studies can be assessed which the researcher can relate to his findings and conclusion.

3.2 MAINTENANCE PLANNING AND SCHEDULING

The online Oxford English Dictionary (OED) simply defines maintenance as “Senses relating to support or assistance” (OED, 2014). Physical assets in plants deteriorate with usage and time thus requiring maintenance to restore them to original operational conditions to reduce the overall probability of outages and thus costs. This type of maintenance called preventative maintenance (PM) generally includes actions such as inspection, cleaning, lubrication, alignment and adjustment and/or replacement (Tam, Chan & Price, 2007).

Condition based maintenance simply implies that maintenance is done when needed and that the condition of a machine can be monitored from the surface while it is still running and then only perform maintenance when it is needed (Berry, 1990). It consists of three main steps: data acquisition, data processing and maintenance decision-making (Jardine, Lin & Banjevic, 2006). This procedure is simplified by use of a computerised vibration analysis and fault diagnosis (Jones, 1994). Since vibration

analysis equipment and other condition monitoring tools can be quite costly, a method called telemonitoring should be used for condition monitoring (Khatib, Nassef, Fors, Chen & Joshi, 2000).

Maintenance helps companies decrease their costs and thereby improve competitiveness (Marmier, Varnier & Zerhouni, 2009). It is mostly a decision of the asset/maintenance managers which maintenance policy to use such that the expected total cost of system failure and maintenance cost will be minimised. Numerous models and methodologies are available for determining effective maintenance schedules and some works include that by Price (2002) on the economics of tube thickness survey and Noori and Price (2005) on inspection effectiveness.

Maintenance of a plant or facility can be performed by default or by plan (Brown, 2004:1):

- Maintenance by default simply means equipment is repaired as it fails.
- Maintenance by plan on the other hand means that there has been forethought in what level of maintenance is required.

It is thus a fundamental requirement that organisations must move away from maintenance by default to maintenance by plan in order for the maintenance teams to gain a better level of control of their plant. The basis for this control is provided mostly by a comprehensive planning and scheduling effort (Brown, 2004:1). Gross (2002:139) supports this very neatly in emphasising that “No plan is a plan for failure”. Diedeman (2004) also urges maintenance managers not to arbitrarily schedule maintenance but to also proactively plan and manage it.

In a recent poll on maintenance managers, it was illustrated by over 40% of them that planning and scheduling was one of their biggest problems (Wireman, 2010). Many maintenance workers feel as though their days are always filled with interruptions. Brown (2004:21) mentions that the most common complaints of maintenance workers are that: “*They are always pulling me off one task to go and start another*”, and “*I’m often assigned to work on a job that someone else has started.*” These complaints point

to the lack of fulfilment on the willingness of employees to start a job and finish it right the first time; a simple lack of good maintenance planning.

3.2.1 The benefit of planning

Palmer (2006) mentions that a plant's capacity remains the lifeblood of a company, which in turn is by definition an investment in maintenance planning. With good maintenance planning and scheduling, an environment can be provided to improve on the frustrations mentioned above and thus increase the motivation of employees to excel and do better in their jobs.

3.2.1.1 Why improvement is needed in maintenance

Effective maintenance makes sure that production capacity is available whenever it is needed, and in doing so reduces the overall cost of the company. Companies make products which they can sell at a profit with the capacity provided by good maintenance. Implementing proper planning and scheduling can improve productive maintenance time from the 25% - 35% of a typical organisation without planning to well above 50% - 70% (Palmer, 2006). Peterson (1998) warns though that, "Planning is a discipline that is difficult to achieve and difficult to maintain".

3.2.2 The planning and scheduling profession

The online pay and salary benchmarking website of Payscale (2014) ranks the median annual salary of a maintenance planner in South Africa at about R306,664. This is probably a good living wage by South African standards, making the planner position fall comfortably into the middle class earner categories. Many organisations leave the job of planning and scheduling to the first-line maintenance supervisor. Although this might seem like a completely logical approach, there are a few limiting factors that can hinder optimal performance. Firstly, this approach assumes that the supervisor is the most knowledgeable on what is required to complete a job and who can best do the actual work. But why is it then that many companies feel an increasing need to add a

dedicated planning function? While in some cases it is felt that the jobs can proceed much more efficiently if they are better supervised, freeing up the supervisor to supervise rather than plan and schedule work can lead to a 10-15% reduction in job duration (Brown, 2004:21). It is also important to note that in most companies, as also emphasised by Brown, a 5% improvement in time on jobs will be more than enough to pay the salary of a planner who can be used to plan for 20, or sometimes even more, employees.

The addition of a planner may also improve on the quality of job execution. This can be achieved by, for one, increasing the available time for maintenance employees to do actual maintenance work by eliminating the need for them to identify, purchase, allocate parts, materials, and other job support equipment which can be normally done by the planner. The step-by-step plans drawn by planners can reduce the amount of time that is normally required for equipment downtime.

Supervisors do not plan that far ahead in terms of their operations since they are more often than not too preoccupied with day-to-day work and performance problems to think of the future. Planners are thus required to address the long-term planning needs of the organisation in planning outages and shutdowns months in advance to save companies from unnecessarily extended plant and equipment downtimes.

Planner positions are often filled by people with very good maintenance background and plant knowledge. In most companies the position will be at the same level of grading as a maintenance supervisor. Although most companies can create separate positions for a planner and scheduler, the job is often done by one person (Brown, 2004:22). When the position is split, the planner will focus on building a plan for a job and will develop the list of the equipment required to complete it, while the scheduler will focus more on developing a schedule based on the workforce available using the labour hours estimated by the planner. Since no real emergency can be planned, most companies will assign the responsibility of handling the emergency work to the first-line supervisor.

3.2.3 Definition of Planning

The OED.com website defines planning as, “*The action or process of forming a plan; the action or work of a planner, (later) esp. the designing or controlling of urban or economic development; an instance of this. Also occas.: the making or delineation of a plan or diagram*” (OED, 2014). Brown (2004:23) on the other hand defines planning as simply “*the allocation of needed resources, and the sequence in which they are needed, to allow an essential activity to be performed in the shortest time or at the least cost*”. The definition by Brown is more consistent with the context of this study and will thus be used as a reference for the purpose of this study.

3.2.3.1 What planning mainly is and what it is mainly not

Maintenance planning involves identifying parts and tools necessary for jobs and reserving or even staging them as appropriate (Palmer, 2006). The common perception of planning is that after someone requests maintenance work to be done, the planner would simply determine and gather the necessary parts and tools before the job is assigned. The planner might even write instructions on how to do the job to reduce the time the craftsmen spends on getting everything ready. The planner might also stage some of the parts needed by placing the latter in a convenient location such as the job site before the actual job starts. A planner might also provide a bill of materials or an illustrated parts diagram. Finally, the planner would be involved in quality assurance and quality control of vendor shipments. Planning thus requires the identification and, if necessary, the allocation of any resource that may be needed to get a maintenance job completed. The planner also needs to define the necessary sequence (or order) of jobs to be done to help the scheduler with their task. And finally, the planner is required to limit the time and the cost of executing maintenance tasks or orders.

Palmer (2006), however, emphasises that, in addition to the basics of planning provided in the previous paragraph, planning must focus on the high productivity desired from the application of planning and scheduling principles.

3.2.3.2 Planning principles

Palmer (2006) presents six principles that he suggests should guide maintenance planning to become effective. The principles are briefly discussed in the following paragraphs.

- **Principle 1: Separate department**

The first planning principle states: *“The planners are organized into a separate department from the craft maintenance crews to facilitate specializing in planning techniques as well as focusing in future work.”*

This principle simply directs that planners should not be members of the crew for which they plan for and thus should report to a different supervisor or senior to the one whom the crew reports to. This ensures that crews will not only work on work assigned to their own supervisor but instead they work on all the planned work.

- **Principle 2: Focus on future work**

The second planning principle states: *“The planning department concentrates on future work ... in order to provide the maintenance department at least one week of work backlog that is planned, approved, and ready to execute...Crew supervisors handle the current day’s work and problems...”*

This principle simply dictates that planners should have their primary focus on future work, which is why they need to be separate in the first place. This principle works hand in hand with the first principle to make sure that planners have enough time to plan for only future work and they do not get distracted to work on current jobs, which will lead them to less planning, which in turn results in more reactive work being done, ultimately reducing the benefits of planning in the first place.

- **Principle 3: Component level files**

The third planning principle states: *“The planning department maintains a simple, secure file system based on equipment tag numbers. The file enables planners to utilize equipment data and information learned on previous work to prepare and improve work plans, especially on repetitive maintenance tasks...”*

This concept dictates that planners do not file on a system level but rather on an individual component basis using “minifiles”. A minifile is simply a file made exclusively for an individual piece of equipment the first time it is maintained. Planners then have to subsequently consult the minifiles for each new job to take advantage of the lessons and information gained on previous jobs on the specific equipment. The file can be securely made available to other personnel such as engineers and supervisors to obtain information for projects or jobs in progress rather than interrupting the planners from their main job of planning future work.

- **Principle 4: Estimates based on planner expertise**

The fourth planning principle states: *“Planners use personal experience and file information to develop work plans to avoid anticipated work delays and quality or safety problems. As a minimum, planners are experienced, top level technicians that are trained in planning techniques.”*

This principle simply means that only the best among the craftsmen in the plant should be chosen to become planners since they will depend a great deal on their experience and available file information to develop job plans.

- **Principle 5: Recognize the skill of the crafts**

The fifth planning principle states: *“The planning department recognizes the skill of the crafts. In general, the planner’s responsibility is “what” before “how”... The craft technicians use their expertise to make the specified repair or replacement...”*

This principle simply means that the planner must be able to count on the experience and expertise of the crew so that they are able to plan the jobs with minimal detail. This does not mean however that the execution team should not

adhere to the job plan, but it means that adherence becomes even more so important as well as feedback at the end of the job.

- **Principle 6: Measure performance with work sampling**

The last planning principle states: *“Wrench time is the primary measure of workforce efficiency and of planning and scheduling effectiveness. Wrench time is the proportion of available-to-work time during which craft technicians are not being kept from productively working on a job site by delays such as waiting for assignment, clearance, parts, tools, instructions, travel, co-ordination with other crafts, or equipment information...”*

This principle emphasises the fact that the effectiveness of the maintenance planning program is determined by mainly the measurement of Wrench time. This simply means that all other delays that keep the crewmen from the ‘wrench’ are ‘wastes’ and should be avoided at all costs, or minimised to as much as possible.

3.2.3.3 The work order system

Planning success is very closely linked to an efficient work order system thus the work order system is the most valuable tool for improving maintenance effectiveness and productivity (Palmer, 2006). A work order system is simply the formal method of requesting and recording work done in the plant. In its simplest form, someone who wants some specific maintenance work performed fills out a specific document. The person turns that document over to the maintenance department who then use the same document to keep track of the work through its execution. This document in question is basically the ‘work order’ and the process that uses it is the ‘work order system’. The system is really the heart of maintenance and helps maintenance personnel obtain necessary origination information and control all the work.

Palmer (2006:126) provides a good summary picture which is displayed in Appendix B: Figure 11, showing the steps of the work order process in its simplest paper based format (although most companies use an electronic work order system these days). The

paper format means that the work request is written on a physical piece of paper, and the same paper format is passed to the planning department and ultimately to the execution team. The 'work order form' is then returned to the planning department for finalisation with the necessary job execution feedback. An example of a work order form to help guide input is shown in Appendix C: Table 9.

3.2.3.4 The planning process

The main duty for planners in the planning process is to take new work orders and then add new information to allow more efficient scheduling and execution of the work. The diagram below in Figure 4 shows the general sequence of the planning operations (Palmer, 2006:129).

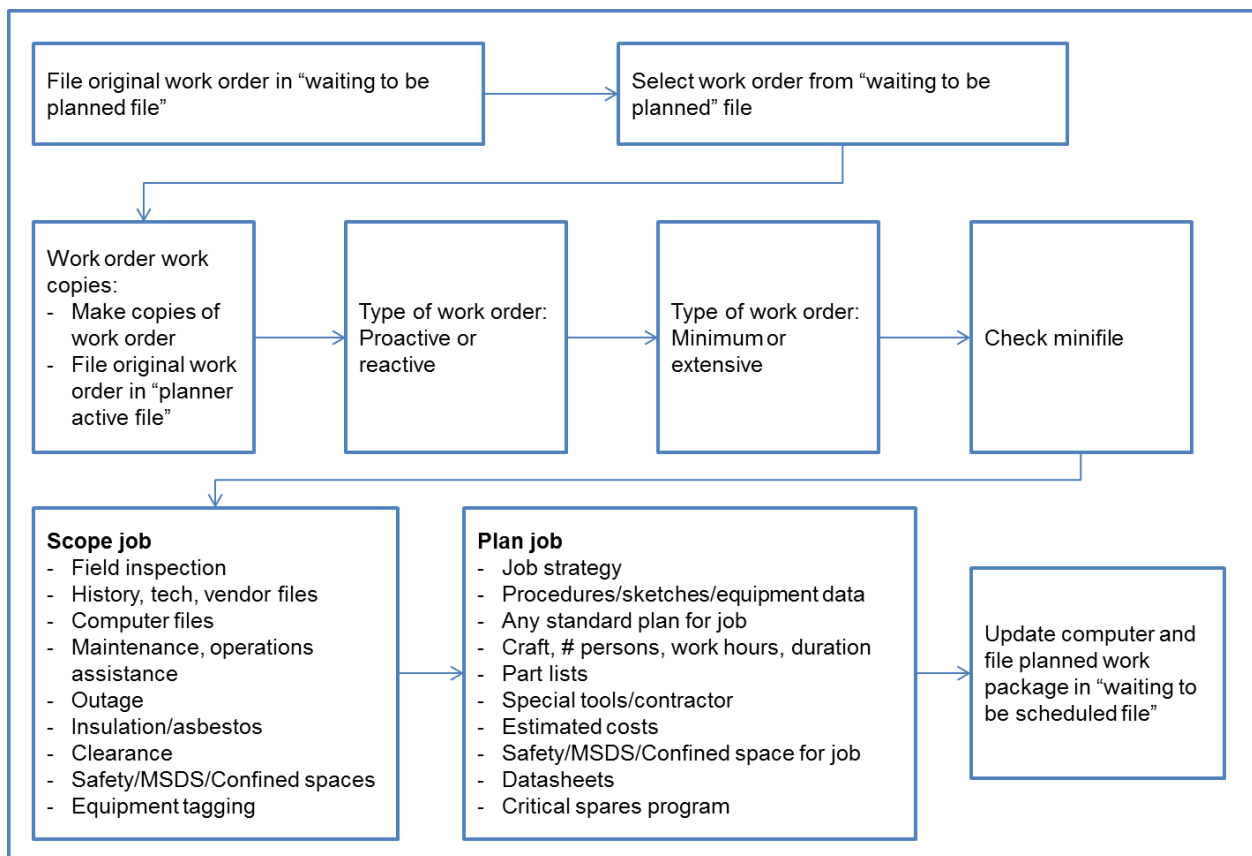


Figure 4: General flow of planning activities

Source: Palmer (2006:129)

3.2.4 Maintenance resources

Planning maintenance work requires identifying all needed resources to complete a job. A resource is anything that is consumed when performing work (Brown, 2004:24). Maintenance work will normally use the following resources: time; labour; materials, parts, supplies, and tools; support equipment such as cranes and lift trucks, and contracted or outside services.

3.2.4.1 Labour

The number of labour hours and the size of the maintenance crew should be considered when planning maintenance work. Some jobs may require special skills that may only be available among certain members of the crew, and thus as a result the allocation of labour may also require the exact person who will do the job. Labour can be identified in months, weeks, or days, but most companies normally report it in hours. The cost of the labour is perhaps one of the most important elements that have to be factored into the planning of the maintenance tasks. Cost of labour normally varies depending on the trade or levels of skill required amongst other factors.

3.2.4.2 Materials, supplies and tools

The planner should also identify the materials, parts and tools that will be needed and used in completing the job. This therefore implies that the planner needs to verify that the needed items are in fact, available and dedicated to the job being planned.

3.2.4.3 Support equipment

Support equipment includes fork lifts, pickup machines and cranes which can be in limited supply during busy periods of maintenance. The planner should thus identify which of these equipment will be needed and ensure that they are available as and when required.

3.2.4.4 Contracted or outside services

The existing workforce may require to be supplemented by external labour in order to finish some jobs that exceed the available workforce's abilities to finish within a reasonable time. Although the company may elect to work overtime, it does at times happen that the cost of overtime far exceeds that of hiring outside labour to complete certain jobs. Contractors and outside labour are also frequently requested to complete jobs that can simply not be done by the existing internal labour skills.

3.3 PLANNING AND ESTIMATING

As discussed in the previous section, the planning of a job requires identifying all needed resources to complete the job. Good planning provides for a thorough framework for proper execution of the work and helps ensure all resources are used more effectively and efficiently (Brown, 2004:84). This section discusses the various methods used to estimate time and costs associated with a job focusing on several means by which estimating is performed.

3.3.1 Planning judgment versus planning guesses

Planning estimation, like all estimation processes, have inherent inaccuracies and therefore good estimating involves good judgment. Thus this is very diligently dependent on the authoritative opinion and experience of the planner. A guess differs from a judgment since an estimate based on a guess is based on little or no evidence (Brown, 2004:31). It can thus be inferred that the planning process can be improved by, for one, improving the ability of a planner to make good judgment calls.

3.3.2 Planning and estimating methods

Estimation methods require that a planner be trained in a specific way of thinking which requires a logical and repeatable process. Brown (2004:34-50) provides the following list of common estimating methods used in industry today:

- Construction planning and estimating,

- Methods time measurement,
- Planning thought process,
- Estimates based on past performance.

The construction planning and estimating method as the name suggests is mostly used for construction related work and thus is not that significantly applicable to maintenance management.

The methods time management (MTM) system is derived from the work done by Frederick Winslow Taylor and other pioneers of scientific management. The system devised elemental activities that are performed by workers in any operation by using time studies and observations and then determining standard times it takes for an 'average' worker to complete a certain task. This effort was mostly proven problematic in applying to maintenance work since most maintenance work is not repetitive like piecework (Brown, 2004:47).

The planning thought process method is the methodology that will be recommended in this study since it is the one estimating method that uses the abilities of the planner to the fullest. The process has three main purposes (Brown, 2004:50):

- Establish an estimate of time required for the job.
- Define understandable steps to complete the job.
- Identify the materials, parts, tools, and equipment required for the job.

To help make the explanation of the process discussed in the above paragraph even easier, the diagram below is used to break down the steps involved (Brown, 2004:51):

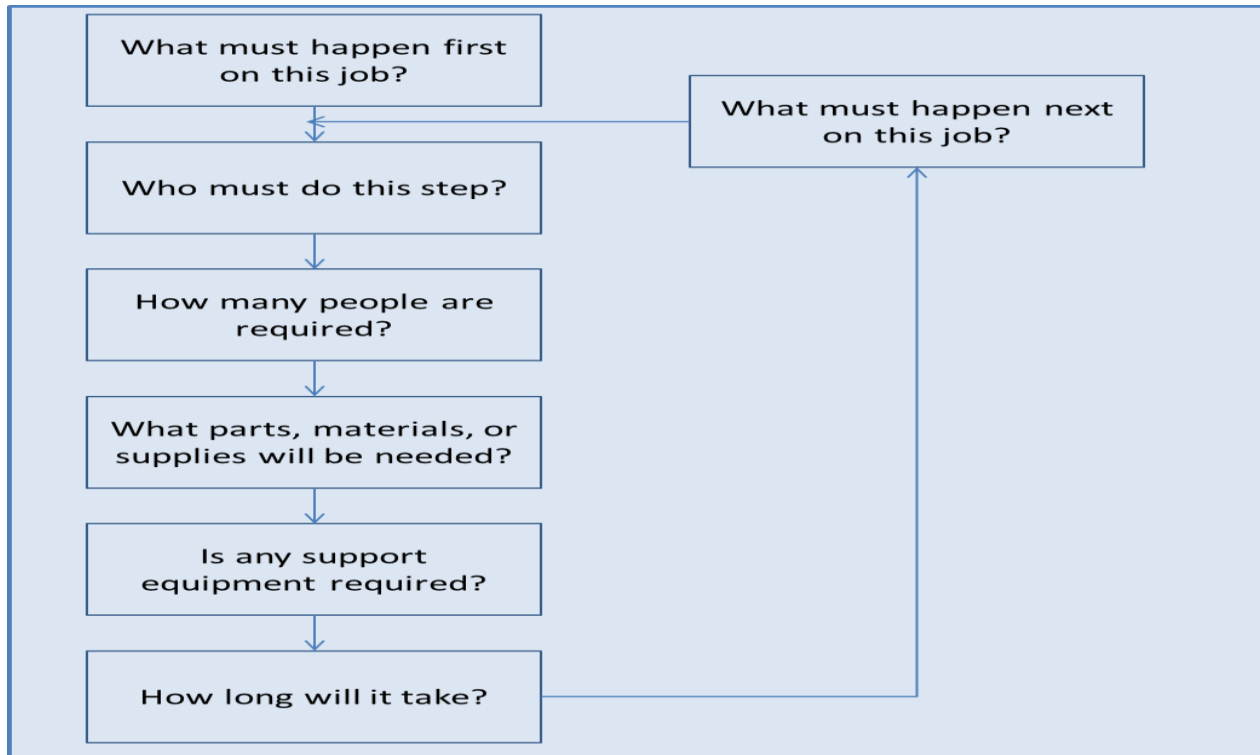


Figure 5: The planning thought process

Source: Brown (2004:51)

The planning thought process steps are described as follows:

- What must happen firstly on the job? – In this step, the planner is required to visit the job site and ask this question. The answer gives clarity on whether or not the operator has to be contacted, or equipment have to locked-out and tools to be collected or not.
- Who must do this step? – The planner needs to, secondly, identify the skills required to complete the job, for instance sometimes the first job to be done requires different skills to the rest of the jobs to be completed.
- How many people are required? – Clarity on the number of crew men to complete each step of the maintenance task needs to be determined by the planner.
- What parts, materials, or supplies will be needed? – The parts, materials and other non-standard supplies need to be identified by the planner before the job is started.

- Is any support equipment required? – In this step, the planner has to make sure that all special tools and equipment such as mobile cranes or others are listed.
- How long will it take? – The experience of the planner is put to the test in this step to determine the elapsed time required for each of the steps required to complete the job.
- What must happen next on this job? – The planner does the same cycle as above for the next step, until all tasks have been identified for the job being planned.

The planner should write down all these steps described in the thought process and visualise them using a planning worksheet; a filled example of a planning sheet can be viewed in Appendix D: Figure 12. The planning work sheet is designed to help the planner go through the steps thoroughly in each planned job. When a planning sheet has been completed, it can easily be used as an input document for a computerized maintenance management system (CMMS) or simply be filed for future reference.

3.3.3 Reasons for planning program failures

Although the principles and guidelines discussed in the previous paragraphs will offer good support for the implementation of good maintenance planning programs, many reasons can lead them to failure. Wireman (2010) presents four major reasons as to why planning programs often fail which include:

- The planner having overlapping responsibilities.
- The planner not being suitably qualified.
- The planner being simply careless in carrying out his/her duties.
- The planner not having sufficient time to properly plan the jobs at hand.

Examining planning failures in more detail can help prevent future programs from not meeting their objectives. Weak job descriptions combined with overlapping job responsibilities will, for example, exacerbate the possibility of planning failures. Eliminating this problem requires more than just strict planning lines but much clearer

responsibilities and strict compliance to plans which are done according to good planning principles.

3.4 SUMMARY

This chapter reviewed literature found in different academic and related sources on the subject of excellent maintenance planning. Research specialist authors highlight that literature is an important method that enables a researcher to refer to previous studies on the same topic that may suggest ways of eliminating inconsistencies between findings and to also avoid duplicating research.

The literature reviewed indicates that maintenance plays an integral role in the running of any business by making sure that assets are restored to original operational conditions after they have naturally deteriorated with their usage and time. Maintenance planning is confirmed to be one of the biggest headaches for maintenance managers but also one of the most critical methodologies to decrease costs and improve maintenance and production efficiencies.

Many benefits for excellence in maintenance planning covered in literature include the following:

1. Improving worker morale by ensuring that tasks are carried out in a systematic, standardised and orderly manner.
2. Ensuring production capacity is available whenever it is needed and therefore reducing costs of production.
3. Improving the quality of maintenance task execution.

Six key principles for excellence in maintenance planning were also discussed in the literature study which can be summarized as follows:

1. **Principle 1:** Planners should be separated from the craft maintenance crews and be employed in a separate department.
2. **Principle 2:** Planners should focus their planning on future work.

3. **Principle 3:** Planners should maintain a simple, secure file system based on equipment numbers used to capture equipment data for completed jobs.
4. **Principle 4:** Planners should base estimates on their experience together with the files from the third principle. Therefore planners should be highly experienced ex-crew members.
5. **Principle 5:** Planners should concentrate on the “what” of the plan and leave the “how” to be determined by the craft crew.
6. **Principle 6:** Tracking planning effectiveness and efficiency should be done by simply tracking the “Wrench” time of the execution crew.

Planning is very closely related to the work order system which is defined as the method of requesting and recording work done in the plant. It is thus particularly imperative that the work order system be closely aligned with the six principles discussed above to enable more effective planning. The recommended planning process that is found in literature and closely aligned to the six principles is summarized in the following seven steps:

1. Step 1: The planner must ask the question, “What must happen first on the job?”
2. Step 2: “Who must do this step?”
3. Step 3: “How many people are required?”
4. Step 4: “What parts, materials, or supplies will be needed?”
5. Step 5: “Is any support equipment required?”
6. Step 6: “How long will it take?”
7. Step 7: “What must happen next on this job?”

In conclusion, the literature highlights that planning is indeed an integral part of maintenance and should be done in a standardised, methodological manner by following a disciplined set of principles as discussed above. Further to this, the seven steps of planning should be followed by the planner in planning each and every maintenance task. In this way planning will help improve maintenance reliability and plant availability and thereby reduce costs, increase efficiencies and improve worker morale.

CHAPTER 4: EMPIRICAL STUDY

4.1 RESEARCH INSTRUMENT

The Asset Reliability Process (ARP) transformation team developed a comprehensive gap analysis tool which consisted of a number of questions under specific criteria that needed to be answered by the departments where the implementation of ARP was undertaken. A survey instrument in the form of a questionnaire was developed and used in this study. The questionnaire was separated into three sections, those being Section A: Bibliographical information, Section B: Maintenance Plans and Section C: Shutdown Planning. Since this research study will also be used for the benefit of the company, it was decided that none of the main questions and criteria contained in the tool should be drastically changed. The main addition to the tool is the bibliographical section of the questionnaire and some minor changes to descriptions of the ratings for the answers. Following in the next few sections is a description of the questionnaire used in this study which can be referred to Appendix E.

4.1.1 Section A: Demographical information

The demographical section gathers data identifying the gender, age, educational qualifications, work experience, and job titles/responsibilities of each respondent.

Constructs and questions for bibliographical section:

A1: Age.

A2: Gender.

A3: Highest level of education.

A4: First language.

A5: Employment status.

A6: Current position of employment.

A7: Number of years in position.

4.1.2 Section B: Maintenance plans

The second section measures the maintenance plans based on the categories discussed below:

Standards and procedures: Determines whether or not standards and procedures are created by competent individuals, approved by the proper level in the organisation, and used on planned jobs. This is required for greater than 80% of all planned work. All standards and procedures should be approved to meet all legal, safety, environmental, occupational or government requirements for the industry.

Equipment history and data usage: Measures the extent of using the equipment history and data for planned work execution, equipment analysis and improvement for all highly rated critical machines.

Parts/Machines removed: Parts and machine assemblies removed from service should always be promptly sent for repair/rebuild if required. Any unused parts, equipment, or materials should be returned to storerooms.

Work order based on facts: More than 95% of maintenance work orders should be formalised and based on facts, and planners should develop a work order for every task to be done.

Kitting: Maintenance must be able to start jobs at a completely prepared work site (for instance, kitted tools, parts, permits, isolation, risk assessment and equipment prepared).

Quality/Detail of plans: Planning should be completely done to include job scope, materials, tools, and estimated man-hours, equipment scheduled, site prepared, clear objective and all other pertinent information. Planning and scheduling procedures should be standardised to adhere to initial planning. SHER (Safety, Health, Environment and Risk) should be part of the plan.

4.1.2.1 Constructs and Questions for Section B (Likert scale):

B1: Standards and procedures are created by competent individuals, approved by the proper level in the organisation, and used on jobs where required for greater than 80% of all planned work.

B2: Standards and procedures that are approved meet all legal, safety, environmental, occupational or government requirements for the industry.

B3: Maintenance personnel extensively use the equipment history and data for planned work execution, equipment analysis and improvement for all critically rated machines.

B4: Parts and machine assemblies removed from service are always promptly sent for repair/rebuild if required and any unused parts, equipment, or materials are always returned to storerooms.

B5: More than 95% of maintenance work orders are formalised and based on facts, and planners develop a work order for every task to be done.

B6: Maintenance is able to start jobs at a completely prepared work site (for example, kitted tools, parts, permits, isolation, and equipment prepared).

B7: Safety, health, environment and risk (SHER) is always included as part of the plan.

B8: More than 75% of all work orders are properly planned that is, with a plan that includes the following:

1. an accurate scope with work activities logically grouped into well-defined tasks, meeting all regulatory requirements;
2. an accurate estimate of labour (internal and/or external) specifying the skill, number of resources and the time required for each task;
3. an accurate estimate of material requirements including plant store parts and externally purchased parts;
4. identification of special tools and equipment;
5. risk analysis, safety permits or assessments, contractor and coordination requests;
6. work orders/tasks are assigned a priority based on early start, late finish date and criticality of the asset.

4.1.3 Section C: Execution of shutdown planning

This section measures the execution of shutdown planning and how the success of the planning section is done over time for tracking and continuous improvement efforts. The section is divided into these categories:

D-Minus planning: There should be a contingency plan with a comprehensive document of the shutdown and a distribution list. Shutdowns should also have a complete detailed work planning and scheduling, with people assigned to jobs. A complete safety plan covering both individual jobs and risk of job interference should be in place. Work permits should be ready. Shutdown scope is highly standardized and challenged by production and maintenance resulting in shifting work outside the shutdown and eliminating non-essential work. All shutdown work is planned in hours and by craft.

Percentage planned work: Less than 2% of maintenance hours should be devoted to breakdown maintenance and 95% of work should be planned.

Planned work not done: No or little work that was planned is cancelled during shutdowns.

Planning performance: The planning element of the maintenance process has process assurance metrics defined (leading indicators). Performance should be tracked and the results used to manage execution of each maintenance process element.

4.1.3.1 Constructs and questions for section B (Likert scale):

C1: There is a contingency plan and a comprehensive document for every shutdown, with its own distribution list.

C2: Gate keeping reviews the full task list, scope of work and the effect on the master plan as well as scrutinizes the scope cost and effect to EMP (Emergency maintenance plan).

C3: The shutdown scope is standardised and challenged by production and maintenance resulting in shifting work outside the shutdown and eliminating non-essential work.

C4: Shutdown work is planned in hours and by craft.

C5: Less than 2% of maintenance hours are devoted to breakdown maintenance.

C6: 95% of work done by craft is actually planned work.

C7: No or little work that was planned is cancelled during shutdowns.

C8: The planning element of the maintenance process has process assurance metrics defined (leading indicators). Performance is tracked and the results used to manage execution of each maintenance process element.

4.1.4 Instructions on how to complete the questionnaire

Following in the next paragraphs are brief instructions on how to complete the questionnaire.

Section A

This section consists of close-ended questions that can be answered by either providing an unambiguous answer such as a **yes** or **no** or by simply ticking/crossing a box from a small selection of possible answers. The answers provided on selection questions are constructed to give the whole range of possible and most probable answers to the question asked. The section also consists of a few questions where the respondent is required to write an answer without any selections provided. These will however also not require long answers as their possible answers are also structurally intended to be very short and unambiguous with actually a very limited number of answers possible.

Section B and Section C

The main sections of the questionnaire i.e. section B and C, will be answered in exactly the same manner although the questions in each section relate to key different categories and focus areas of maintenance planning. To answer a question in the sections a respondent will choose the number which best describes his agreement or disagreement with the statement being tested. Each statement is intended to test the current conditions of the maintenance planning based on each of the planning categories that are being evaluated and have been discussed in detail in the previous section.

For example, in section B, the first category evaluated is that of the standards/procedures with regards to the maintenance plans. A selection of possible answers based on key possible statements is provided with each answer corresponding to a certain statement and a certain condition of the category being evaluated. With regards to the standards/procedures category the first statement will be the one that reads *“Standards and procedures are created by competent individuals...”* If a respondent feels that the current standards/procedures for planning in the maintenance department currently do not fit this statement’s description, then the respondent will choose “1” from the possible list of available answers and then write this number in the block provided for under the column of “score”.

A rating scale as below is shown to help the respondent with the answer by providing a category of what each possible ‘score’ basically says about the condition that is being evaluated. The scale shows the lowest number ‘1’ to indicate a strong disagreement with the statement while a ‘5’ indicates exactly the opposite. The scale is summarized in Table 2 below.

Table 2: Questionnaire answering scale

| 1 | 2 | 3 | 4 | 5 |
|-------------------|-------|---------------------------|-------|----------------|
| Disagree strongly | Agree | Neither Disagree or Agree | Agree | Agree strongly |

Respondents are thus to simply repeat the process outlined above for each of the categories evaluated, and for each category choose a “score” to state whether or not they agree with the statement for each item being researched in both sections B and C. The respondent is done completing the questionnaire if each and every one of the categories assessed has a score in the blocks provided for scoring.

4.2 RESEARCH OUTPUT

The following sections will provide the research output in a consolidated analysis of the data gathered from responses on the questionnaire. Suggestions for improvements based on the available information and the literature study conclusions will be provided in the next chapter.

The results have been interpreted on the basis of the following empirical analysis tools:

1. Descriptive statistics.
2. Validity.
3. Reliability.
4. Correlation.
5. ANOVA and effect sizes.

4.2.1 Analysis of responses from the demographical section of the questionnaire

4.2.1.1 Study population and sampling

A non-probability convenience sampling method was used to select the research respondents. Non-probability sampling means that the probability that any element of analysis will be included cannot be specified (Welman *et al.*, 2010:67). Convenience

sampling on the other hand simply means that those subjects that are easiest to obtain for sampling purposes are used (Welman *et al.*, 2010:69). The population of the study was entirely made up of the people employed in the maintenance departments of the Vereeniging works. In the current maintenance structures, a total of 172 positions exist of which 151 are filled and thus 21 are vacant seats. Of the 151 people that were available to complete the questionnaire, approximately 70 of them worked on shifts and therefore could not be reached directly by the researcher. To solve this issue, questionnaires were distributed to the maintenance managers who in turn distributed them to the superintendents in charge of the groups on night shifts to enable their teams to participate in the survey. A full explanation was provided to the managers so that they could effectively relay the main messages, purpose and objectives of the questionnaires to their teams.

A 100% response rate was experienced in this study since all the questionnaires that were distributed came back filled and of the 151 people who were available for the survey, a total 125 of them completed the questionnaire. This puts the reach and effective response rate of the survey to 82.8% (125/151) from the available population for the study which is statistically significant enough to make sure that the results of the study can be inferred as an accurate picture of what the population of the maintenance personnel at Vereeniging works experience in working there.

4.2.2 Age and racial groups analyses

The diagram below of Figure 6 shows that the maintenance people are of a very widely varied age, with some of them close to retirement while on the other hand we have some of the people who have just started working in the early to mid-twenties. This presents an obvious inter-generational possibility of cultural and perhaps even racial conflicts. Closely looking at the data, one sees that most of the old people are white Afrikaans speaking while the younger generations consist of more African young men. In terms of the relevance to the planning function, perhaps this presents the first challenge that has to be taken into account in coming up with any transformation initiatives to improve the maintenance planning efficiency and effectiveness.

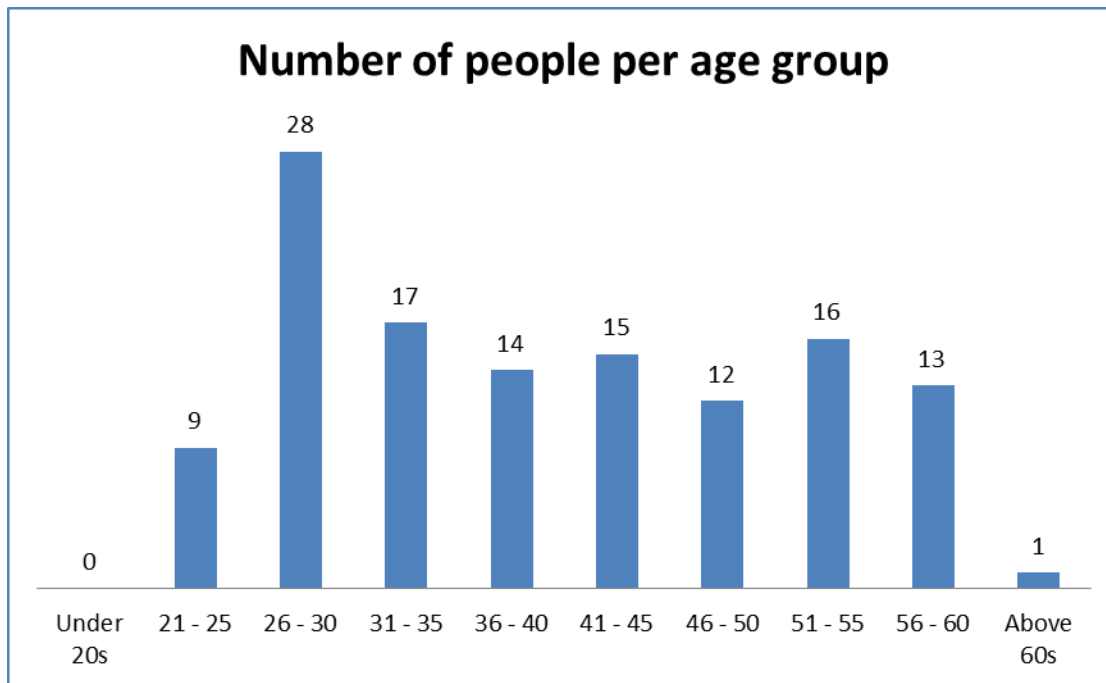


Figure 6: Number of people per age group

An interesting point to note from the sample is that only 3 of the respondents out of the whole 125 were female workers. With this low representation of the female view, it makes it a very challenging experience for the female workers to work in this environment since men are much less aware than women of the challenges female employees face at work (McKinsey Global Survey Results, 2014). This is probably mainly because of the nature of the work, which is hard, industrial labour and thus more culturally and physically attuned to males. This should obviously not form any excuses for management to increase the female workforce within the ranks of the maintenance team.

4.2.3 Level of education

Another interesting illustration is indicated in Figure 7, which shows the educational backgrounds of the respondents. It is very clear that only a few of the maintenance crew had any formal education higher than the South African national matric certificate, with only 6% of the respondents saying that they had a university qualification. This might

also add to the inferred racial and cultural misunderstandings that can be derived from the age and racial demographics.

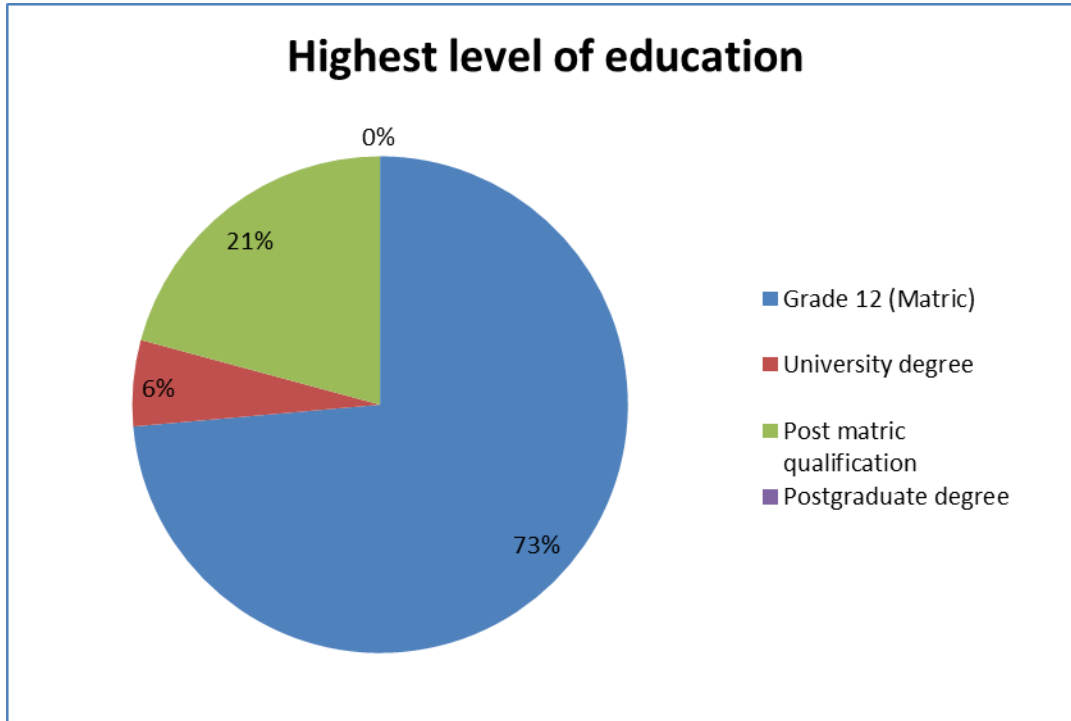


Figure 7: Educational levels

The misunderstandings and unease might be caused by the largely different educational and work experience knowledge that has been acquired by the different racial groups. The white personnel have more experience working in the plant but lower levels of education (mostly Grade 12) while the African generation has a slightly higher average educational level (post matric FET qualifications) while they have none to very little experiential training in the plant. There can thus be a tendency among the Africans to think they are more qualified since they have better and more educational training, while the whites will also think they know much better since they have been in the plant for longer (average tenure of more than 15 yrs. among the white colleagues).

4.2.4 Job profiles

Figure 8 below indicates that a wide majority of the respondents are fitters (34%), with only a few of the people actually occupying planning positions (7%). This is a true

reflection of reality since the planner position is viewed to be mostly at the same level as a superintendent and as such, it is a middle management position.

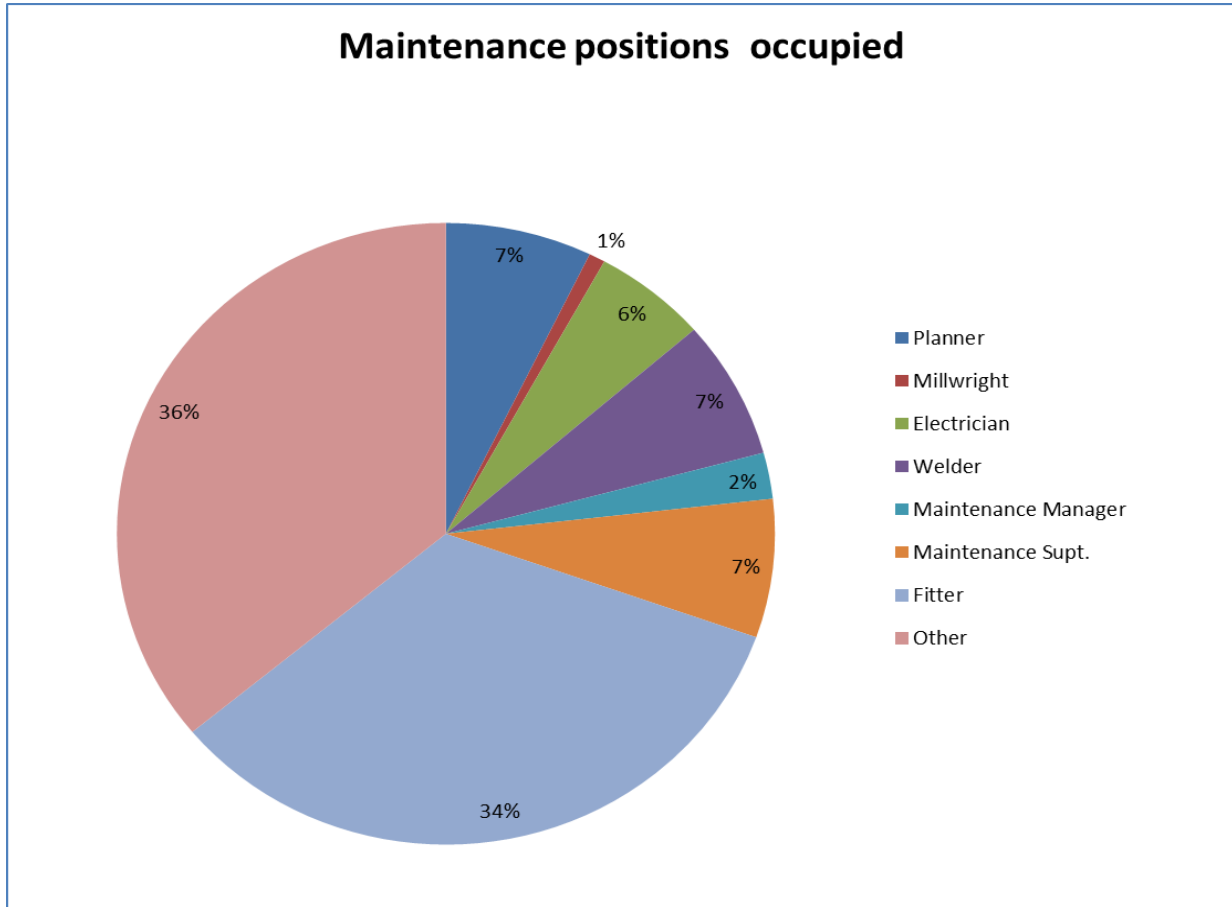


Figure 8: Maintenance positions occupied

It is therefore not a coincident that the pie chart also indicates that the sups occupy exactly the same percentage of the workforce as the planners do (7%). There were four maintenance managers included in the sample of responses (one from steel making and three from the production mills). In an ideal maintenance environment, each maintenance manager should have at least four planners reporting to him, with two planners concentrating on mechanical jobs and the other two on electrical work. Thus the ideal situation would require that at least 16 planners should have responded, but as can be seen in the research results, only 9 planners were available among the 4 maintenance managers. This is a strong indication that the planners are currently

probably overworked and possibly unable to do their required duties as per the optimal requirements and recommendations for world class practice.

The positions that responded also highlight the main fact that no schedulers are employed in the Vereeniging works and as such none was available to fill in the questionnaire. This is also additional evidence that the planners might be overworked since they have to probably do both planning and scheduling of maintenance tasks without a dedicated person available to complete that job.

The large majority of the responses came from the mills (62%) since there were three of them, and the rest (38%) came from the steel making department.

4.3 DESCRIPTIVE STATISTICS AND FREQUENCY ANALYSIS

The Statistical Consultation Services (SCS) of the North-West University at the Potchefstroom campus helped the researcher by performing some of the statistical analysis using the IBM SPSS Statistics Version 20 on the data collected (SPSS, 2012). The analysis included descriptive and frequency analysis which will be discussed in the following sections of the report.

A mean of a sample can be described as a measure for central tendency which basically makes the average score (Field, 2009:22). Levine, Stephan, Krehbiel and Berenson (2011:114) describe the mean as the common measure of central tendency which indicates a balance point in a dataset.

Levine *et al.* (2011) describe the standard deviation of a sample as the average scatter of values around the mean. The Investopedia (2014) website simply states it as a measure of the dispersion of a set of data from its mean. The more spread apart the data, the higher the deviation. The mean and standard deviation values for each of the research constructs are provided in the following tables; Table 3 and Table 4:

Table 3: Descriptive statistics for section B on maintenance plans

| | | % Disagree strongly | % Disagree | % Neither agree nor disagree | % Agree | % Agree strongly | Mean | Standard Deviation |
|-------------------------------------|--|---------------------|------------|------------------------------|---------|------------------|------|--------------------|
| Section B: Maintenance Plans | | | | | | | | |
| B1 | Standards and procedures are created by competent individuals, approved by the proper level in the organization, and used on jobs where required for greater than 80% of all planned work. | 2.4 | 4 | 10.4 | 72 | 11.2 | 3.86 | 0.76 |
| B2 | Standards and procedures that are approved meet all legal, safety, environmental, occupational or government requirements for the industry. | 0 | 5.6 | 11.2 | 64.8 | 18.4 | 3.96 | 0.72 |
| B3 | Maintenance personnel extensively use the equipment history and data for planned work execution, equipment analysis and improvement for all critically rated machines. | 1.6 | 4 | 30.4 | 56 | 8 | 3.65 | 0.75 |
| B4 | Parts and machine assemblies removed from service are always promptly sent for repair/rebuild if required and any unused parts, equipment, or materials are always returned to storerooms. | 1.6 | 12 | 17.6 | 54.4 | 14.4 | 3.68 | 0.92 |
| B5 | More than 95% of Maintenance work orders are formalised and based on facts, and planners develop a work order for every task to be done. | 2.4 | 10.4 | 15.2 | 57.6 | 14.4 | 3.71 | 0.92 |
| B6 | Maintenance is able to start jobs at a completely prepared work site (e.g., kitted tools, parts, permits, isolation, and equipment prepared). | 0.8 | 10.4 | 13.6 | 60 | 15.2 | 3.78 | 0.86 |
| B7 | Safety, Health, Environment and Risk (SHER) is always included as part of the plan? | 0 | 1.6 | 4.8 | 63.2 | 30.4 | 4.22 | 0.61 |
| B8 | More than 75% of all work orders are properly planned i.e with a plan that includes the following? 1. an accurate scope with work activities logically grouped into well-defined tasks, meeting all regulatory requirements; 2. an accurate estimate of labour (internal and/or external) specifying the skill, number of resources and the time required for each task, 3. an accurate estimate of material requirements including plant store parts and externally purchased parts; 4. identification of special tools and equipment; 5. risk analysis, safety permits or assessments, contractor and coordination requests; 6. work order/tasks are assigned a priority based on early start, late finish date and criticality of the asset | 1.6 | 4.8 | 27.2 | 49.6 | 16.8 | 3.75 | 0.85 |

Table 4: Descriptive statistics for section C on shutdowns

| | | % Disagree strongly | % Disagree | % Neither agree nor disagree | % Agree | % Agree strongly | Mean | Standard Deviation |
|-------------------------------------|--|---------------------|------------|------------------------------|---------|------------------|------|--------------------|
| Section B: Maintenance Plans | | | | | | | | |
| C1 | There is a contingency plan and a comprehensive document for every shutdown, with its own distribution list. | 1.6 | 3.2 | 10.4 | 66.4 | 18.4 | 3.97 | 0.75 |
| C2 | Gate keeping reviews the full task list, scope of work and the effect on the master plan as well as scrutinizes the scope cost and effect to EMP (Emergency Maintenance Plan). | 2.4 | 2.4 | 20.8 | 63.2 | 11.2 | 3.78 | 0.77 |
| C3 | The shutdown scope standardized and challenged by production and maintenance resulting in shifting work outside the shutdown and eliminating non-essential work. | 1.6 | 9.6 | 20 | 60 | 8.8 | 3.65 | 0.84 |
| C4 | Shutdown work is planned in hours and by craft. | 0 | 7.2 | 12.8 | 63.2 | 16.8 | 3.9 | 0.76 |
| C5 | Less than 2% of maintenance hours is devoted to breakdown maintenance. | 3.2 | 12 | 22.4 | 50.4 | 12 | 3.56 | 0.96 |
| C6 | 95% of work done by craft is actually planned work. | 1.6 | 11.2 | 15.2 | 59.2 | 12.8 | 3.7 | 0.89 |
| C7 | No or little work that was planned is cancelled during shutdowns. | 0.8 | 19.2 | 21.6 | 48 | 10.4 | 3.48 | 0.95 |
| C8 | The planning element of the maintenance process has process assurance metrics defined (leading indicators). Performance is tracked and the results used to manage execution of each maintenance process element. | 2.4 | 3.2 | 18.4 | 63.2 | 12.8 | 3.81 | 0.79 |

4.4 DETAIL DISCUSSION OF RESPONSES FROM SECTION B ON MAINTENANCE PLANS

Following in the next few paragraphs is a detailed discussion on the responses for each sub-section of the Maintenance Plans:

Standards and procedures: The descriptive statistics in Table 3 show a mean response of 3.86 for the first statement and a mean of 3.96 for the second statement measuring the standards and procedures. This result thus indicates that standards and procedures do exist in the current maintenance environment of the Vereeniging works, but these are not as optimally used and updated as can possibly be the case. This can be inferred since the distribution of the responses actually shows a majority of respondents agreed with the first statement (72%) while only a 6% minority disagreed or strongly disagreed with it. This strongly suggests that, when drawn up, the standards are of an acceptable level of quality and meet all legal and safety related compliance issues. The only concern is that 10% of the respondents chose the neutral view of (3) in the first statement, which indicates that although the standards might be of good quality, they are not being necessarily used as they are supposed to be in the current maintenance environment.

Equipment history and data usage: The average response for this statement in Table 3, indicates the respondents were not quite sure about whether or not the equipment history is used in the planning of maintenance jobs since the result shows most of them choosing the neutral view (30%). Although 2% of the respondents actually disagreed with the statement indicating the negative, a bigger percentage (64% of them) actually responded positively to it and agreed or strongly agreed which shows a more positive shift for the sentiment. Therefore one can infer that the equipment history is used in planning but not optimally or sometimes not at all. To see more closely what happens, a deep dive into the responses of only the planners was done and from this, one can see that indeed only 78% of the planners agree that they extensively use the equipment history while the rest neither agree nor disagree (22%).

Parts/Machines removed: Parts and machine assemblies are definitely not always promptly sent for repair/build after being removed from service as indicated by some of the respondents disagreeing with the fourth statement. Although only a minority 14% of the respondents actually strongly disagreed or disagreed with this statement, there was an impressive majority of 54% of people who agreed. 18% indicated to be neutral whilst only a small minority strongly agreed that parts and machinery are promptly removed and sent for repairs timeously. The disagreement might be an indication in the sub statement which mentions that parts are always sent back to storerooms when not used, which from the author's personal experience on the plants, does not always occur. Some personnel prefer to keep the parts at their workplace thinking that it will be of convenience when next they need to use the specific part but however do not consider the effects on the parts in terms of storage area and environmental conditions required to keep them in good working condition. This also makes it harder for procurement and parts inventory counting and stock optimization exercises thus adding to more planning inefficiencies at the end of the day.

Work order based on facts: The requirement of the fifth statement to have more than 95% of maintenance work orders being formalised and based on facts seems to be mostly met as per the respondents (72% agree or strongly agree). What is likely causing the small disagreements to the statement is that the planners themselves might not necessarily develop a work order for every task to be done since some tasks are done on an immediate emergency mode because of the existing firefighting culture.

Kitting: Kitting can be defined as having the required tools, resources, spares and requirements to start a job in place before actually commencing work on it. It is clear from the responses that Maintenance is not always able to start a job at a completely prepared work site. Only 75% of the people agreed or strongly agreed that kitting occurs. This clearly shows that even if at times, maintenance can start jobs at a well kitted workplace, this does not occur as often as it should be the case.

SHER (Safety, Health, Environment and Risk): It is clear from the responses that SHER is a major priority in the works. The average responses for the safety statement were the strongest compared to all the other statements, with more than 90% of the respondents agreeing or strongly agreeing to the positive on the statement. One can safely then confirm that SHER is taken very seriously in all the planning of maintenance and other related tasks.

Quality/Detail of plans: This was one of the longest statements in both sections of the planning questionnaire but probably also one of the most important. This statement was constructed to effectively summarise all the other statements and give an overall picture of what good maintenance planning should be about. The average response on this statement was surprisingly one of the most positive responses in the whole questionnaire. More than 60% of the people responded positively to this statement. It can thus be inferred that maintenance planning does definitely occur to a large extent within the Vereeniging works of the Company, but given the responses from the other statements, it is quite clear that this has not been standardised, communicated clearly and /or even optimised for use by all planning and other maintenance personnel. A lot can thus still be done to make sure that a single message is communicated to all involved personnel for a more simplified, standardised, and more optimally practiced set of planning tools, principles and methodologies.

The outcomes discussed above were all expected and correspond clearly and precisely with the literature research completed in the previous chapter.

4.5 DETAIL DISCUSSION OF RESPONSES FROM SECTION C ON SHUTDOWN PLANNING AND MEASURES FOR PLANNING

The next few paragraphs will provide a detailed discussion on the responses for each sub-section of the shutdown planning and measures section:

D-Minus planning: As mentioned clearly in the planning principles by Palmer (2006), all shutdown work should be planned in hours and by craft. The indicatively strong agreement with the first statement by the respondents (66% agree and 18% strongly

agree) and the other related statements (all have agreements for more than 60% from respondents) measuring the effectiveness of the D-minus planning shows that this requirement actually takes place. There is thus little room for improvement on this issue. The D-Minus meetings includes production personnel and thus the shutdown scope should be highly standardised and challenged by production and maintenance. One of the most common mistakes or shortcomings is that production personnel would just accept the shutdown plan as-is without challenging it and thus causing further unnecessary delays or maintenance disruptions during shutdowns.

Percentage planned work: An intuitive general feeling among most maintenance workers at the Vereeniging works is that most time is spent on emergency, breakdown and firefighting work than planned work. While the literature clearly indicates that less hours of maintenance should actually be spent on breakdown work, the empirical evidence from the questionnaire responses seems to agree with the people's intuition, clearly indicating that more time is spent on breakdowns than should be the case. Quite a high number of the respondents (15% either disagreed or strongly disagreed) responded negatively to the two statements 6 and 7, thus implying that more work needs to be planned than is currently the case and fewer hours need to be devoted and spent on breakdown work. Increasing planned work will have obvious positive effects on wrench time, thus increasing utilization of employees and improving labour costs per average plant outputs.

Planned work not done: Interruptions during shutdown execution seem to be a norm in the Vereeniging works maintenance environment with a clear indication from a high number of responses (20%) saying that they strongly disagree or just disagree with the statement that "No or little work that was planned is cancelled during shutdowns." This can be clearly linked to the previous statement as well, since the more work that is not planned; the more interruptions will be in carrying out the work that is actually planned and vice versa. An effort to increase the amount of work that is planned to adhere to the simple motto "no work order, no plan, and no job", will definitely go a long way in improving these issues. This is one of the initiatives that require very strong

management support, since the planners and the maintenance crew need to be able to say that if a job has not been formally ordered, planned and scheduled, then it will not be done even if production says otherwise.

Planning performance: As simply stated by the old famous adage “what gets measured, gets done”, the measurement of all relevant planning KPIs (key performance indicators) is what will keep the implementation of any performance improvement efforts for the long term. The planning element of the maintenance process should have process assurance metrics defined (leading indicators) and performance should be tracked and results used to manage execution of each maintenance process element. It seems that there are some KPIs that are being currently utilized for measuring planning efficiency and effectiveness, although these might be incorrectly used or applied since these do not seem to so far have any positive relation to improving the maintenance availability and planning performance. This can be derived from 30 of the respondents disagreeing, strongly disagreeing or just not knowing what is happening to the maintenance planning measures.

To summarily conclude, the outcomes discussed above were also mostly expected and correspond accurately with the literature research completed in the previous chapter.

4.6 VALIDITY

The validity of an empirical measure can be described as the extent to which it adequately reflects the meaning of the concept under consideration (Babbie & Mouton, 2007). In simple terms validity can thus be described as the degree to which a research study measures what it intends to measure. Golafshani (2003) describes the validity in quantitative research as “construct validity”. He continues to mention that the construct is the initial concept, notion, question or hypothesis that determines which data is to be gathered and how it is to be gathered. Construct validity was used in this study to determine the validity of the questionnaire used in the study as well as determine whether or not the questions covered the full range of the constructs (Field, 2009).

4.7 RELIABILITY

The reliability and validity of the questionnaire were tested before any collection of data and analysis commenced.

Golafshani (2003) also indicates that reliability can be described as “ ... *the extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable*”. Reliability therefore measures whether or not a particular technique, when applied repeatedly to the same object will yield the same result. In the case of this study, this simply means that the respondents will be expected to statistically provide the same answers each time they are asked the same questions as the ones asked in the study.

The Cronbach method of determining reliability of a questionnaire is the most commonly used measure of scale reliability (Field, 2009). The Cronbach's alpha coefficients have been calculated for each of the constructs tested by the Statistical Consultation Service of the North-West University by means of SAS (2011) software and the coefficients have been used to determine reliability on the internal consistency of the questionnaire. All the constructs tested yielded values above 0.7 for the Cronbach's alpha as shown in Table 5 below. Field (2009) also indicates that the cut off value of 0.7 for ability tests on the Cronbach's alpha is more suitable but values below 0.7 can be used with caution when dealing with psychological constructs. From Table 5 below, it is clear that all values of the Cronbach's alpha are all above 0.7 and therefore the data gathered by the questionnaire can clearly be interpreted as reliable.

Table 5: Reliability statistics

| Reliability | Cronbach's Alpha | Cronbach's Alpha Based on Standardized Items | N of Items |
|---|------------------|--|------------|
| Section B: Maintenance Plans | .797 | .794 | 8 |
| Section C: Shutdown Planning and Planning Measures | .834 | .837 | 8 |

As a result of the above, the mean results from the questionnaire were accepted and interpreted as reliable and could thus be used to draw conclusions on the effectiveness of maintenance planning at the Vereeniging works by the two constructs that were tested. With the above conclusion, it was decided that further analysis to each individual question was not necessary.

4.8 CORRELATIONS

The Spearman's correlation coefficient is a standardized measure of the strength of a relationship between two variables that does not rely on the assumptions of a parametric test (Field, 2009). Field proposes that the level of significance for the correlation coefficient should be $p < 0.5$ (p-value, 2 tailed) thus implying that a statistically significant relationship between two constructs will have any value of p less than 0.5. Table 6 below indicates that there were very significant correlations between the constructs of the research study since all the p values were much less than the norm of 0.5. It can therefore be statistically inferred with certainty that the constructs were correlated to one another and would have an effect on one another. Field (2009) gives the following guideline to determine significant relationships with the Spearman's coefficient (also known as Spearman's rho, depicted as r by the SPSS system):

- $r \sim 0.1$: small, no practical significant relationship,
- $r \sim 0.3$: medium, practical visible relationship,
- $r \sim 0.5$: large, practical significant relationship.

In Table 6 below, the results indicate that a large significant correlation exists between the different constructs of the study which implies that one can be confident with the

results of the research. This simply implies that the constructs correlated to one another and therefore they will have an effect on one another.

Table 6: Correlations

| Spearman's rho | | Maintenance Planning | Shutdown Planning and Planning Measures |
|---|-------------------------|----------------------|---|
| Maintenance Planning | Correlation Coefficient | 1 | .655** |
| | p-value (2-tailed) | | 0 |
| | N | 125 | 125 |
| Shutdown Planning and Planning Measures | Correlation Coefficient | .655** | 1 |
| | p-value (2-tailed) | 0 | |
| | N | 125 | 125 |

** . Correlation is significant at the 0.01 level (2-tailed/p-value).

4.9 ANOVAS AND EFFECT SIZES

An effect size is an objective, standardised evaluation of the importance of an experimental outcome that basically gives an indication of the relationship strength that exists between two variables (Field, 2009). Ellis and Steyn (2009:52) state that many measures of effect sizes exist but Cohen's *d* is one of the most reliable and frequently used.

Cohen (1988) gives the following guidelines for interpretation of the effect size:

- (a) small effect: $d=0.2$;
- (b) medium effect: $d=0.5$; and
- (c) large effect: $d=0.8$.

The effect sizes shown in Table 7 below were calculated by the Statistical Consultation Services department of the North-West University using the SPSS (2013) software. The *d* values show a small to medium effect between the research age groups since they are a little higher than 0.2 but smaller than 0.5 for the maintenance plans section.

The results also show a very small effect on the way the age groups will respond to the statements with regards to the section on shutdowns and planning measures since both

the resulting effect sizes are smaller than 0.2. This clearly indicates that the age groups have similar experiences of the way maintenance planning occurs at the Vereeniging works. Since the result outcome shows that the age groups are also closely related to the racial groups, this can also be a positive effect to show that the different races also have the same view of what should be improved in the maintenance planning.

Table 7: ANOVA and effect sizes

| Age Groups | | N | Mean | Std. Deviation | ANOVA | Effect sizes | |
|------------------------|-------------------|-----|--------|----------------|-------|---------------------------|--------------------------------|
| | | | | | | Maintenance Plans with... | Shutdowns and Measures with... |
| Maintenance plans | 18 - 35 year olds | 54 | 3.9306 | .52680 | 0.14 | | |
| | 36 - 50 year olds | 41 | 3.7317 | .54167 | | 0.37 | |
| | Older than 51 | 30 | 3.7708 | .44538 | | 0.30 | 0.07 |
| | Total | 125 | 3.8270 | .51777 | | | |
| Shutdowns and Measures | 18 - 35 year olds | 54 | 3.8472 | .63444 | 0.13 | | |
| | 36 - 50 year olds | 41 | 3.6220 | .57179 | | 0.36 | |
| | Older than 51 | 30 | 3.6708 | .40932 | | 0.28 | 0.09 |
| | Total | 125 | 3.7310 | .57217 | | | |

The analysis of variance (ANOVA) is used to compare several means with each other in order to see if there are any statistically significant differences between responses in certain groups of interest (Field, 2009). An ANOVA was completed on the age groups as illustrated in Table 7 above and the results indicates that there are no statistically significant differences between the means of the age groups – thus the groups responded to the research questions in the same manner. Statistically significant differences would be indicated if the values for the ANOVA were found to less than 0.05 in Table 7.

The results and the discussion above therefore confirms statistically that the age groups did not have any statistically significant differences in the manner in which they answered the research instrument, therefore the research constructs tested apply

positively to the objectives of the research. This simply means that the results of the research are applicable and can be used to make valid conclusions for the population of interest being the maintenance departments of the whole Vereeniging works.

4.10 SUMMARY

The outcomes from the literature and empirical research indicate that planners are not optimally used in many organisations and the Vereeniging works is unfortunately not an exception. It seems most of the planners are qualified by their experience with an average tenure of 15.5 years among them. The planners do seem to however be very overworked and have many overlapping job responsibilities. One of the key and obvious causes for this is the fact that the works do not currently employ any schedulers and thus planners have to complete both the planning and scheduling job responsibilities.

The empirical research highly indicates that most of the maintenance personnel have very low skills and educational qualifications. A majority of the highly skilled among them are white men at a very advanced age and close to retirement while the lowly skilled are young males of African descent who have just started working.

The demographics emphatically highlight that there are very few females in the employ of maintenance, with only 3 females actually responding to the questionnaire from the whole sample of 125 people. There is thus a very strong indication for possible intergenerational, cultural and gender based discrimination and conflicts that could happen within the group of maintenance in the works.

The respondents came from basically three departments: from the production mills and one group from the steel making side of the works. Thus the group covered four different maintenance managers and areas of responsibility. Ideally speaking, each maintenance manager should have at least four planners working for him, with two planners responsible for mechanical work and the other two for electrical work. From the results, we can clearly see that only nine planners responded versus the possible 16 (four planners for each of the four managers) that should have responded. This may be

a strong indication that indeed the planners are overworked and with some having to possibly plan for both mechanical and electrical work for which they might have little or no experience of performing themselves. This might result in poor plans being drafted for some of the work and thus lower execution quality and increased rework.

The strongest most positive responses in the survey were for the SHER, thus indicating that safety is probably one aspect that is well taken care of in the works with very little if any opportunities for improvement. The safety responses are further supported by the responses on the standards and procedures statements, which also indicate that the works have most if not all the standards and procedures in place, but they lack the necessary communication and sharing between levels of employees to make sure that they are thoroughly, consistently and sustainably implemented.

Maintenance history and data is definitely collected as per the responses, but the use thereof is questionable, as it seems the planners rely more on their own experience to plan jobs rather than what the data or system might say. This poses a danger for the new planners who might not necessarily have the plant experience in certain trades for which they plan work for.

The motto of “no work order, no plan, and no job” does not seem to be strictly applied in the works since a weak agreement was recorded from the responses testing for compliance with this motto. It is also very clear that although some “kitting” is done for shutdowns, it is not done for all planned maintenance tasks.

The maintenance plans, like the standards and procedures at the works seem to be of a good quality when they are drawn up, but a limitation is that these are not drawn up for everything that they should be drawn up for. It is also a possibility that the plans are not adequately reviewed and updated to conform to the latest state of the equipment in the plant, thus leading to some being redundant and introducing unnecessary tasks or even worse lagging behind on the correct frequency for day-to-day maintenance and inspections on certain machinery and equipment.

The lack of communications as suggested by Kister (2006) also exists in the Vereeniging works. This means that many of the jobs become completed without any work orders and some of the actually planned jobs are stopped during shutdowns and replaced with other unplanned jobs.

The research output also indicates that planners do not sufficiently have a focus on the 'future' currently in the works since there is much "firefighting" that goes on which limits the time to plan some of the jobs sufficiently in advance.

Last but not least, the performance tracking or performance measurement for planning efficiency and effectiveness seems to be very weak among the personnel in the maintenance departments. Although some KPIs exist for planning, these do not seem to be linked to any incentive for the maintenance crew to 'worry' about a lot and thus the old adage is proven true "what is not measured, is not done".

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

The most difficult thing is the decision to act, the rest is merely tenacity.

Amelia Earhart (Forbes, 2014).

5.1 INTRODUCTION

This final chapter of the mini-dissertation provides summaries of the key takeaways and suggestions for implementation to ensure the future success of the company's maintenance team.

The literature study and the empirical research findings from the planning questionnaire confirmed most of the intuitions that the researcher had and mentioned in the problem definition and motivation of the study sections of this study. This is very good in that it affirms that the conclusions and recommendations made from this report should be taken to be considerably accurate and thus followed through to ensure success of the Vereeniging works maintenance team.

This chapter will begin with a summary of the key conclusions from each of the sections in the report, first starting with the literature study and then concluding with the empirical research findings. A number of recommendations will then be discussed in a few categorised sections based on a suggested implementation framework developed by the researcher.

5.2 CONCLUSIONS FROM THE LITERATURE STUDY

Planning is a critically important functional area of maintenance and actually forms the foundation of everything else. From the history of CSSA and the Vereeniging works, it is clear that the maintenance organisation here has existed for a long time and thus has to deal with old and aged plant and equipment that has seen a couple if not a lot of generations of CSSA employees since 1911.

The history and scale of the organisation also indicates that the theory of maintenance optimisation is nothing new to the employees of the company and there are certainly some departments/sections or pockets of the company that probably have world-class maintenance and planning practices. There is thus a real opportunity for Vereeniging works to learn from within the bigger organisation itself without necessarily seeking any external help to improve the way they currently work and do maintenance planning.

A key consideration in the planning of any maintenance related initiatives is the Asset Reliability Process (ARP) which the company seems to have invested a lot of effort and time in crafting and has already successfully implemented in other plants of the group. It is in fact shown as part of the literature study that the improvement of planning is in itself a part and parcel of the overarching maintenance transformation and improvement effort of ARP. Any plans made to improve the maintenance planning at Vereeniging works should thus be properly aligned with the efforts of the total ARP implementation program.

The objectives and outcomes of ARP are also quite nicely aligned with those found in literature on world-class maintenance planning efforts and thus the implementation of the planning improvement should also take note of the ARP priorities and targets mainly being to increase plant reliability and equipment availability. This alignment of ARP and planning optimisation is further underlined by the fact that improving scheduling and planning is itself mentioned and treated as a separate key element and process in the steps of the ARP model, i.e. P7 and P8.

Brown (2004) states that, “ ... *the basis for organisations to move away from maintenance by default to maintenance by plan is the beginning of maintenance success*”. Planning is thus thoroughly proven in the literature to reduce many unnecessary wastes and maintenance personnel frustrations if and when implemented correctly. Planning can thus significantly improve worker motivations and boost employee morale effectively.

From the literature we can also see that the benefits of planning include making sure that production capacity is available whenever it is needed, and thus ultimately reducing the overall cost of maintenance to the company. Planning is simply defined by Palmer (2006) as identifying parts and tools necessary for maintenance jobs and reserving them as appropriate. Palmer continues to suggest six principles to guide maintenance in improving their planning efficiency and effectiveness. The principles can be summarised as follows:

1. **Separate department:** Planners should have their own department separate from the execution crew.
2. **Focus on future work:** Planners should concentrate on future work and provide the maintenance department with at least one week of backlog work that is planned, approved and ready to execute at any time.
3. **Component level files:** The planning department should maintain a simple but secure file system to utilize equipment data and information learned from previous work thus enabling continuous improvement effort at all times.
4. **Estimates based on planner expertise:** The planner should be someone with a good maintenance background and experience in order for him/her to be able to make good and accurate estimates for work completion times.
5. **Recognize the skill of the crafts:** The plan should allow sufficient autonomy by the crafts, thus planners should supply the “what” and let the “how” be determined by the maintenance execution crew.
6. **Measure performance with sampling:** Continuously track and measure the planning efficiency and effectiveness KPIs.

The literature study also highlighted the fact that planning success is very closely linked to the formal methodology of requesting and recording work done in the plant that being the work order system. Any optimisation to the work order system is therefore an important prerequisite success to ensure the long-term sustainability of maintenance planning transformation. Good planning should thus provide a thoroughly excellent and well thought framework for proper execution of work and help make sure that resources are ultimately effectively and efficiently used at all times.

5.3 CONCLUSIONS FROM THE EMPIRICAL STUDY

The responses from the research instrument agreed very positively with the intuitive views of the researcher and the literature that was completed.

The outcomes from empirical research indicate that planners are not optimally used in the Vereeniging works since the planners seem to be overworked with many overlapping job responsibilities. One of the causes for this is the fact that the works do not currently employ schedulers, and planners have to complete both the planning and scheduling job responsibilities.

The research indicates that most of the maintenance personnel have low skills and educational qualifications with a majority of the highly skilled among them being white old men while the lowly skilled are young African males.

The demographics highlight that there are very few females in the employ of maintenance, with only 3 females actually responding to the questionnaire from the whole sample of 125 people. There is thus a very possible presence of intergenerational, cultural and gender based discrimination and conflicts within the maintenance personnel in the works.

The span of control due to the number of planners employed in the works per maintenance manager suggests that planners have to, at times, plan for jobs for which they are not competent for and thus resulting in poorly planned maintenance plans being drafted for some of the work. This also negatively affects the quality of execution, increases rework and thus lowers worker morale.

The strongest most positive responses in the survey were for the SHER, thus indicating that safety is probably one aspect that is well taken care of in the works with very little if any opportunities for improvement.

Maintenance history and data per job is collected as per the responses, but the use thereof is questionable, as it seems the planners rely more on their own experience to plan jobs rather than what the data or system might say which poses a danger for the new planners.

The motto of “no work order, no plan, and no job” does not seem to be strictly applied in the works and although some “kitting” is done for shutdowns, it is not done for all planned maintenance tasks.

There is a lack of communication and firefighting that exists in the Vereeniging works which leads to many of the jobs being completed without any work orders and some planned jobs being stopped during shutdowns.

The research output also indicates that planners do not sufficiently have a focus on the ‘future’ due to the “firefighting”.

Lastly, the performance tracking and performance measurement for planning efficiency and effectiveness is weak among the personnel in the maintenance departments since there are no incentives to currently motivate excellence among employees.

5.4 RECOMMENDATIONS FOR MANAGEMENT

The implementation of the improvement for maintenance planning should be guided by the following key objectives to align the whole transformation with business wide strategic objectives:

1. **Transforming maintenance in general and not only the planning department:** The main aim is to improve the works wide maintenance and planning is only part and parcel of the bigger picture. The main activities that should be focused on in this regard will include the following:

- a. Improve plant availability; Target: Close the gap to benchmark plant availability by 40%.
 - b. Direct improvement on plant throughput.
 - c. Direct improvement on quality.
 - d. Reduction in maintenance costs in the long term.
 - e. Train, up-skill and empower maintenance personnel.
2. **Identify quick win projects and fast-track implementation:** To gain the momentum and quickly improve personnel buy-in in the 'new way' of doing things, quick win projects should be identified and its implementation should be fast-tracked and prioritised with sufficient support from top management. It is essential that quick win projects are given to highly capable and competent personnel to complete in order to make sure that they are quickly and successfully implemented. The main activities that should be focused on in this regard will include the following:
- a. Identify quick wins through a diagnostic phase.
 - b. Roll out of all quick wins and tracking of accrued benefits.
 - c. Heavily communicate early successes and relay positive outcomes to improve employee buy-in for the longer term in the more challenging projects and initiatives.
3. **Reduction in safety and environmental incidences:** At the end of the day, the maintenance personnel are the most important assets of the organisation and thus their wellbeing and that of the environment and the people around should always be looked after. This will ensure the future sustainability of the maintenance organisation and the company at large. The main activities that should be focused on in this regard will include the following:
- a. More visible leadership at plant and shop-floor level.
 - b. Continuous communication, tracking and recording of any safety and environmental incidences with thorough root cause analysis, corrective actions identified, implemented and tracked accordingly.

- c. Proactive management of incidences and proper incentives for positive behaviour and results.

5.5 KEY PRINCIPLES AND THEMES TO GUIDE IMPLEMENTATION

Throughout this report it was emphasized, more especially by Palmer's planning principles, that in order to be successful, maintenance planning has to be guided by certain principles and guidelines. The following framework of key guidelines is a suggestion that can remove a bit of the uncertainty on how to go on with the implementation. The framework is based on the author's understanding and interpretation of the literature combined with his experience in the maintenance environment of what might practically work and not work.

It is suggested by the author that the implementation of the maintenance planning transformation and recommendations above be based on these five key guidelines in addition to the planning principles:

1. Human Resources,
2. Technology,
3. Time,
4. Finances, and
5. Strict processes.

The explanation of each of the five guidelines, rationale and how it should be used in the implementation to improve the chances of success is discussed in the **Table 8** below.

Table 8: Five guidelines to ensure successful implementation

| Principle | Description and rationale | How to be used in transformation |
|------------------|--|---|
| Human resources | Involvement has been identified as a core element in the strategy-making process (Hart, 1992: 329). Management has to make sure that everyone feels a part of the success of this project implementation at all times. All people employed in the maintenance environment as well as those affected by their service will have to buy-in for the change to be successful | Make sure that the people can see and feel the benefit of the transformation as soon as possible by implementing successful quick wins earlier in the process |
| Technology | Enabling technologies such the SAP ERP systems and other maintenance improvement systems should be leveraged upon to improve efficiencies | Use available systems to make life a bit easier for people |
| Time | There is a limit in terms of the time one can take to implement a change | Make sure that success is seen and communicated as early as possible in the process. Do not spend more time than is needed on failing initiatives |
| Finances | This is the resources available for the implementation of the transformation which might need new machinery, tools and people to be employed | Use all available resources efficiently and effectively to derive maximum benefit from the transformation |

| Principle | Description and rationale | How to be used in transformation |
|------------------|---|--|
| Strict Processes | This is the chosen planning and overall maintenance transformation methodology, practice and processes. | The six principles suggested by Palmer would be a good base to start the search for an excellent improvement methodology for planning. This can be optimised to allow for alignment with each plant's specific requirement |

5.6 OVERCOMING RESISTANCE TO THE CHANGE

Change can generate many forms of resistance in people in organisations and thus make it difficult, if not impossible to implement organisational improvements (Cummings & Worley, 2009). To effectively counteract this in the implementation of the maintenance transformation, there are at least three major strategies that can be recommended for dealing with resistance to change (Cummings & Worley, 2009):

1. **Empathy and support.** A first step in overcoming resistance is learning how the people in the maintenance environment and the Vereeniging works at large are experiencing the change. This strategy is used to identify the people who are having trouble accepting the changes, the nature of their resistance, and then jointly working together with them to find possible ways to overcome the resistance. This thus requires a great deal of empathy and support from senior management and those charged with implementing the change.
2. **Communication.** One reason people might also resist change is if they are uncertain about its consequences as a lack of communication fuels rumours and gossip and thus unnecessarily adds to the anxiety generally associated with change. Effective communication about the changes and their likely results can thus help reduce this speculation and allay any unfounded fears.
3. **Participation and involvement.** This is one of the most effective oldest strategies of overcoming change resistance by simply involving the organisation member in directly planning the change, thus effectively allaying the fears of implementing something they do not fully understand.

5.7 HIGH LEVEL TIMELINE FOR THE IMPLEMENTATION OF RECOMMENDATIONS

The main deliverables of transforming the maintenance planning organisations will be the following:

- Introduce planner and scheduler positions
- Implement works-wide shutdown planning

- Introduce centralised planning and scheduling service to manage MST (Maintenance Support Team) and central contracts

To support the implementation of the planning transformation and ensure its success, the maintenance management has to also make sure that they have a higher focus on the following issues:

1. Skills and training

1. Review and align training documentation and programs
2. Training of personnel based on new roles and responsibilities
3. Adapt individual development programmes (IDPs) to meet new position requirements
4. Staffing of technical, support and maintenance positions

2. Maintenance measurement

1. Align maintenance key performance indicators (KPIs) with best practices
2. Introduce implementation measurements

This quote by Thomas (2005) summarises what the management team needs to focus on for the future, *“As a leader within your company, if you don’t know where you are going, then you will never be able to put in place processes that will get you there and you will never arrive”*. It is thus highly imperative that a carefully crafted implementation plan be constructed to show the steps that will be taken and the roadmap for successful delivery of the maintenance transformation. The implementation plan should, however, also heed the advice of the old Chinese general Sun Tzu as illustrated in his famous writings on the Art of War translated for modern readers by Chou-Wing and Abe Bellenteen. In the writings, Sun Tzu warns that while foolish haste in war is not good, at the same time a smart operation is never prolonged (Tzu, 2003:18). This basically can be applied in the maintenance transformation aspect to make sure that the program lasts as shortly as practically possible in order to make sure that the benefits from it can be realized by the business as quickly as possible, before employees get tired of the change, lose faith and resort to resistance.

The timeline below in Figure 9 is a suggestion of how management can go about making this implementation a success. This provides detailed descriptions of the phases, activities and deliverables for each suggested state of the implementation process.

| <i>Before Start of transformation project</i> | <i>4 weeks</i> | <i>3 weeks</i> | <i>3 weeks</i> | <i>3 weeks</i> | <i>1 week</i> |
|--|---|--|---|--|---|
| Prepare | Diagnostic | PDCA 1 | PDCA 2 | PDCA 3 | Refine |
| <ul style="list-style-type: none"> <input type="checkbox"/> Communicate start of planning transformation to site <input type="checkbox"/> Local Steercom kick-off meeting <input type="checkbox"/> Finalise team logistics <input type="checkbox"/> Train team members , <input type="checkbox"/> Define work plan <input type="checkbox"/> Request data from site | <ul style="list-style-type: none"> <input type="checkbox"/> Stakeholder analysis <input type="checkbox"/> Mindsets & Behaviours assessment <input type="checkbox"/> Evaluate maintenance technical KPIs <input type="checkbox"/> Assess As-Is org structure <input type="checkbox"/> Conduct Maintenance planning assessment <input type="checkbox"/> Quantify stream target <input type="checkbox"/> Skills determination | <ul style="list-style-type: none"> <input type="checkbox"/> Implement quick wins <input type="checkbox"/> Finalise skills profiling for new positions <input type="checkbox"/> Start appointment process <input type="checkbox"/> Detailed training on ARP Process & Maint Methodology <input type="checkbox"/> Define medium to long term initiatives <input type="checkbox"/> Boot camp for maintenance leadership <input type="checkbox"/> Train the trainer | <ul style="list-style-type: none"> <input type="checkbox"/> Implement quick wins <input type="checkbox"/> Detailed training on ARP & Planning Methodology <input type="checkbox"/> M&B coaching <input type="checkbox"/> Plant communication <input type="checkbox"/> Address deviations <input type="checkbox"/> Train the trainer | <ul style="list-style-type: none"> <input type="checkbox"/> Implement quick wins <input type="checkbox"/> Detailed training on ARP & Maint Planning Methodology <input type="checkbox"/> M&B coaching <input type="checkbox"/> Mindsets & Behaviours assessment <input type="checkbox"/> Address deviations <input type="checkbox"/> Train the trainer | <ul style="list-style-type: none"> <input type="checkbox"/> Develop further implementation plan <input type="checkbox"/> Develop tracking and auditing plan |

Figure 9: High level suggested implementation plan

5.8 ACHIEVEMENT OF THE STUDY OBJECTIVES

The general objective for this research was to compare the current planning characteristics of the company to those that are widely considered proper as benchmarked in various literatures and to prove that the organisation is not performing according to these traits and therefore has an opportunity to improve by implementing some of the recommendations from the literature, industry and academia.

The objective has been met and successfully concluded since the report highlighted the six principles for excellent maintenance planning as well as a planning thought process for planning each maintenance task that is ideally aligned to the principles.

Following is a discussion and evaluation of how the specific objectives of the study were met:

- The first specific objective of the study was to identify what qualities in planning are required to run a successful maintenance organisation. This objective has been successfully met and concluded as illustrated in this report that in order to do planning excellently, an organisation must align its process to the six planning principles.
- To find out if the maintenance management and personnel of the Vereeniging works have these qualities. This objective has been successfully met and concluded as illustrated in this report by the results of the empirical study done on the maintenance personnel of the organisation which was proven to be statistically valid and usable.
- To summarily suggest a framework of activities that can be applied by Vereeniging management and leadership in other companies to improve their maintenance performance and plant availability based on the good qualities and characteristics of their planning functions. This objective has been successfully met and concluded since this report outlined detailed implementation plans to be considered by management for improving the current status of their maintenance planning effort. The recommendations are not only applicable to the organisation that was studied but any company that has similar needs for maintenance.

From the above discussion, it can therefore be summarily concluded that all the objectives for the study were positively and successfully met and concluded.

5.9 RECOMMENDATIONS FOR FUTURE RESEARCH

This research was started because of a corporate need for the company to improve the maintenance environment at their works, with a specific focus on planning. The literature study, however, proved that this is not a unique concern for the company only but for probably any industrial company that has to do any kind of plant maintenance. The key takeaways and recommendations in the previous chapter can thus be optimally implemented at any organisation to help improve and drive not only their maintenance planning but general approach to maintenance improvement for success. For the future it is recommended that scholars focus on the following areas for improvement and additional value to the research done in this study:

1. More research should be done on how to successfully manage the interracial, gender based and intergenerational conflicts that arise because of the mix of racial groups and different skill sets that exist in the South African industrial workplace. This is mostly caused by our history as a country since more whites were employed in these industries in the past, but now with more (Broad Based Black Economic Empowerment) BBBEE initiatives, the race demographics are quickly changing and thus introducing these challenges.
2. A second interesting perspective that could be explored by further research is perhaps an action research study that can test a formal methodology for planning improvement using the ARP and the Palmer's six principles of planning. This will be an interesting research that could test if the theory really works as well as it is suggested in this report that it should.
3. Lastly, more research could be done on how the skills of recently employed planners and other maintenance personnel could be fast-tracked for improvement for the benefit of their companies and this country in general.

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APPENDIX A: THREE DIMENSIONS OF OPERATIONAL EXCELLENCE

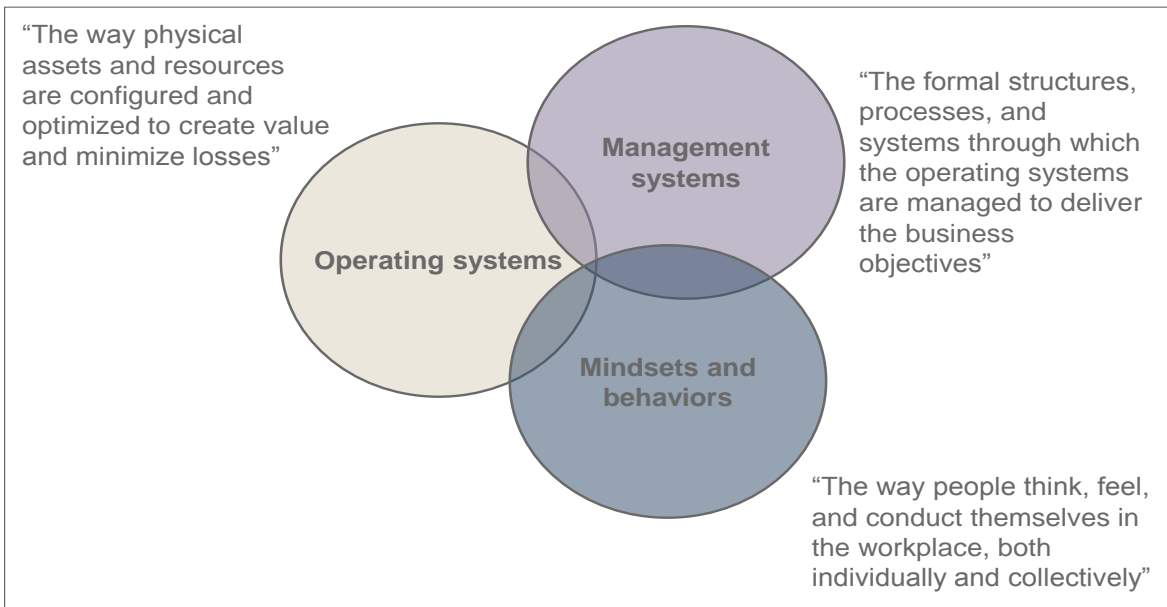


Figure 10: The three dimensions of operational excellence

Source: Company Blueprint (2014)

APPENDIX B: A WORK ORDER SYSTEM

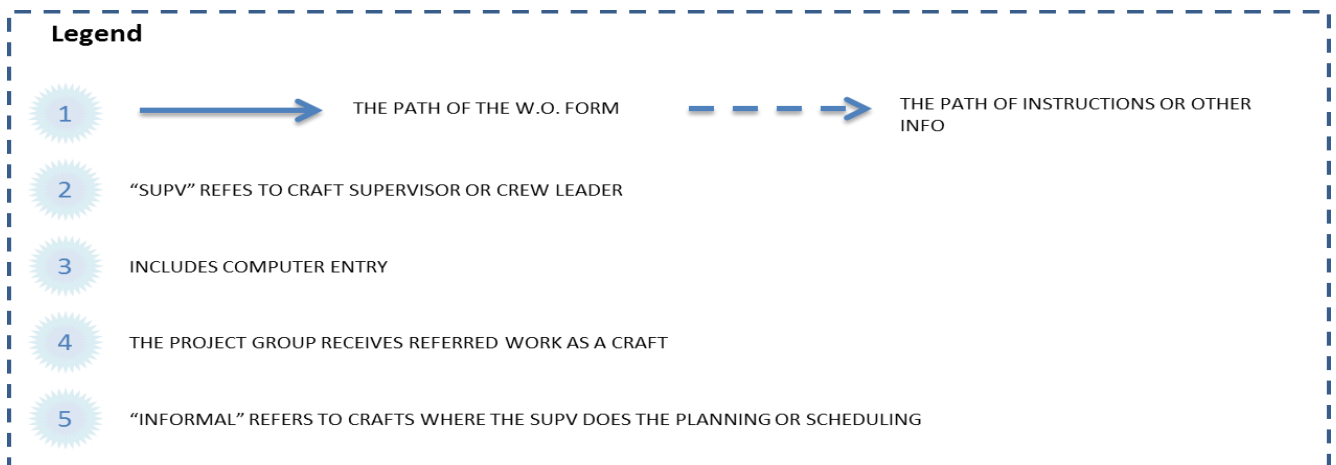
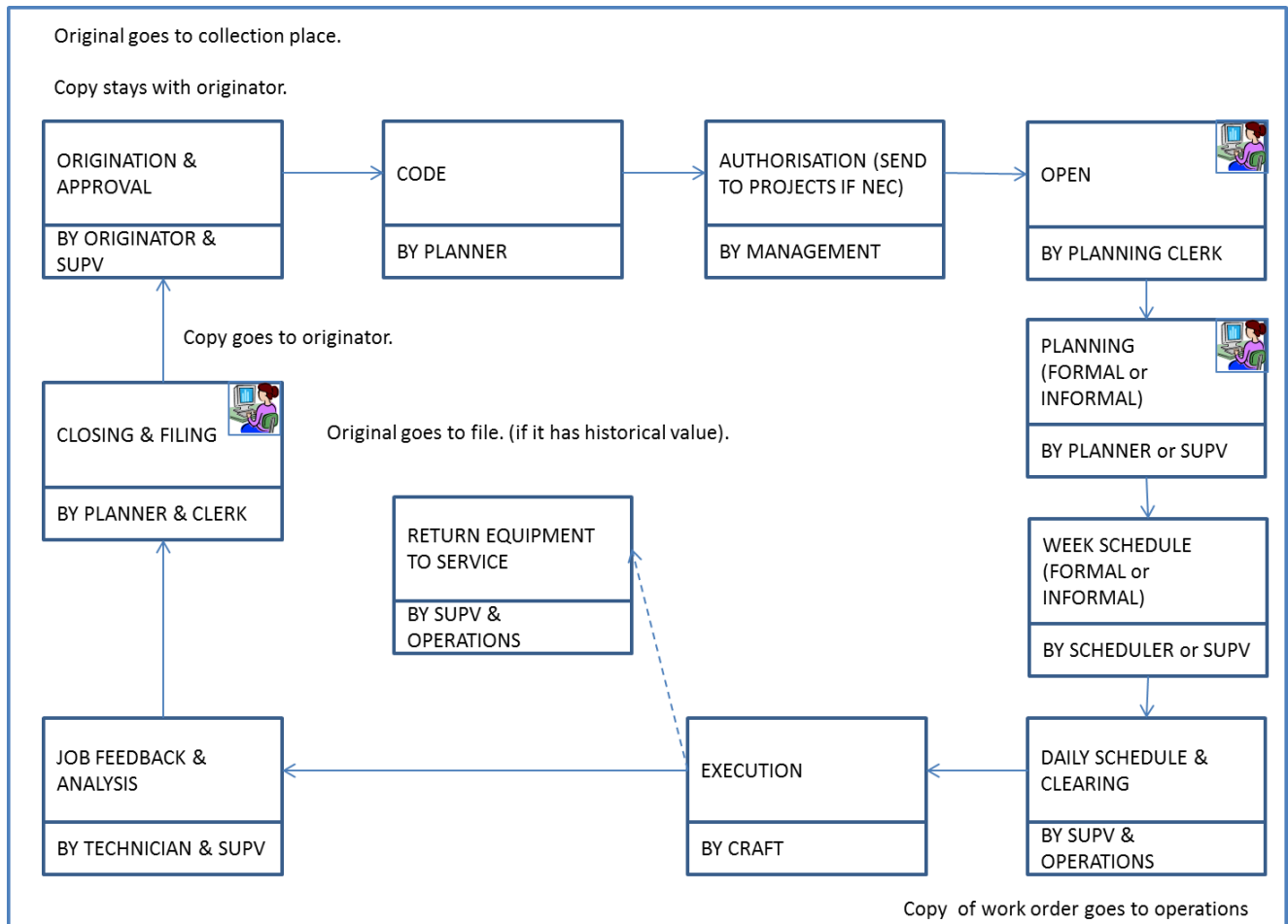


Figure 11: A work-order system

Source: Palmer (2006:126)

APPENDIX C: AN EXAMPLE OF A WORK ORDER

Table 9: Example of a work-order form

Source: Palmer (2006:131)

| | |
|---|--|
| <p><i>REQUESTER SECTION</i></p> <p>Equipment _____</p> <p>Problem or work requested:</p> | <p><i>WORK ORDER #</i></p> <p>Priority _____</p> <p>Tag # _____</p> <p>Def Tag # _____</p> |
| <p>By _____</p> | |
| <p><i>PLANNING SECTION</i> Assigned crew: _____ Attachment? Y/N</p> <p>Description of work to be performed:</p> <p>Labour requirements:</p> <p>Parts requirements:</p> <p>Special tools requirements:</p> | |
| <p>By: _____ Date & Time: _____ Job Estimate: _____ Actual: _____</p> | |
| <p><i>CRAFT FEEDBACK</i> (Modify plan sections above: actual labour, parts, & tools). Work performed including equipment changes & any problems or delays:</p> | |
| <p>Date & Time Started: _____ Date & Time Completed: _____</p> | |
| <p>By: _____ Date: _____ APPROVAL</p> | |
| <p><i>CODING</i></p> | |

APPENDIX D: AN EXAMPLE OF A PLANNING SHEET

Planning Sheet

W/O # 24585 Equip. West Dust Collector Blower Seq. TMH Planner TMH Date 5/22/02

Job Title: Change V-belts. Cracked and worn.

Job Scope

| Job Steps | Crew | Est. Hours | Material, Tools & Equipment Description | Qty | Stock # | Cost |
|---|------|-------------|--|--|--|---|
| 1. Lock out and tag motor starter | 1 ME | .5 | | | | |
| 2. Remove belt guard, loosen, and jack the motor. Remove belts. | | .25 | | | | |
| 3. Check both sheaves for sidewall wear, radial runout and wobble. Runout and wobble should not be more than .015" for the large sheave and .010" for the small. Replace worn sheave or hubs if required. | | .5 | Dial indicator, mag base (tool crib) Sheave gauge (tool crib) If sheaves are worn: 4MV5V150R sheave 1 7/8" bore R1 bushing 4MV5V109R sheave 2 3/8" bore R1 bushing | 1 ea 1 ea 1 ea 1 ea 1 ea 1 ea | 43-515-100 43-923-750 43-510-100 43-918-750 06-510-112 | \$173.00 24.00 124.00 24.00 53.00 |
| 4. Install new belts, align sheaves, tighten motor bolts. | | 1.0 | 5V1120 belts Belt laser alignment tool | 4 ea | | 53.00 |
| 5. Tension belts using force deflection method, and recheck alignment. | | .5 | Belt tension gauge (tool crib) | | | |
| 6. Re-install guard. | | .25 | | | | |
| 7. Remove locks, release to operations and clean up. | | .5 | | | | |
| | | Total Hours | Total Labor Cost | | Total Mat. Cost | |
| | | 3.5 | \$130 | | \$53.00 | |
| Drawings/Forms: _____ | | | Total Job Estimate \$183.00 | | | |

Figure 12: An example of a filled planning sheet
Source: Brown (2004:44)

APPENDIX E: THE PLANNING QUESTIONNAIRE

Please complete all the questions. Thank you for your effort.

Section A: Bibliographical information

A1. How old are you now? _____years

A2. What is your gender? Male Female

A3. Educational qualifications (Mark only the highest level of education)

Grade 12 (Matric) Post matric qualification (diploma)
 University degree (BA, BCom, BSc) Postgraduate degree (Honours,
Masters or Doctorate)

A4. What is your home / first language?

1. Afrikaans 2. English 3. Sepedi 4. Sesotho
 5. Setswana 6. isiSwati 7. Tshivenda 8. isiNdebele
 9. isiXhosa 10. isiZulu 11. isiTsonga 12. Other

A5. Which of the following best describes your employment status?

1. Permanent 2. Part time 3. Other (Please specify)

A6. In which section of Vereeniging works do you work _____

A7. What role/job do you do in the maintenance department (e.g. Planner, Supervisor, Maintenance manager etc) ? _____.

A8. How many years have you been working in the current position / level of employment (as in question 6 and 7)? _____years.

Please turn over the page

Section B: Maintenance plans

For each statement below, write the number that best describes how much you agree or disagree with each statement. 1=DISAGREE strongly 5 = AGREE strongly

| | | | | |
|--------------------------|----------|----------------------------|-------|-----------------------|
| 1 | 2 | 3 | 4 | 5 |
| Disagree strongly | Disagree | Neither agree nor disagree | Agree | Agree strongly |

| | | Score |
|-----------|--|-------|
| B1 | Standards and procedures are created by competent individuals, approved by the proper level in the organisation, and used on jobs where required for greater than 80% of all planned work. | |
| B2 | Standards and procedures that are approved meet all legal, safety, environmental, occupational or government requirements for the industry. | |
| B3 | Maintenance personnel extensively use the equipment history and data for planned work execution, equipment analysis and improvement for all critically rated machines. | |
| B4 | Parts and machine assemblies removed from service are always promptly sent for repair/rebuild if required and any unused parts, equipment, or materials are always returned to storerooms. | |
| B5 | More than 95% of Maintenance work orders are formalised and based on facts, and planners develop a work order for every task to be done. | |
| B6 | Maintenance is able to start jobs at a completely prepared work site (e.g., kitted tools, parts, permits, isolation, and equipment prepared). | |
| B7 | Safety, Health, Environment and Risk (SHER) is always included as part of the plan? | |
| B8 | More than 75% of all work orders are properly planned i.e with a plan that includes the following? 1. an accurate scope with work activities logically grouped into well-defined tasks, meeting all regulatory requirements; 2. an accurate estimate of labour (internal and/or external) specifying the skill, number of resources and the time required for each task, 3. an accurate estimate of material requirements including plant store parts and externally purchased parts; 4. identification of special tools and equipment; 5. risk analysis, safety permits or assessments, contractor and coordination requests; 6. work order/tasks are assigned a priority based on early start, late finish date and criticality of the asset | |

Please turn over the page

Section C: Shutdown planning and maintenance planning measures

For each statement below, write the number that best describes how much you agree or disagree with each statement. 1=DISAGREE strongly 5 = AGREE strongly

| | | | | |
|--------------------------|----------|----------------------------|-------|-----------------------|
| 1 | 2 | 3 | 4 | 5 |
| Disagree strongly | Disagree | Neither agree nor disagree | Agree | Agree strongly |

| | | Score |
|-----------|--|-------|
| C1 | There is a contingency plan and a comprehensive document for every shutdown, with its own distribution list. | |
| C2 | Gate keeping reviews the full task list, scope of work and the effect on the master plan as well as scrutinizes the scope cost and effect to EMP (Emergency Maintenance Plan). | |
| C3 | The shutdown scope standardized and challenged by production and maintenance resulting in shifting work outside the shutdown and eliminating non-essential work. | |
| C4 | Shutdown work is planned in hours and by craft. | |
| C5 | Less than 2% of maintenance hours is devoted to breakdown maintenance. | |
| C6 | 95% of work done by craft is actually planned work. | |
| C7 | No or little work that was planned is cancelled during shutdowns. | |
| C8 | The planning element of the maintenance process has process assurance metrics defined (leading indicators). Performance is tracked and the results used to manage execution of each maintenance process element. | |

Thank you very much for your time and effort

APPENDIX F: LETTER FROM LANGUAGE EDITOR

October 23, 2014



TO WHOM IT MAY CONCERN

Re: Letter of confirmation of language editing

The dissertation "An analysis of effective maintenance planning at a steel manufacturer" by M.E. Moshidi (23971673) was language, technically and typographically edited. The sources and referencing technique applied was checked to comply with the specific Harvard technique as per North-West University prescriptions. Final corrections as suggested remain the responsibility of the student.

A handwritten signature in black ink, appearing to read 'Antoinette Bisschoff'.

Antoinette Bisschoff

Officially approved language editor of the NWU since 1998
Member of SA Translators Institute (no. 100181)